Geodata models and core concepts for analysis

Spatial Data Analysis and Simulation modelling,
2020, Simon Scheider

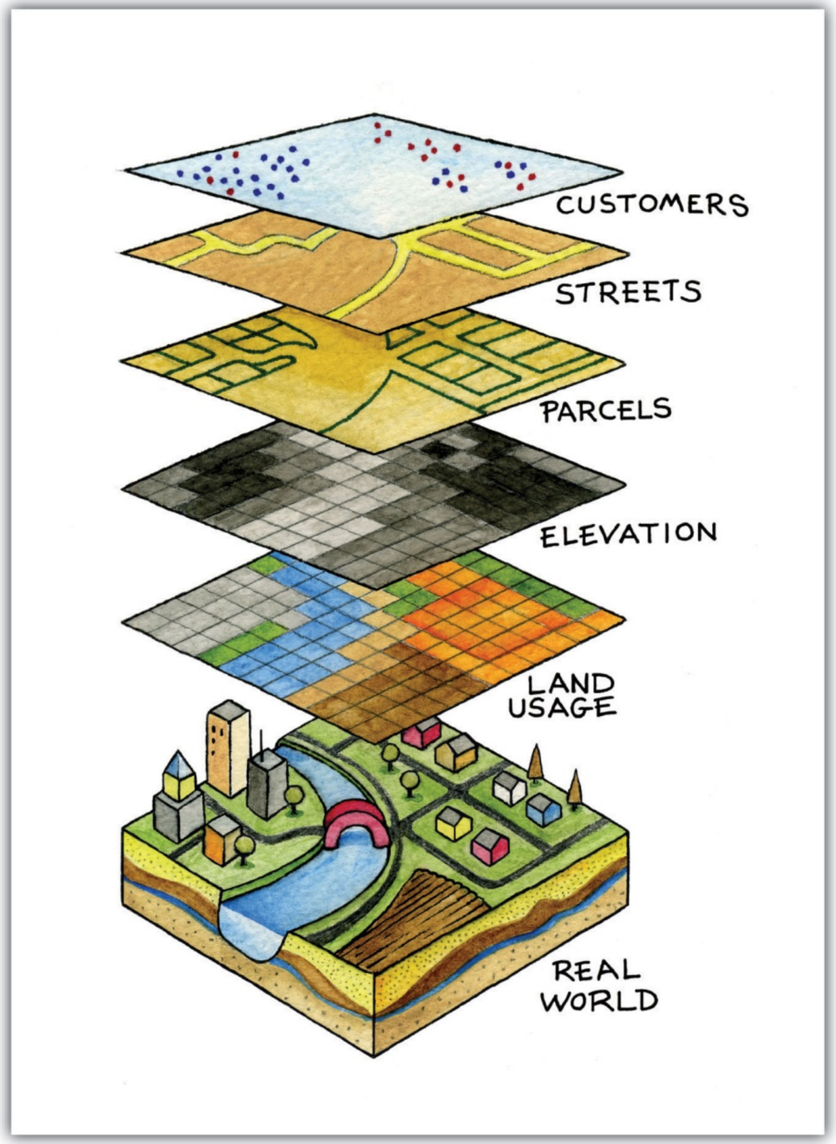
Outline

- Principles of spatial data transformation
  - Layer principle and overlay in GIS
  - Analysis process
  - Different types of overlay
  - Different methods for point data
- Geometric data models
  - Geometric layer models
  - Vector geometry models
  - Basic geometric manipulations
- Core concept data types
  - Core concepts
  - Core concept data types (CCD)
  - Examples
  - Constraints for possible transformations

Principles of spatial data transformation

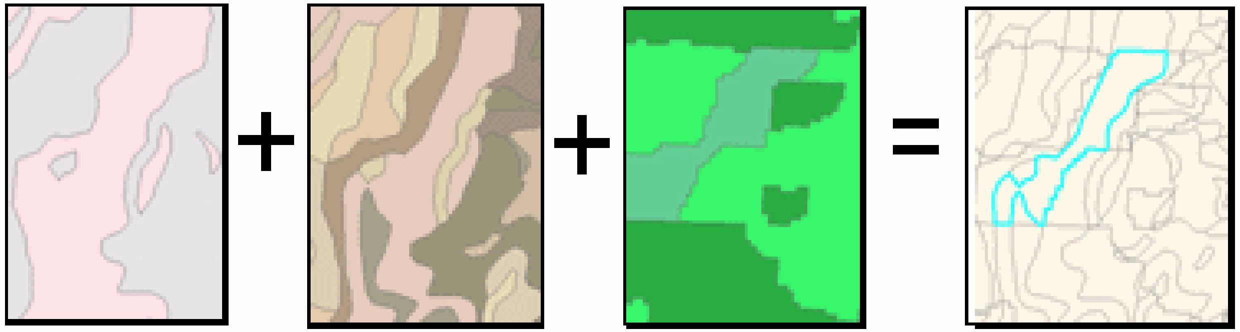
Layer principle of GIS

- Fundamental principle
- Layers (vector, raster) are overlaid
  - To derive new layers
  - To spatially analyse landscape
  - To aggregate and summarize data
- Overlay methods for vector and raster data differ, however (and are not always called overlay)



Vector overlay analysis in GIS

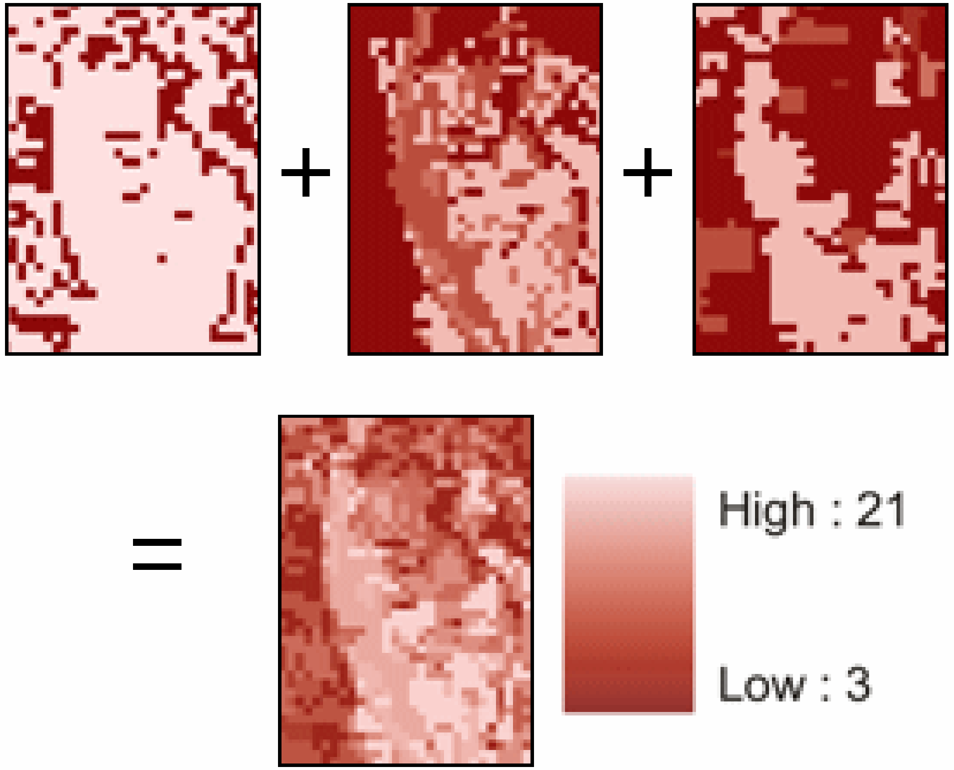
- Development suitability analysis
- Steep slopes, soil, and vegetation type given as polygons



FID	Shape*	FID_soils	CODE	CLASS	FID_sl	SLOPE	FID_veg	DET_TYPE
3039	Polygon	508	38F	6	0	60	117	A
3040	Polygon	508	38F	6	0	60	119	SS
3041	Polygon	508	38F	6	0	60	157	U
3042	Polygon	508	38F	6	0	60	158	A
3043	Polygon	508	38F	6	0	60	160	FC

Raster overlay

- Three raster layers (steep slopes, soils, and vegetation) are ranked for development suitability on a scale of 1 to 7.
- Sum = suitability for development

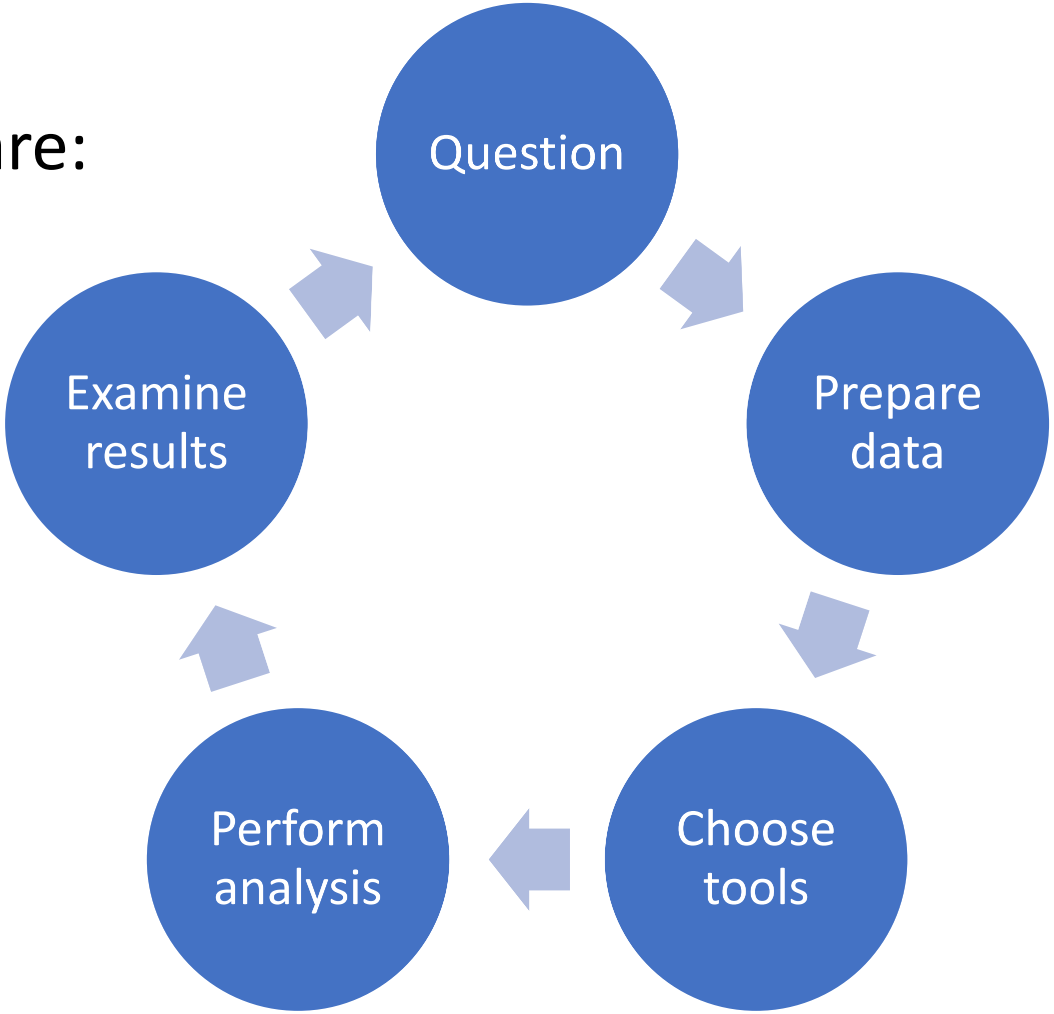


Analysis as a process

The five steps in the analysis process are:

- Frame the question
- Explore and prepare data
- Choose analysis methods and tools
- Perform the analysis
- Examine and refine results

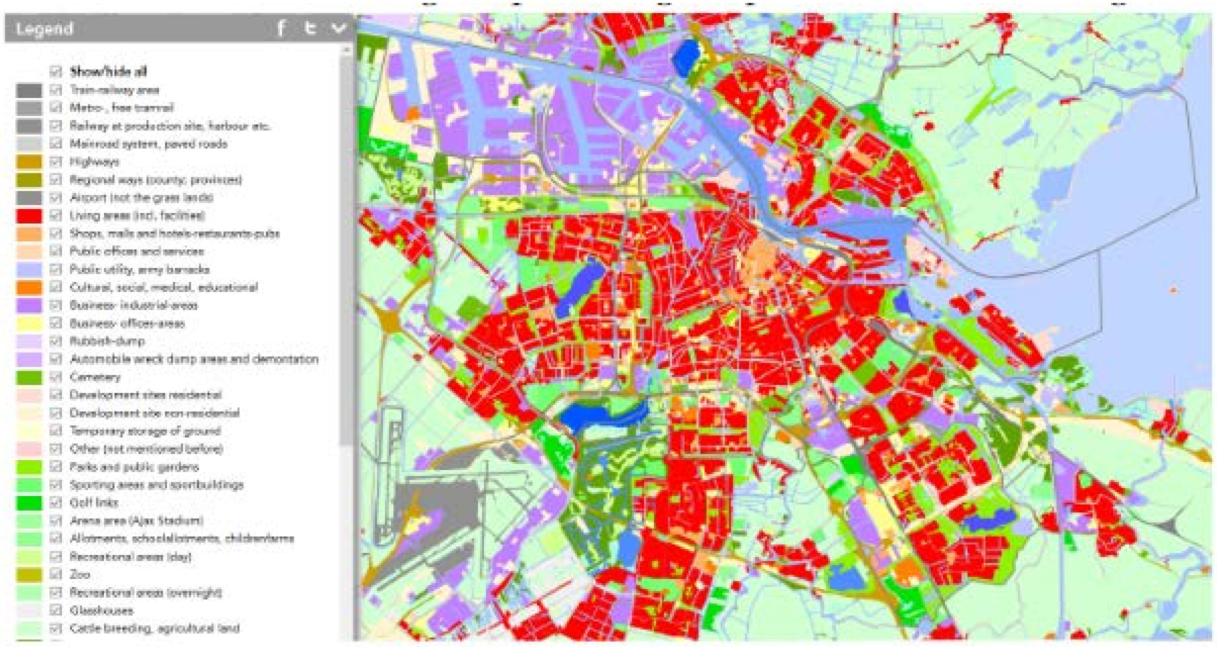
How to decide on each step?



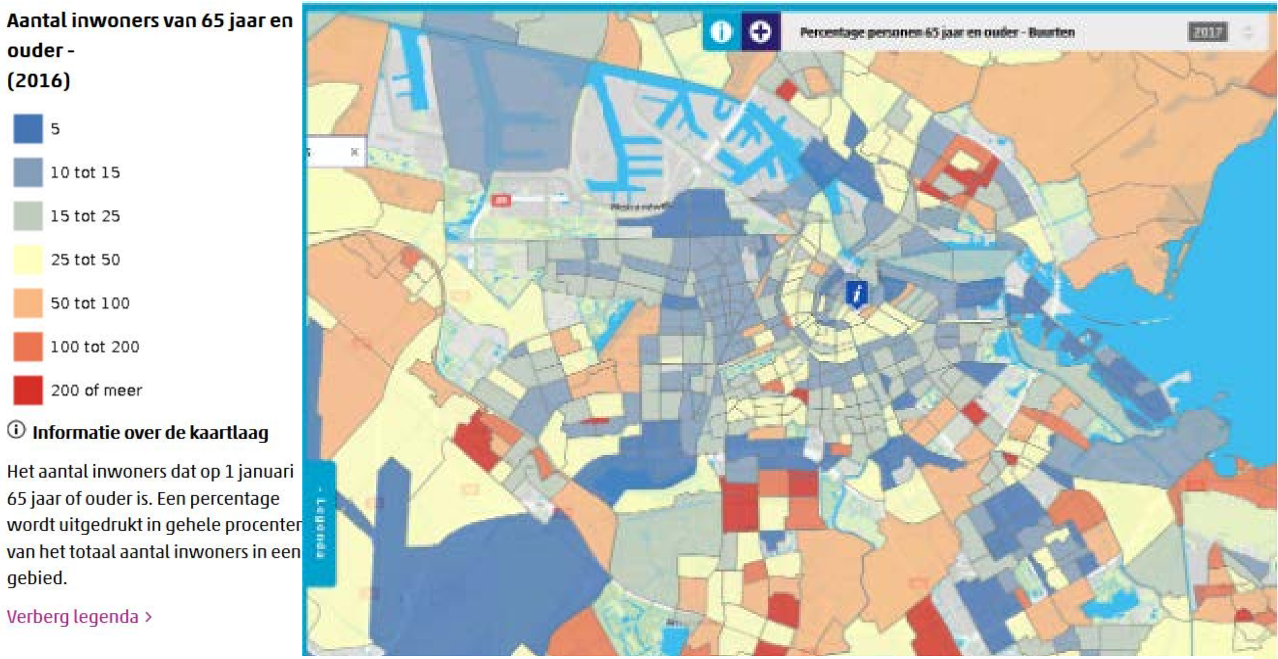
Breaking down an analytic question

What is the proportion of green space in Amsterdam?

What is the amount of elderly people living in PC4 areas in Amsterdam?



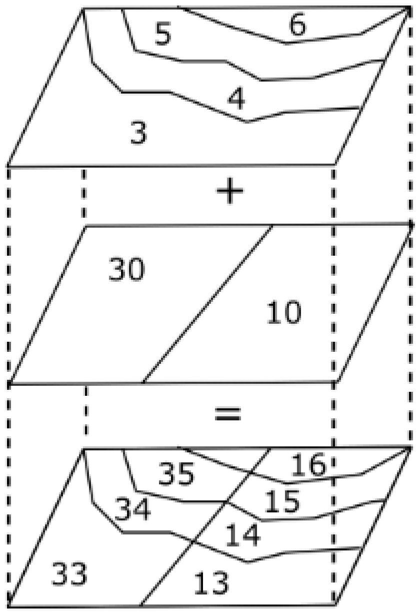
Landuse map (Grondgebruik) of the Amsterdam Municipality



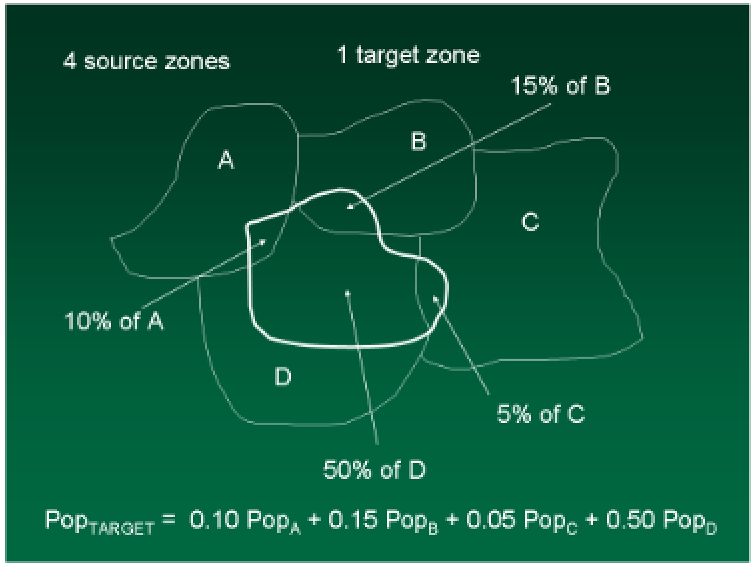
CBS Buurt (neighborhood) statistics

Selecting overlay methods for analysis

- Which overlay method could be used for assessing the amount of elderly people living in PC4 areas?



(a) Vector overlay method.

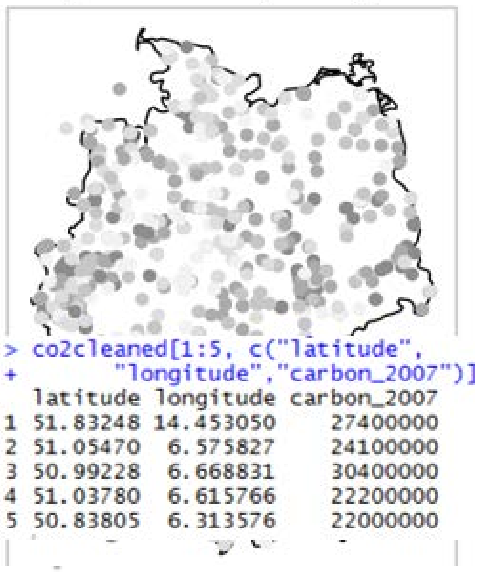


(b) Simple areal interpolation method. Image by kind permission of Michael Goodchild.

Methods for spatially combining polygon data. Which one is applicable for analysing a given polygon data set?

How much polluted is Germany?

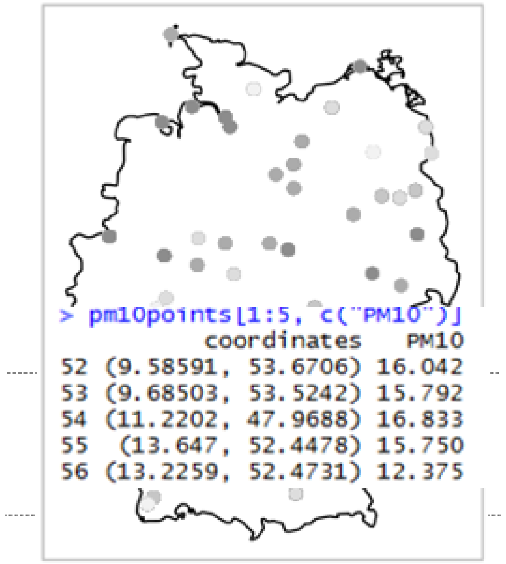
CO$_2$ emissions of power plants



Given: some point datasets in R with pollution measurements.

How to assess pollution intensity of Germany?
By interpolation? Aggregation?

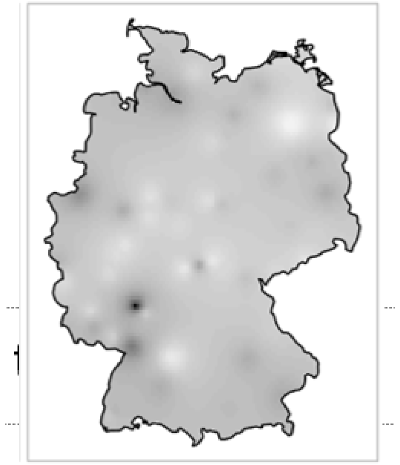
PM$_{10}$ measurements



Interpolated CO$_2$ emissions

Sum of CO$_2$ emissions

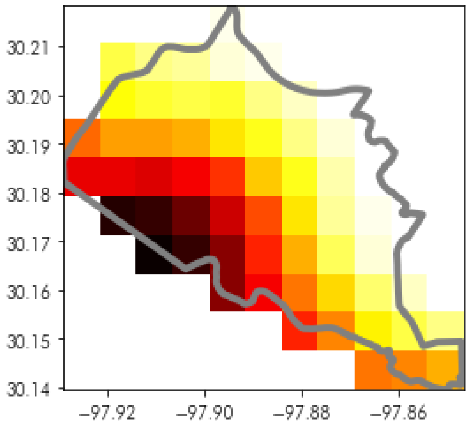
Interpolated PM$_{10}$ measurements



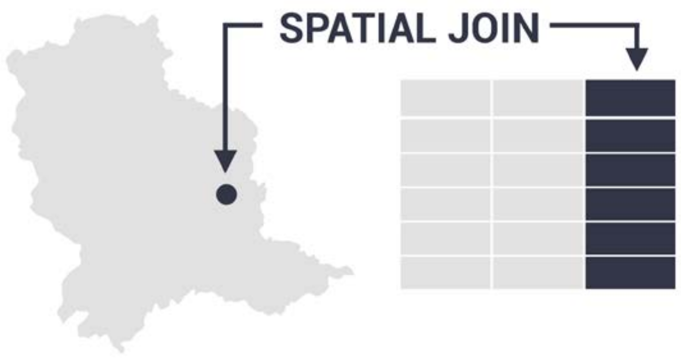
Sum of PM$_{10}$ measurements

Aggregation or interpolation?

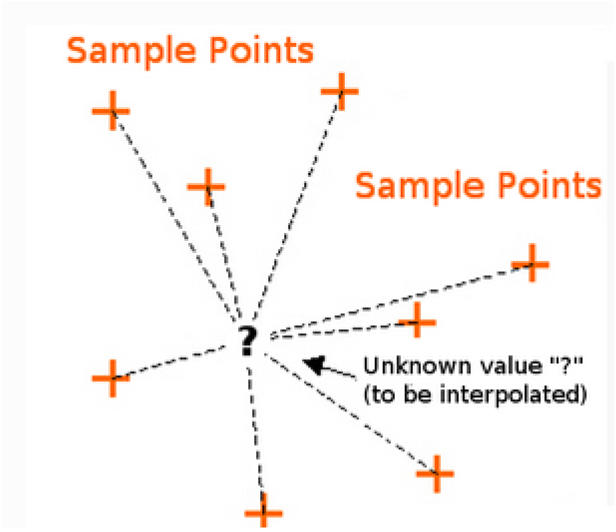
- … which GIS methods are appropriate?



Zonal statistics?



Spatial join?

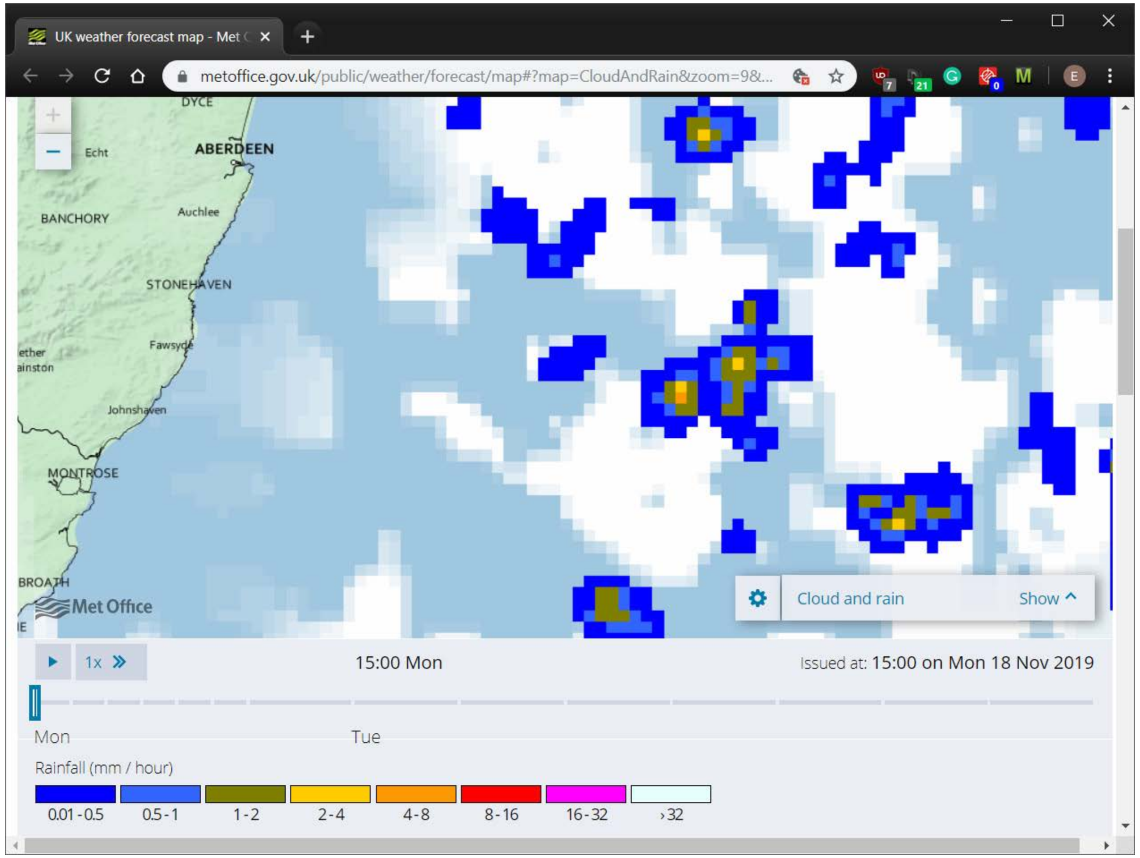


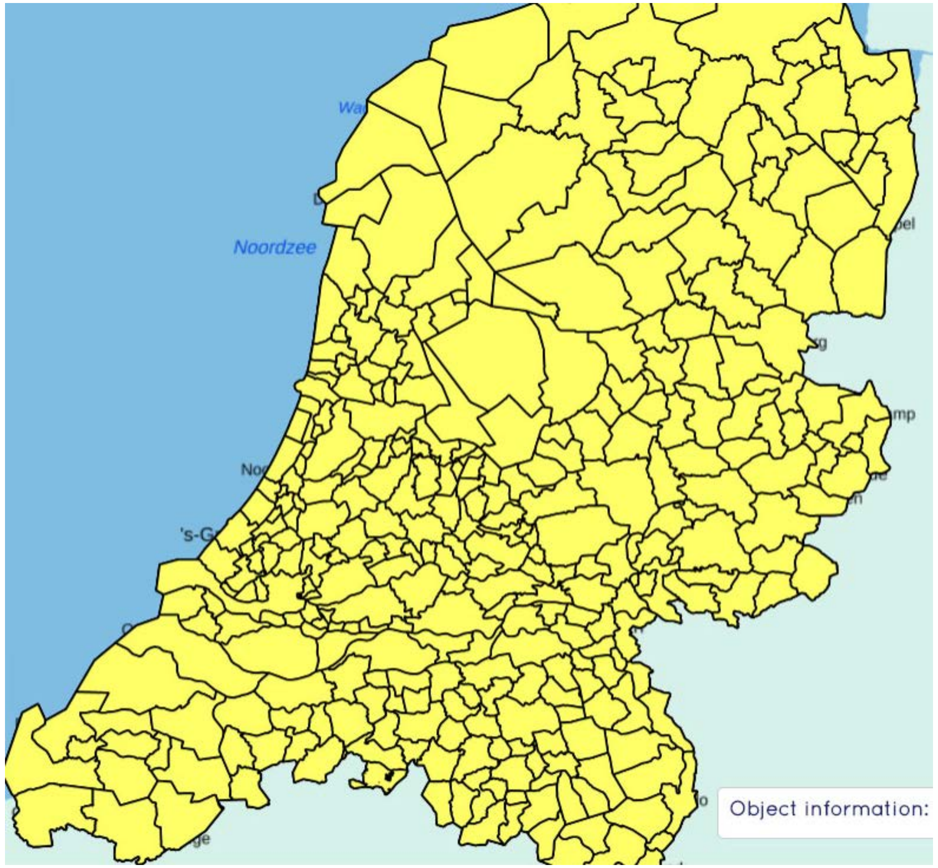
Point Interpolation?

Geometric data models

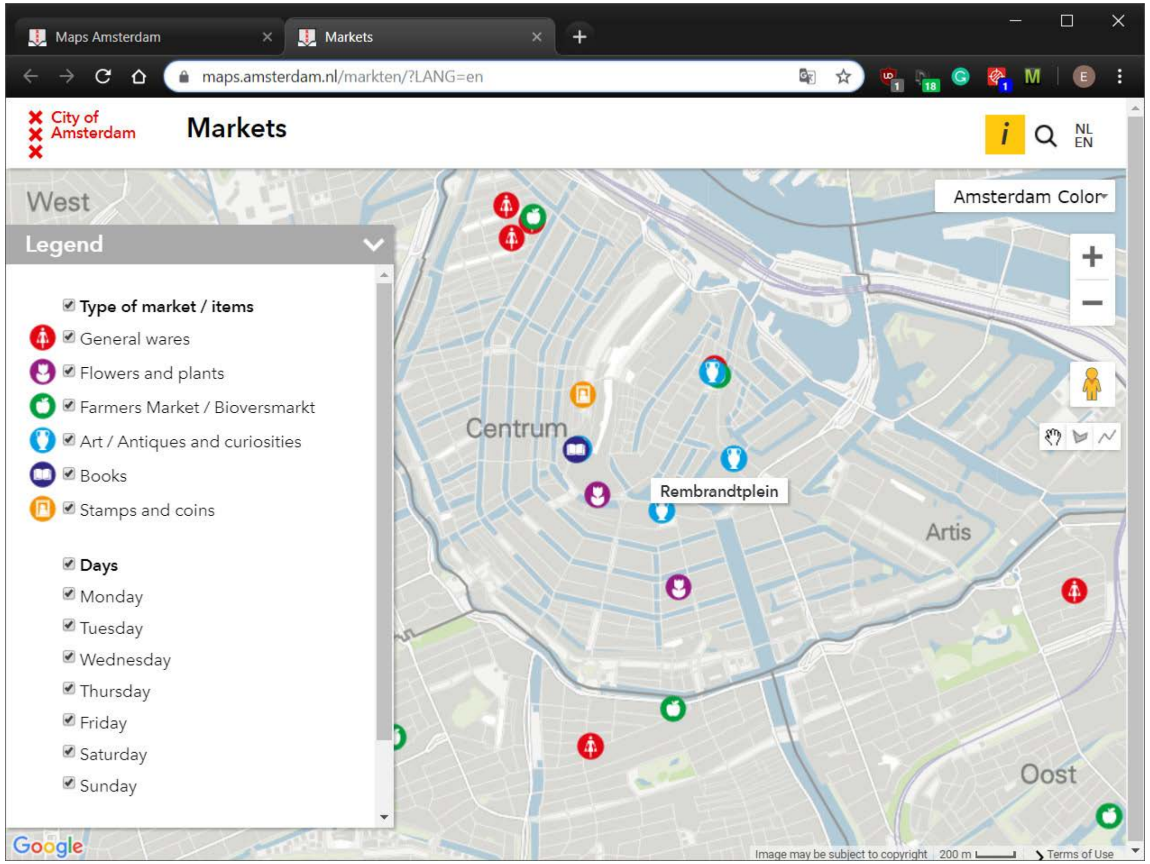
Tessellations

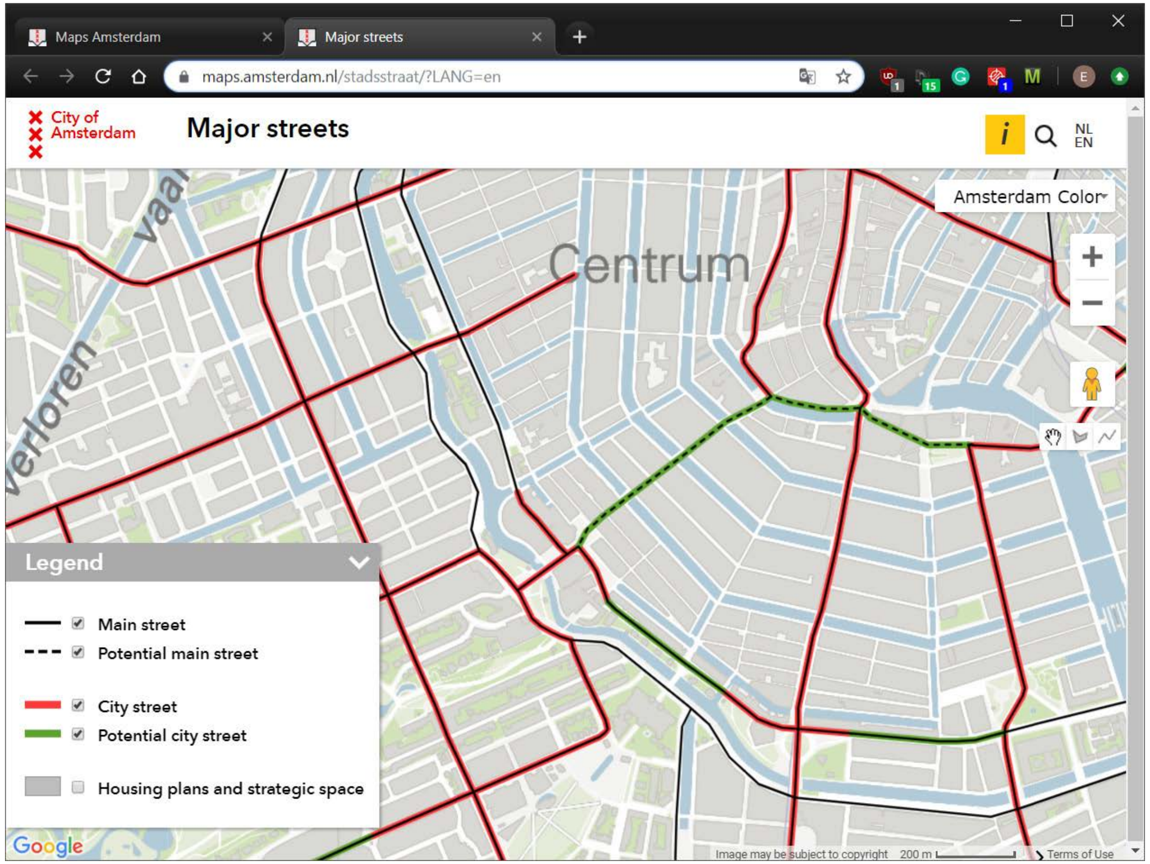
- Regular (Raster) and irregular (Vector)





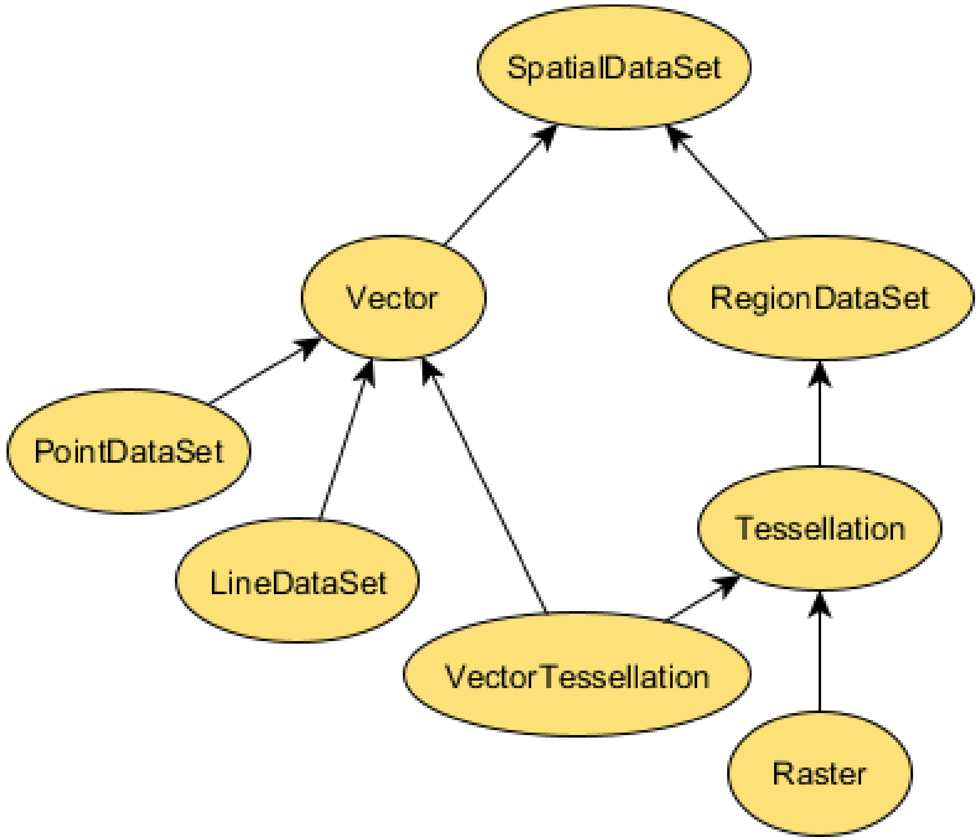
Point and Line datasets





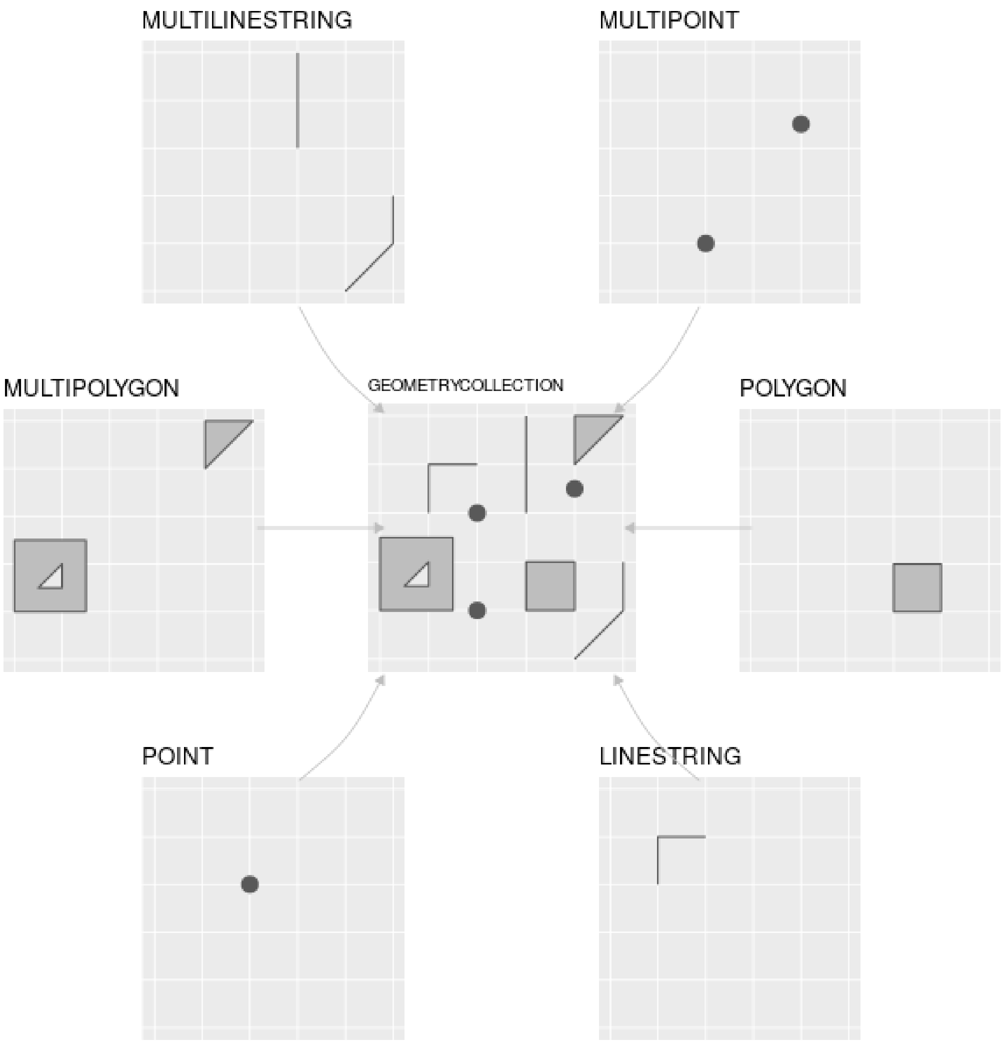
Generalized geometric layer model

- *Region*: dataset where the geometric primitives are regions (polygons or cells)
- *Tessellation*: A specific form of *Region* Regions are non-overlapping, and fill the entire extent of the dataset without gaps
- *Raster*: A special kind of *Tessellation* , where the regions are all squares (cells)
- *VectorTessellation*: Irregular tessellation

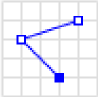
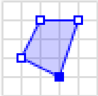
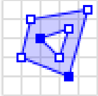


Vector geometry model (Simple Features)

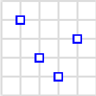
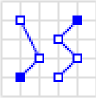
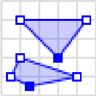
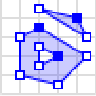
(WKT standard)



Geometry primitives (2D)

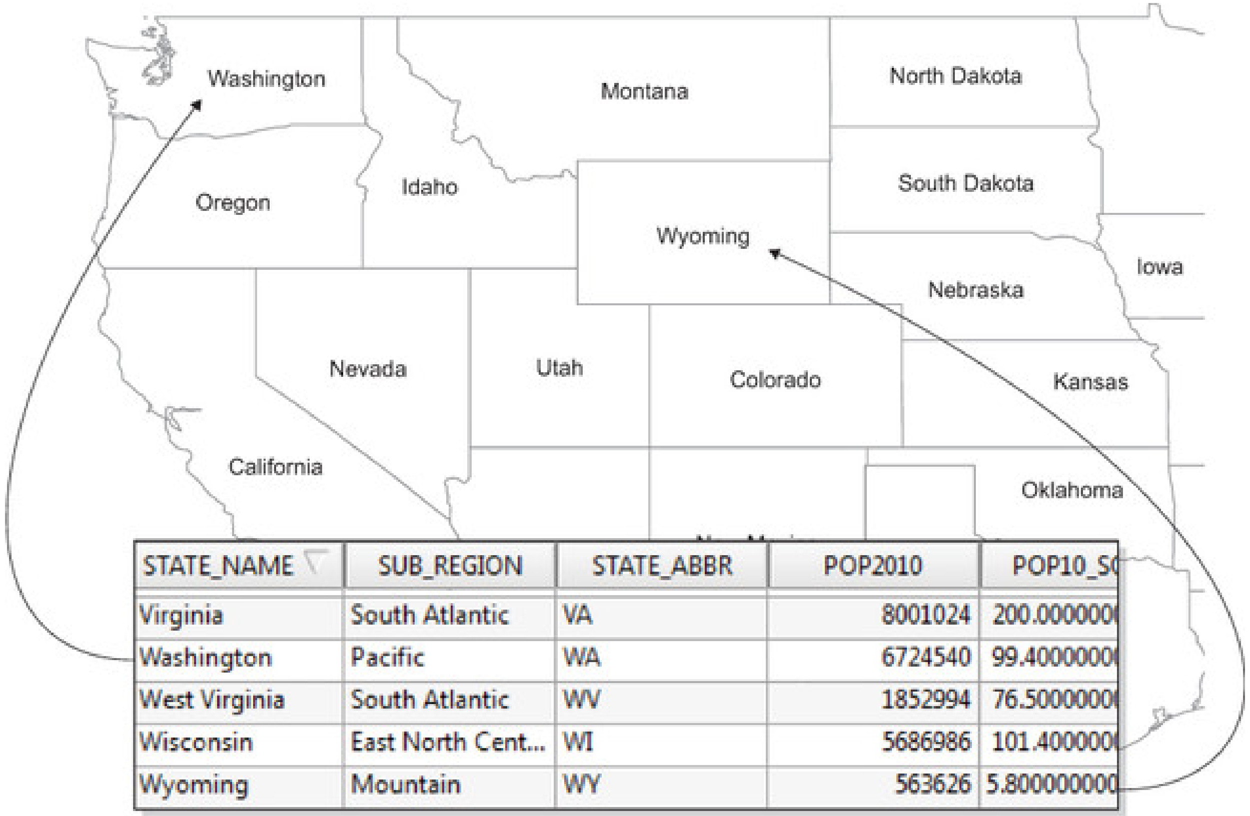
Type	Examples	
Point	`POINT (30 10)`	
LineString	`LINESTRING (30 10, 10 30, 40 40)`	
Polygon	`POLYGON ((30 10, 10 20, 20 40, 40 40, 30 10))`	
	`POLYGON ((35 10, 10 20, 15 40, 45 45, 35 10), (20 30, 35 35, 30 20, 20 30))`	

Multipart geometries (2D)

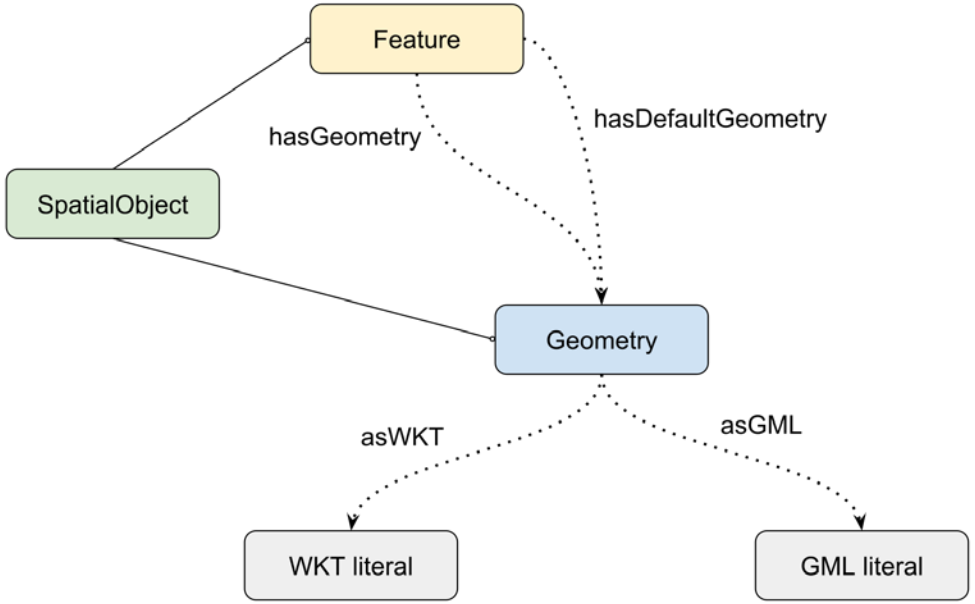
Type	Examples	
MultiPoint	`MULTIPOINT ((10 40), (40 30), (20 20), (30 10))`	
	`MULTIPOINT (10 40, 40 30, 20 20, 30 10)`	
MultiLineString	`MULTILINESTRING ((10 10, 20 20, 10 40), (40 40, 30 30, 40 20, 30 10))`	
MultiPolygon	`MULTIPOLYGON (((30 20, 10 40, 45 40, 30 20)), ((15 5, 40 10, 10 20, 5 10, 15 5)))`	
	`MULTIPOLYGON (((40 40, 20 45, 45 30, 40 40)), ((20 35, 45 20, 30 5, 10 10, 10 30, 20 35), (30 20, 20 25, 20 15, 30 20)))`	

Vector data model (Geometry + attributes)

- The association of attributes and spatial geometries makes geodata special. Captured by OGC's notion of a *feature (here: GeoSPARQL)*

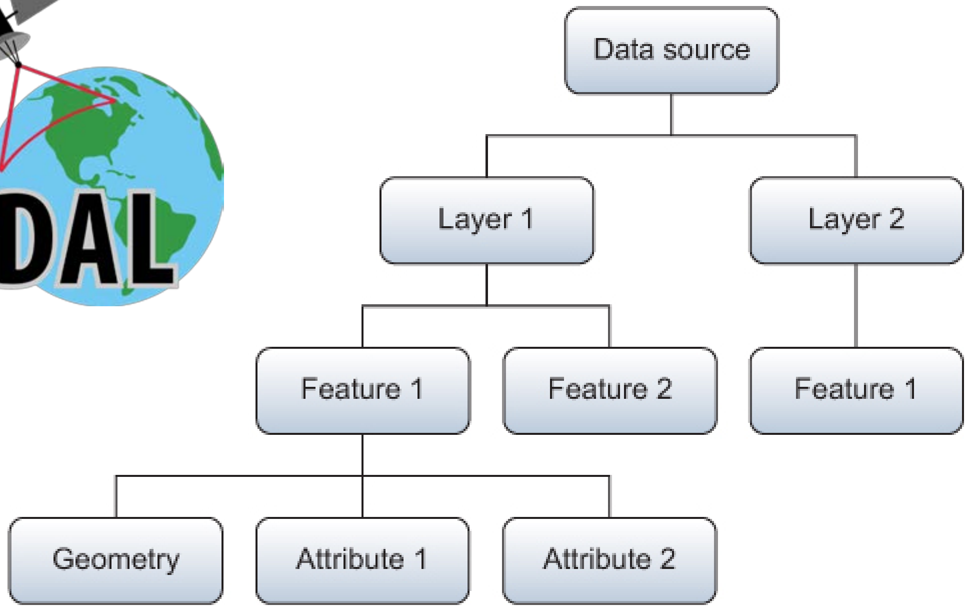


STATE_NAME	SUB_REGION	STATE_ABBR	POP2010	POP10_S
Virginia	South Atlantic	VA	8001024	200.000000
Washington	Pacific	WA	6724540	99.4000000
West Virginia	South Atlantic	WV	1852994	76.5000000
Wisconsin	East North Cent...	WI	5686986	101.400000
Wyoming	Mountain	WY	563626	5.80000000

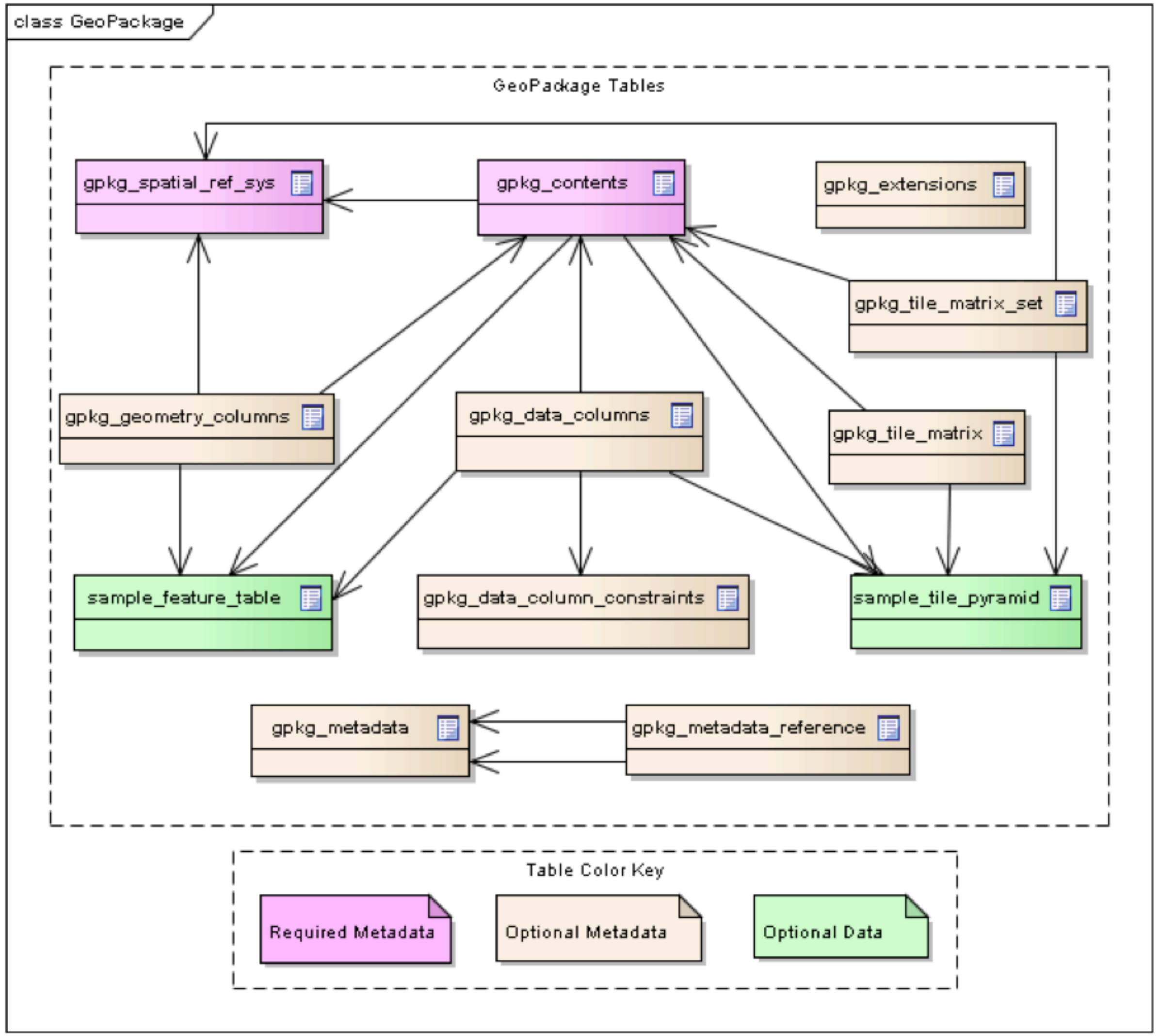


Vector data model (Geometry + attributes)

- GDAL/OGR is a universal library for dealing with vector (and raster) formats https://gdal.org/



OGR class structure



Basic geometric operations: Point in Polygon and Centroid

- To find out whether a point is located inside a polygon
- To find out the center of gravity

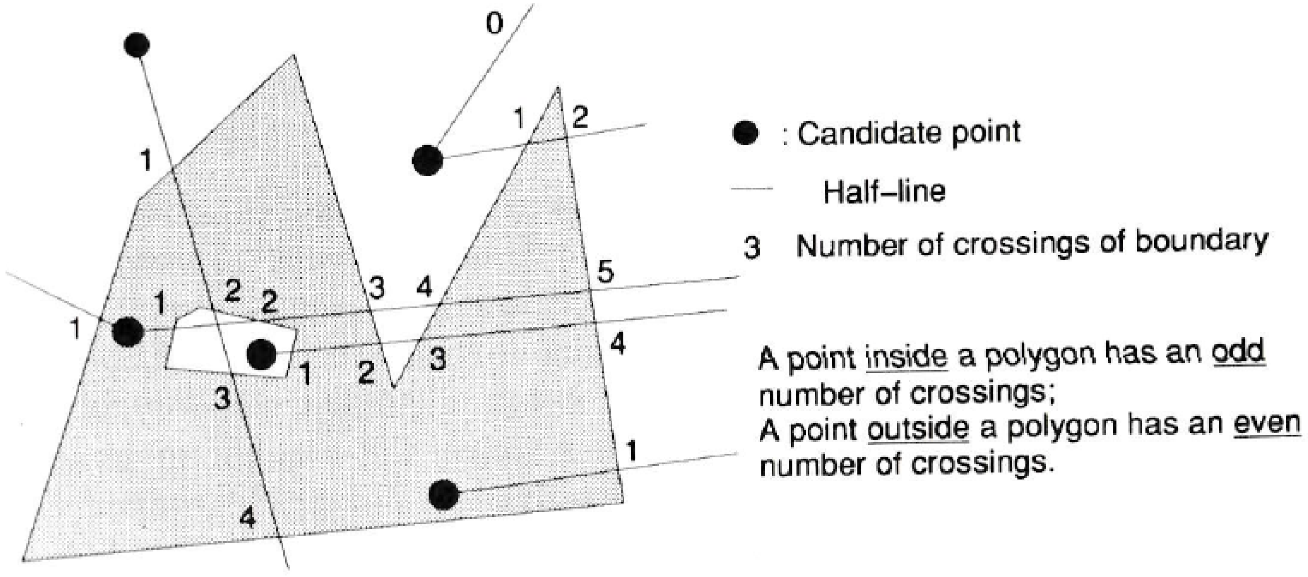


Figure 7.7 Illustration of the half-line theorem (point-in-polygon rule).

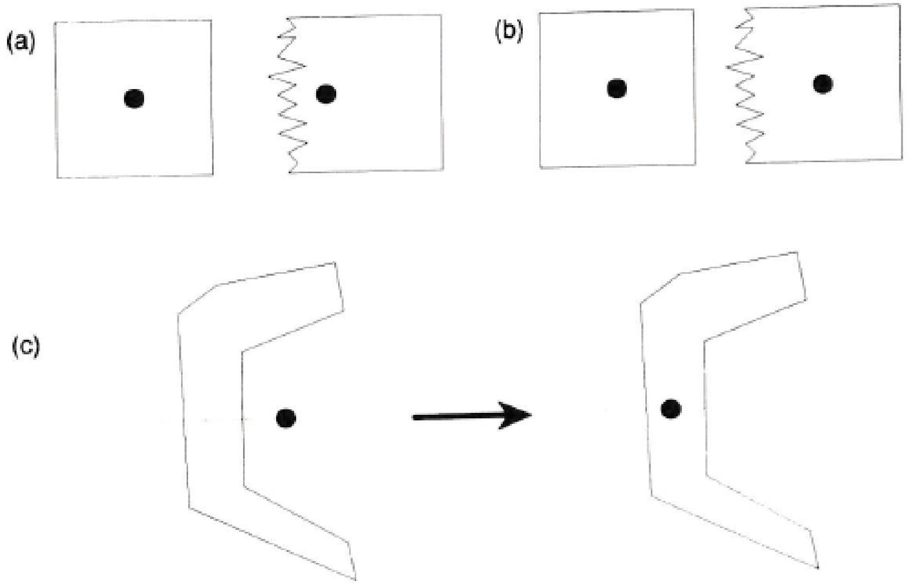


Figure 7.8 Definition of centroids. (a) Examples of centroids. (b) Examples of centroids defined as centres of gravity. (c) Moving an outside centroid.

Laurini/Thompson 1996

Basic geometric operations: Geometric intersections

- Compute the difference, union and intersection of polygons

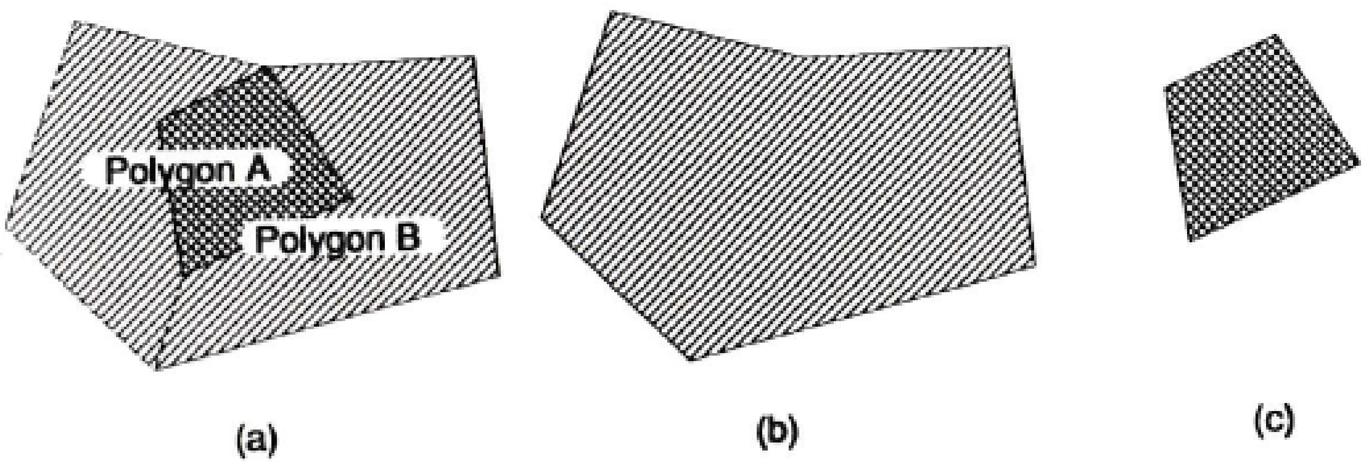


Figure 7.10 Union and intersection of polygons. (a) Two intersecting polygons. (b) Union of A and B. (c) Intersection of A and B.

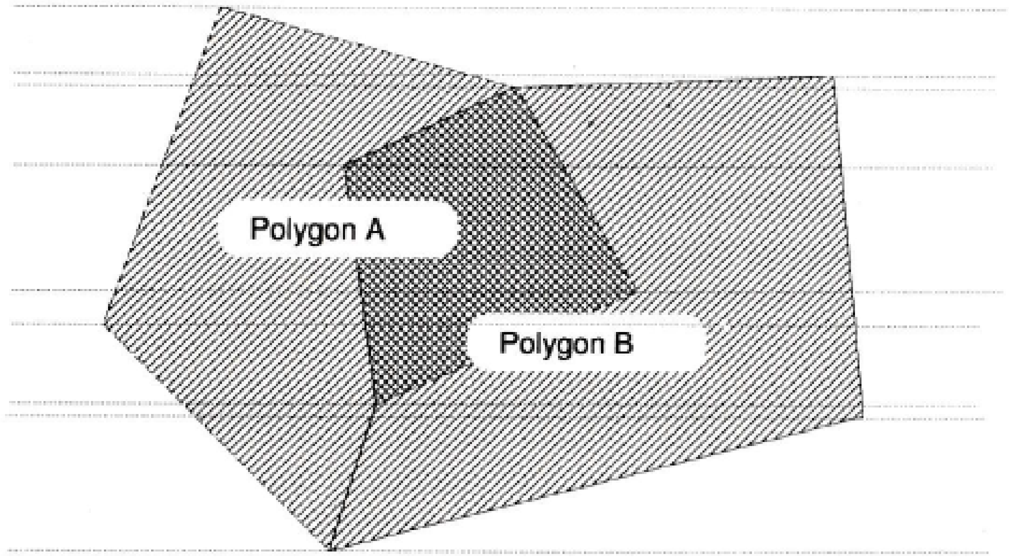


Figure 7.11 Splitting two polygons into slabs.

Laurini/Thompson 1996

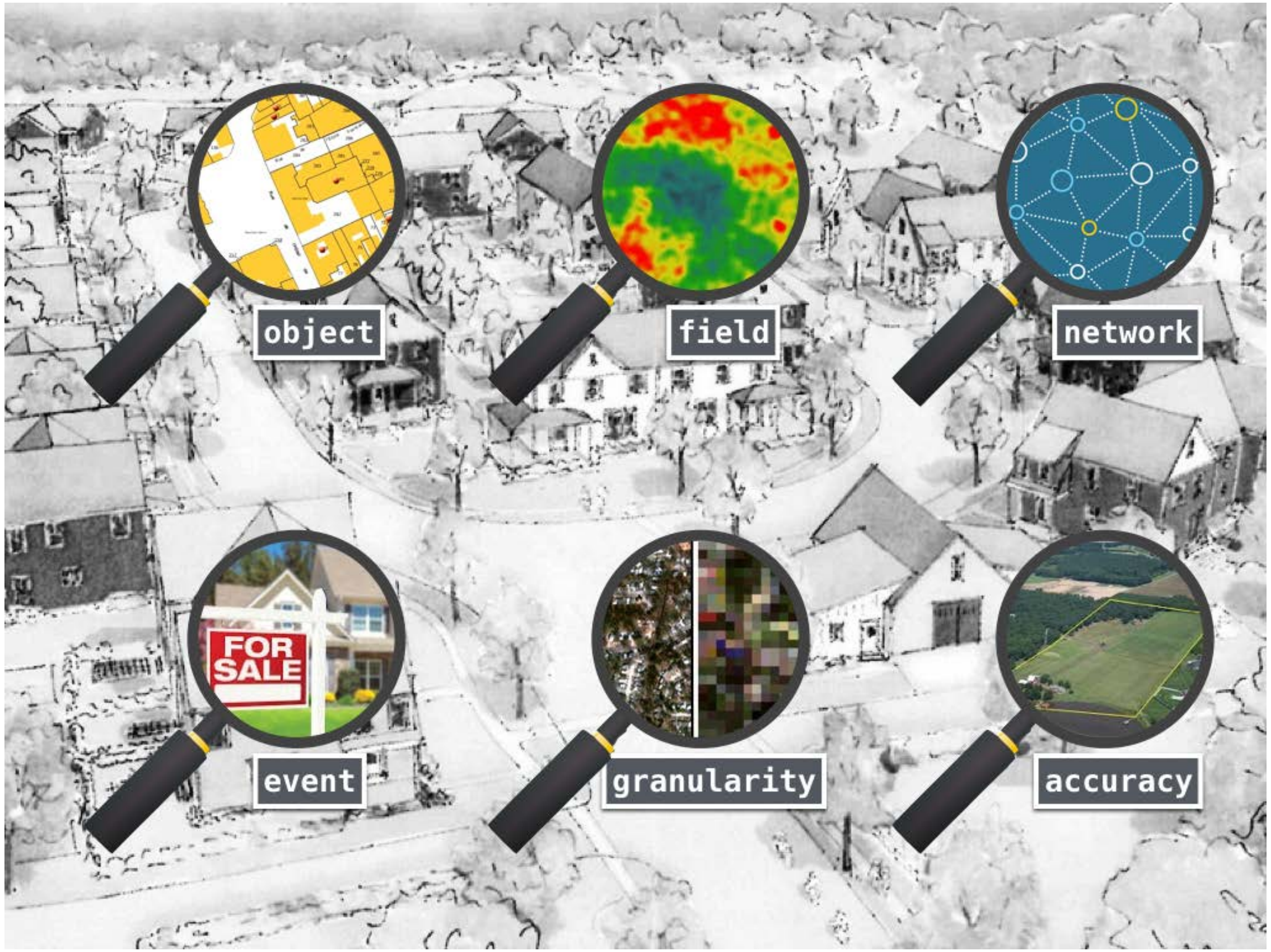
Core concept data types

Core concepts of spatial information (Kuhn 2012)

Cognitive lenses through which the environment can be studied
(… like "cell" in biology or "value" in economics)

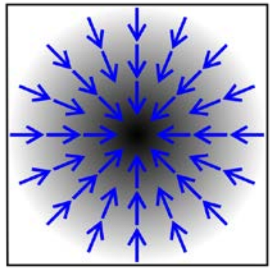
Provides constraints for…

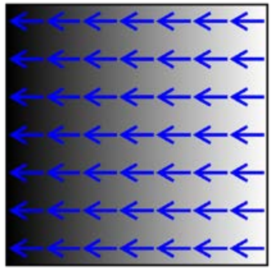
1. Analysing geodatasets with tools
2. Posing analytical questions
3. Finding answers with GIS workflows



Core concepts (= what geodata represents)

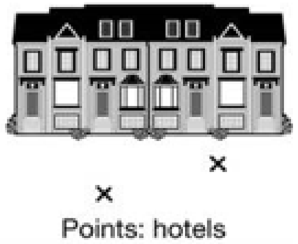
Field

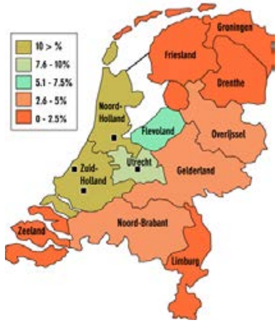




- continuous phenomenon
- Space -> Quality (value field)
- boundaries are irrelevant

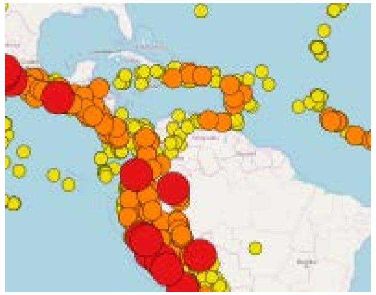
Object





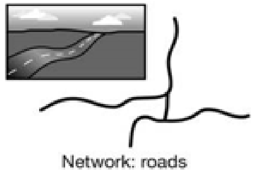
- discrete phenomenon with qualities
- Object -> Space (projected in space, not time)
- boundaries are relevant
- Object -> Quality

Event



- like objects, but…
- Event -> Time, Space (projected in time and space)

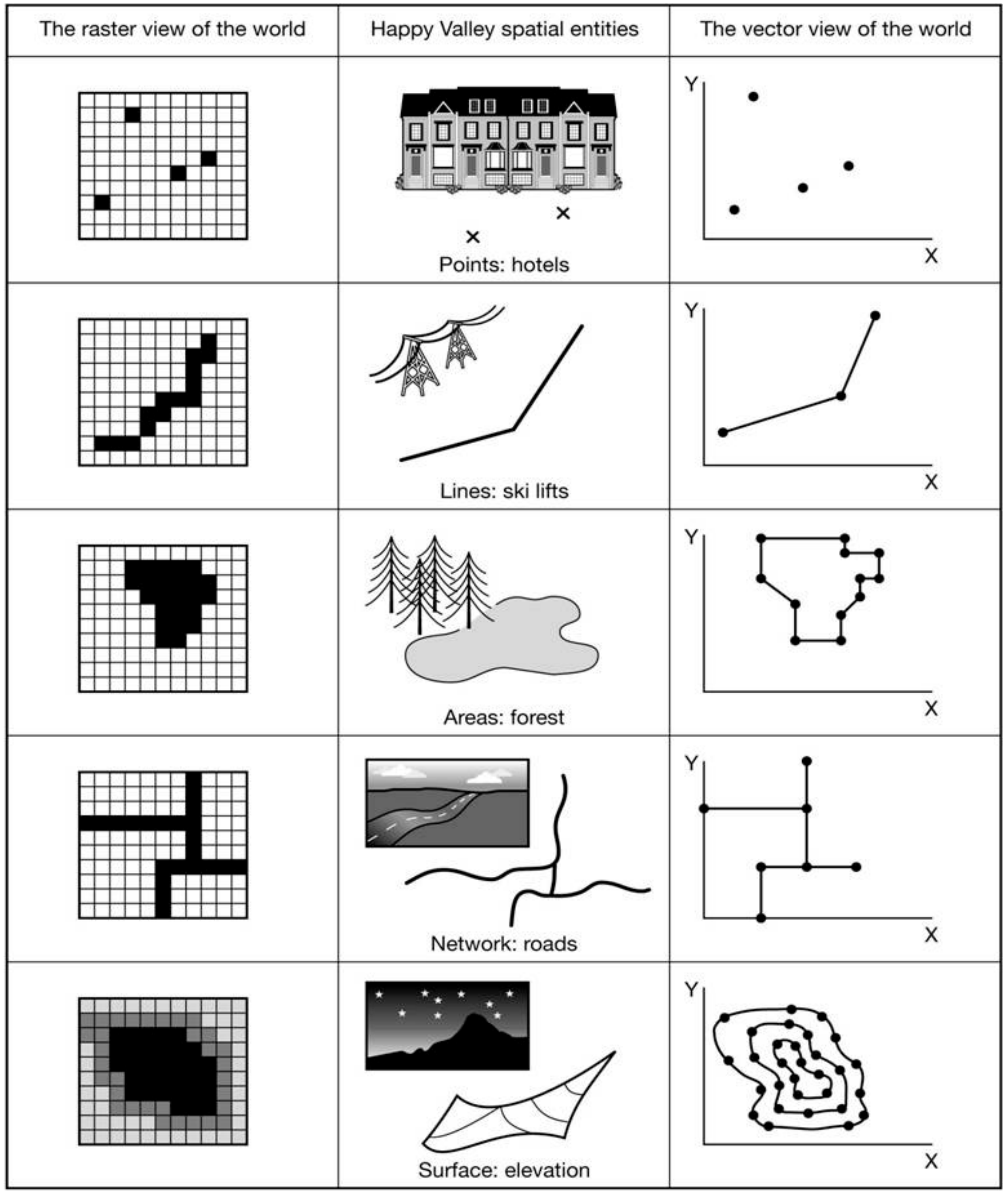
Network



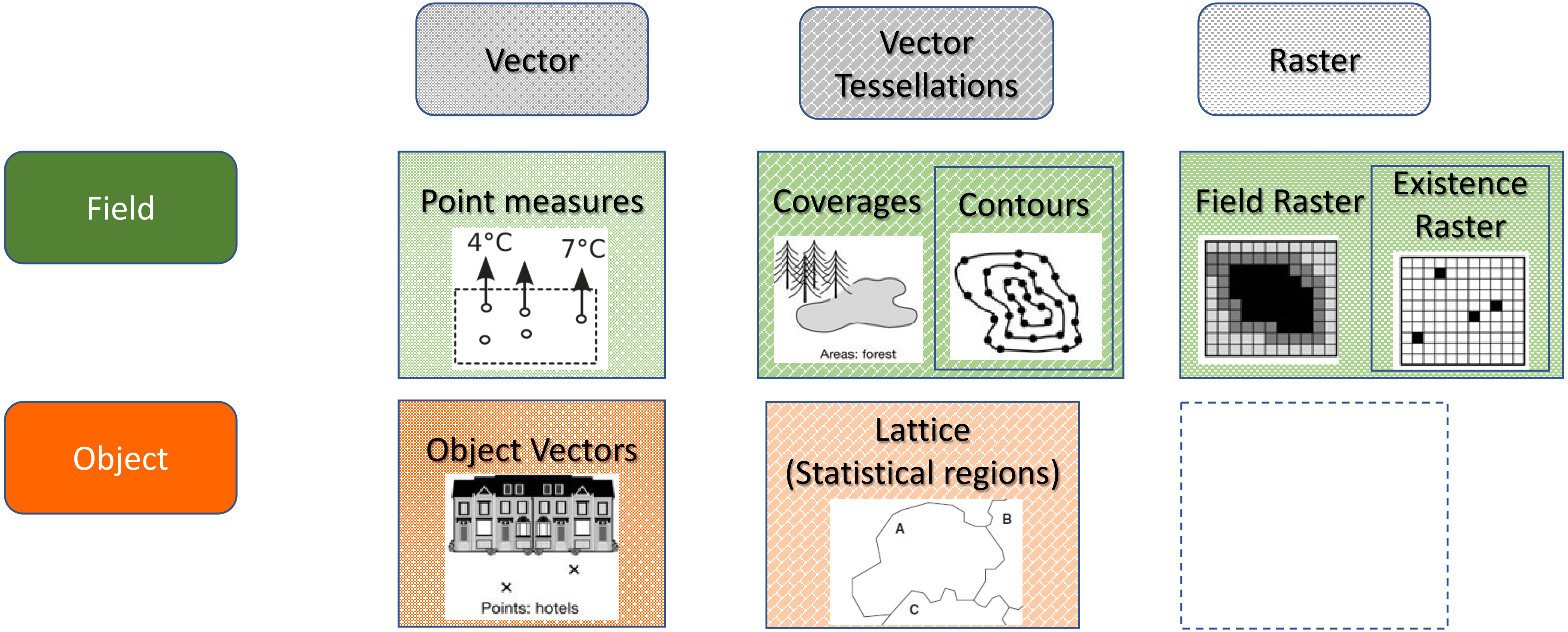
- Quantified relations between objects
- Object x Object -> Quality

Raster/vector data model (= how geodata represents)

- Concept != data model
- Raster – Vector data model
- Can both represent fields, and objects, and networks ...
- So why do we use one over the other?
- Concept is “added” by human interpreter of data
- Concept is needed to understand analysis and possible transformations



How geodata models represent core concepts

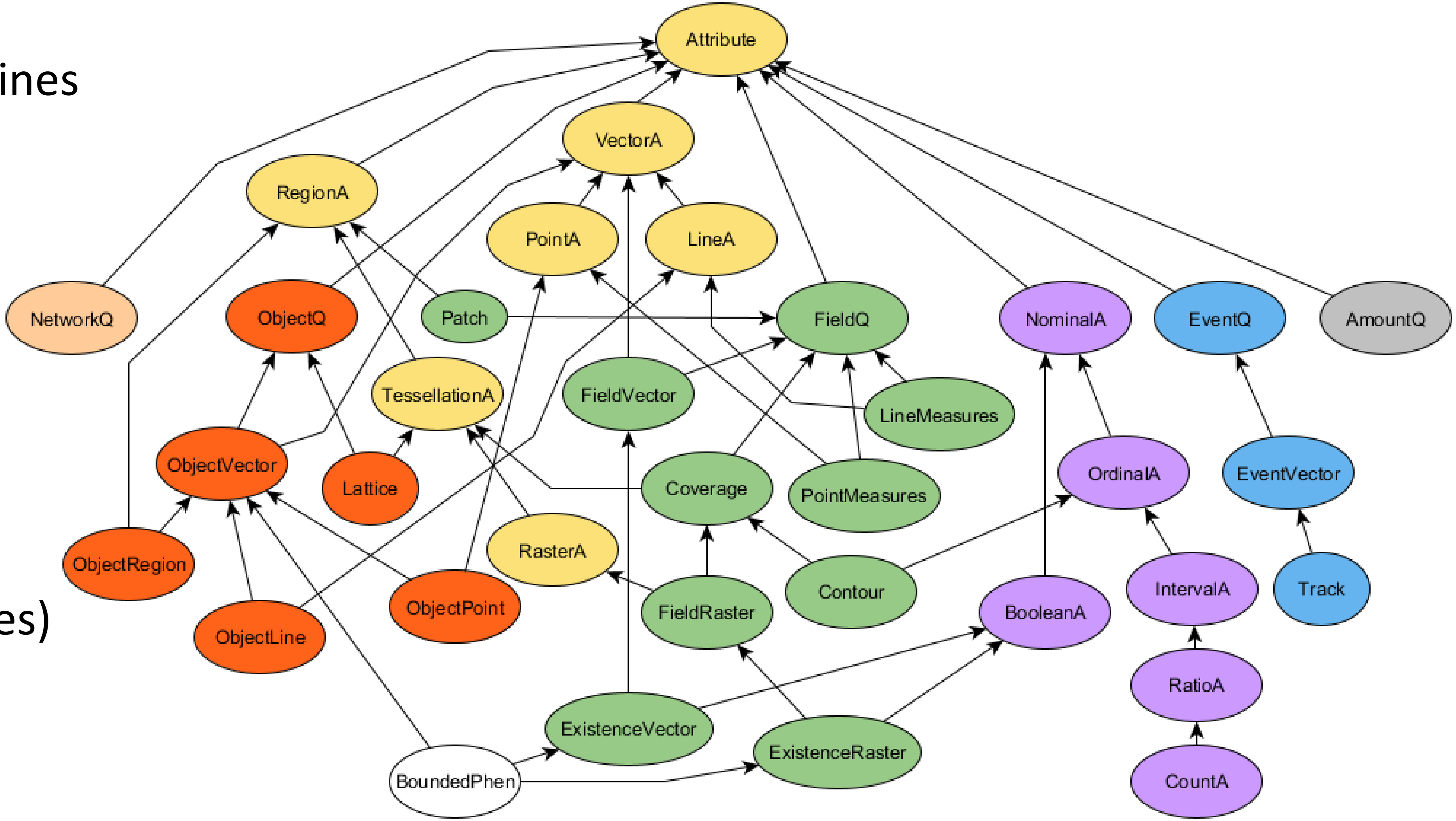


Core concept data types (CCD) ontology

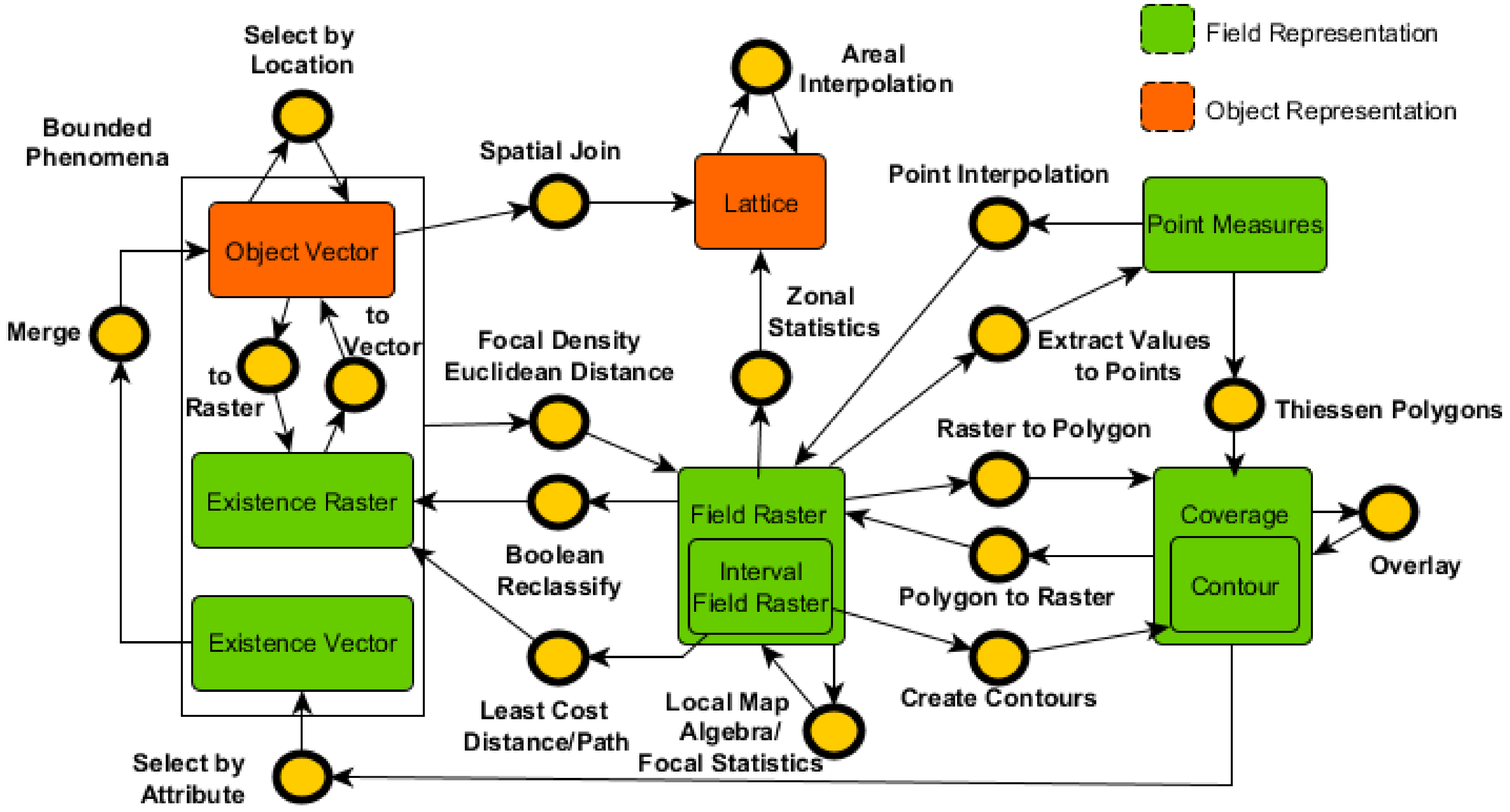
The ontology combines three dimensions:

1. Layer types
2. Core concepts field, object, event, network
3. Levels of measurement

(see lab for examples)



In which ways can geodata be transformed?



CCD Ontology

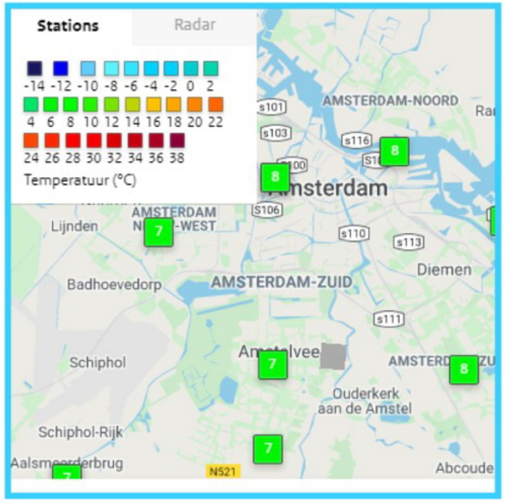
The ontology
can be used to
annotate geodata
resources.
(Scheider et al. 2020)

Examples
from the Amsterdam
data portal

https://maps.amsterdam.nl/open_geodata/

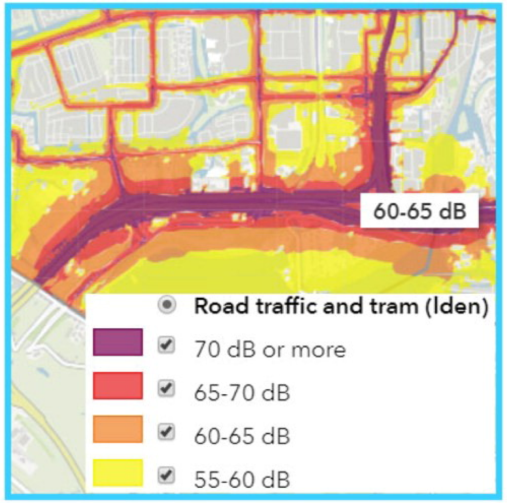
ObjectPoint

EventPoint

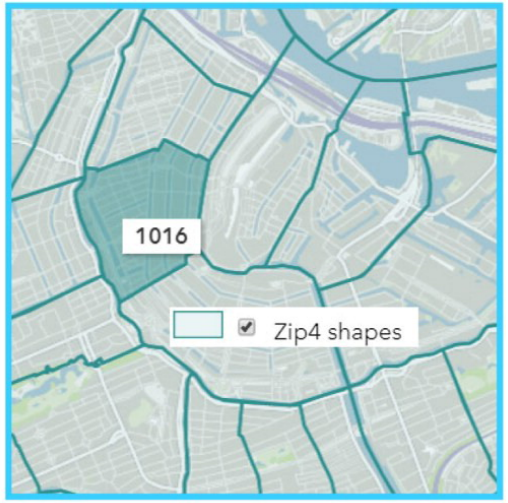


PointMeasures

Coverage



Contour



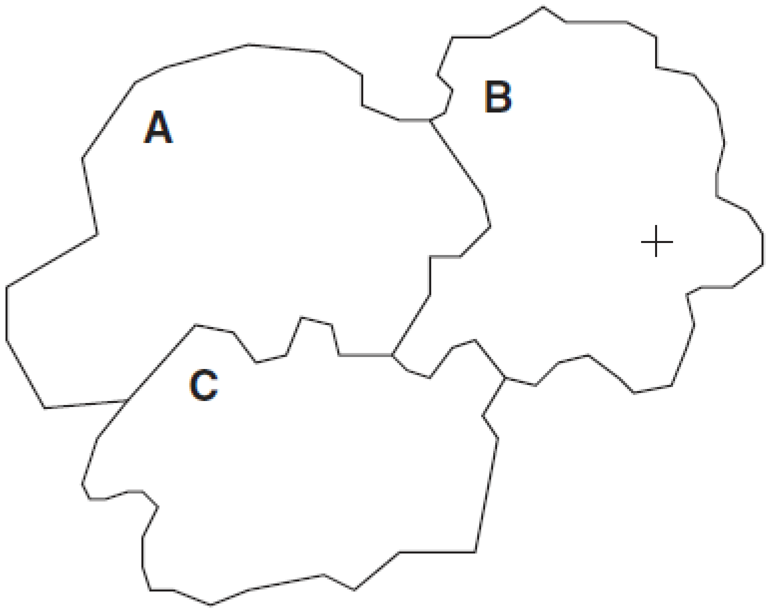
Lattice

The difference between Coverages and Lattices

Tessellations are regions that fully cover space without overlap. For three polygons A, B, and C, land cover type and average elevation values are given in the table. At an arbitrary location inside a polygon, for example, the location marked with a +, a *coverage* yields the quality for that location, such as its land cover type. For a *lattice*, such as average elevation, the elevation value at this particular location (+) is not available.

Coverage: self-similar
(the attribute value of the whole applies also to parts)

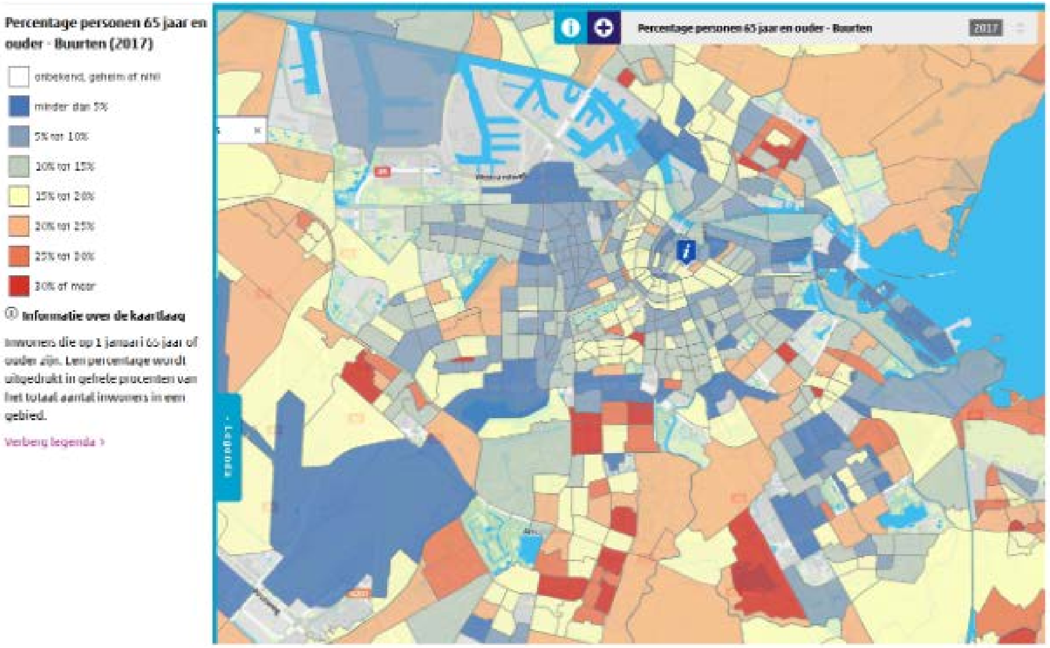
Lattice: not self-similar



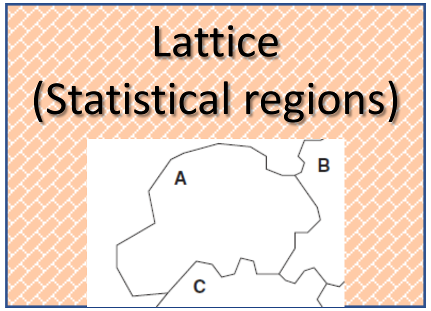
	Coverage	Lattice
	land cover type	average elevation (m)
A	Forest	631
B	Urban	220
C	Water	42
+	Urban	

Which overlay method could be used for assessing the amount of elderly people living in PC4 areas?

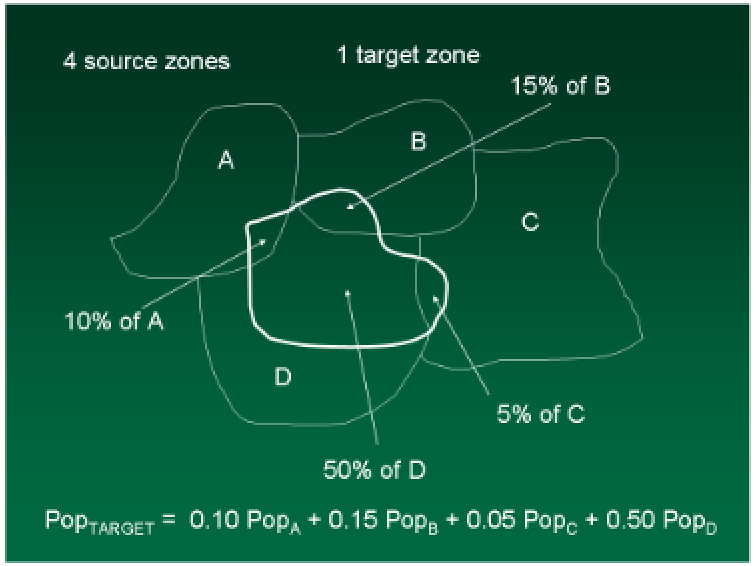
Answer:



(a) CBS Buurt statistics, showing the percentage of persons over 65 in neighborhoods.

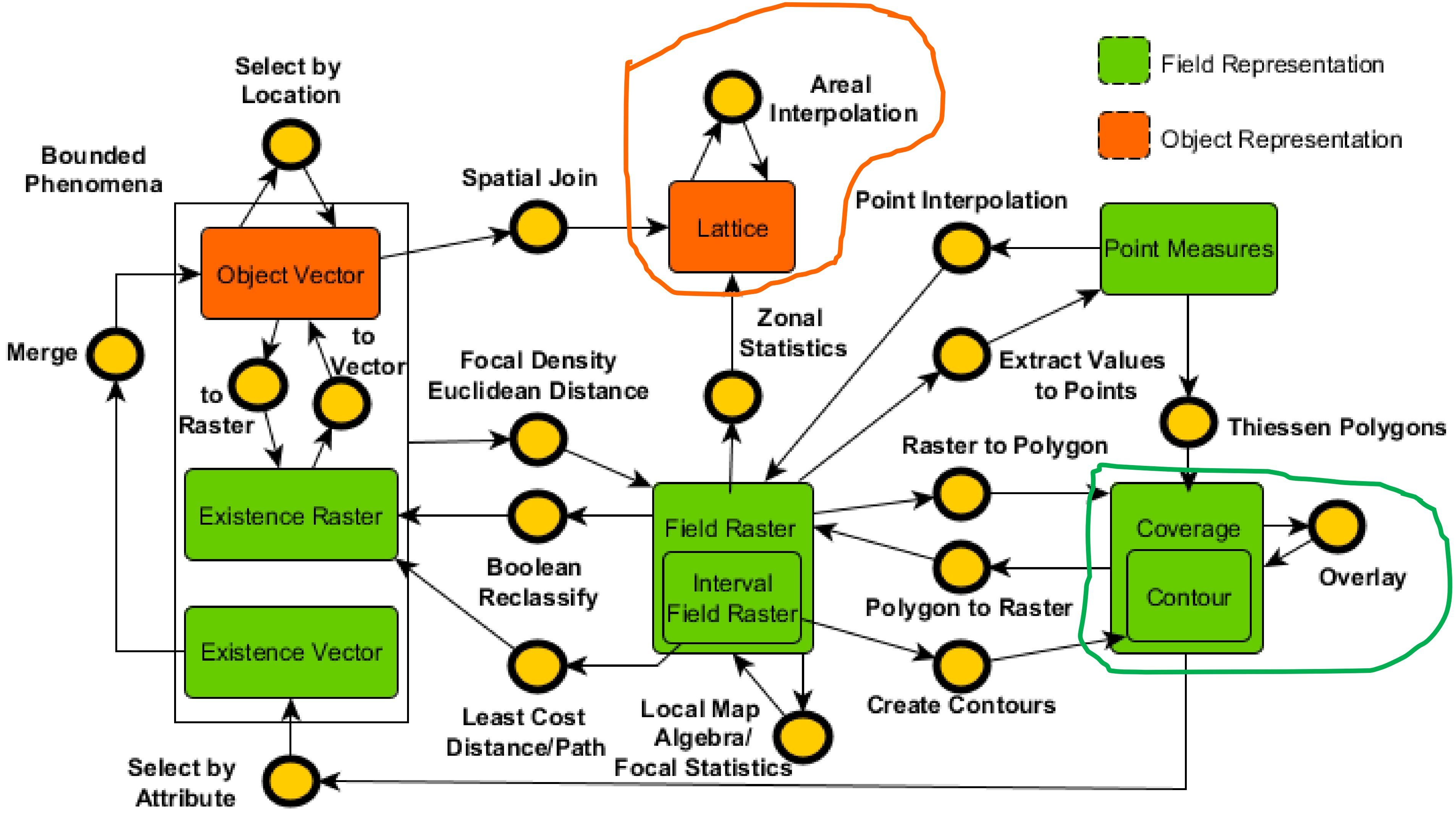


Lattices are not self-similar, thus overlay needs to account for this



(b) Simple areal interpolation method. Image by kind permission of Michael Goodchild.

In which ways can geodata be transformed?



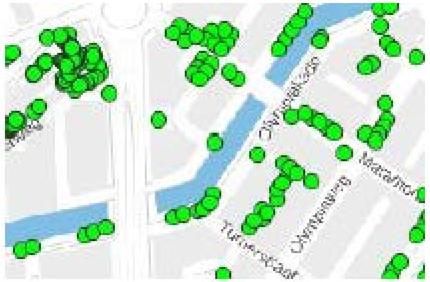
The difference between ObjectPoints, PointMeasures, LineMeasures and Contours

ObjectPoints are point representations of objects

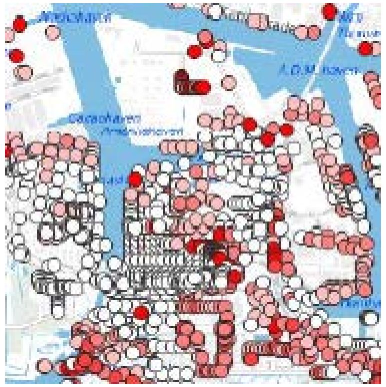
PointMeasures are pointwise measurements of fields

LineMeasures are linewise measurements of fields

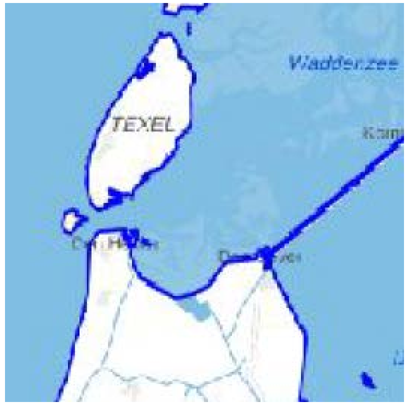
Contours are tessellated regions of field intervals



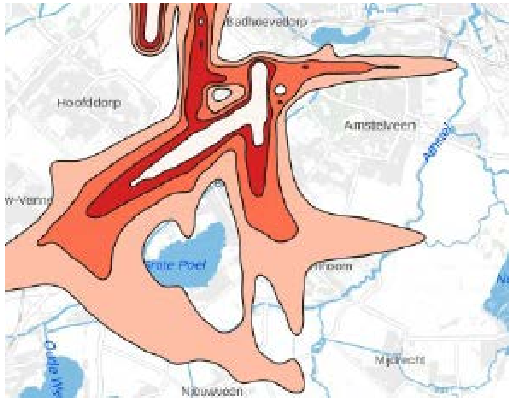
Trees: ObjectPoint



Temperature: PointMeasures

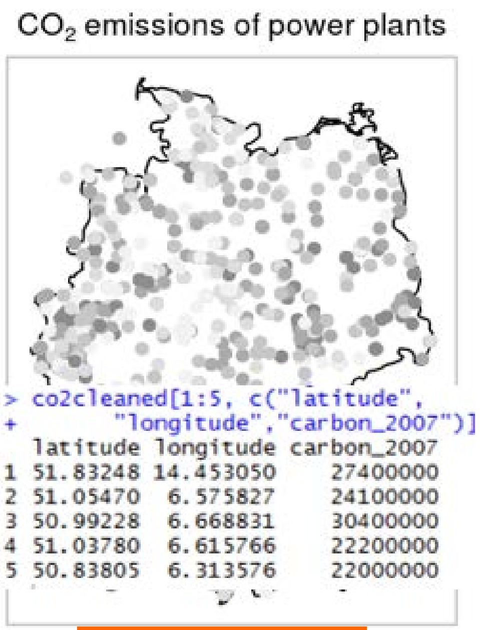


Coast: LineMeasures

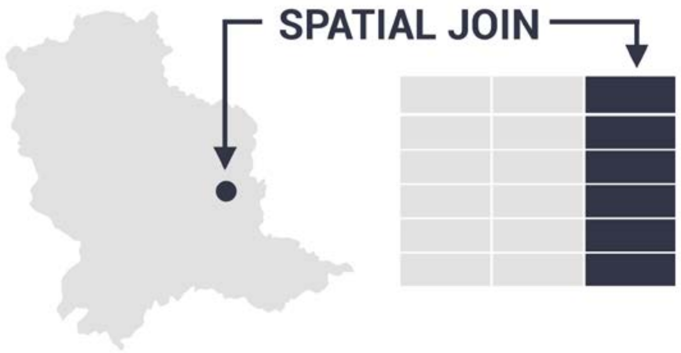


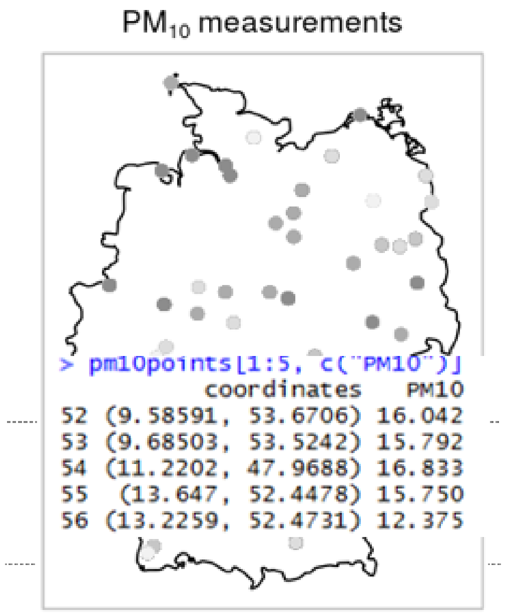
Noise: Contours

How much polluted is Germany?

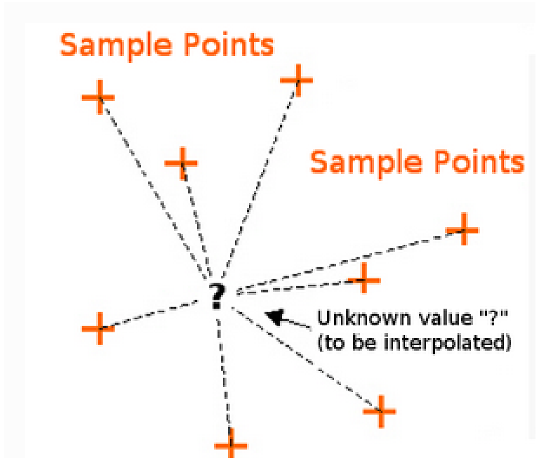


ObjectPoints

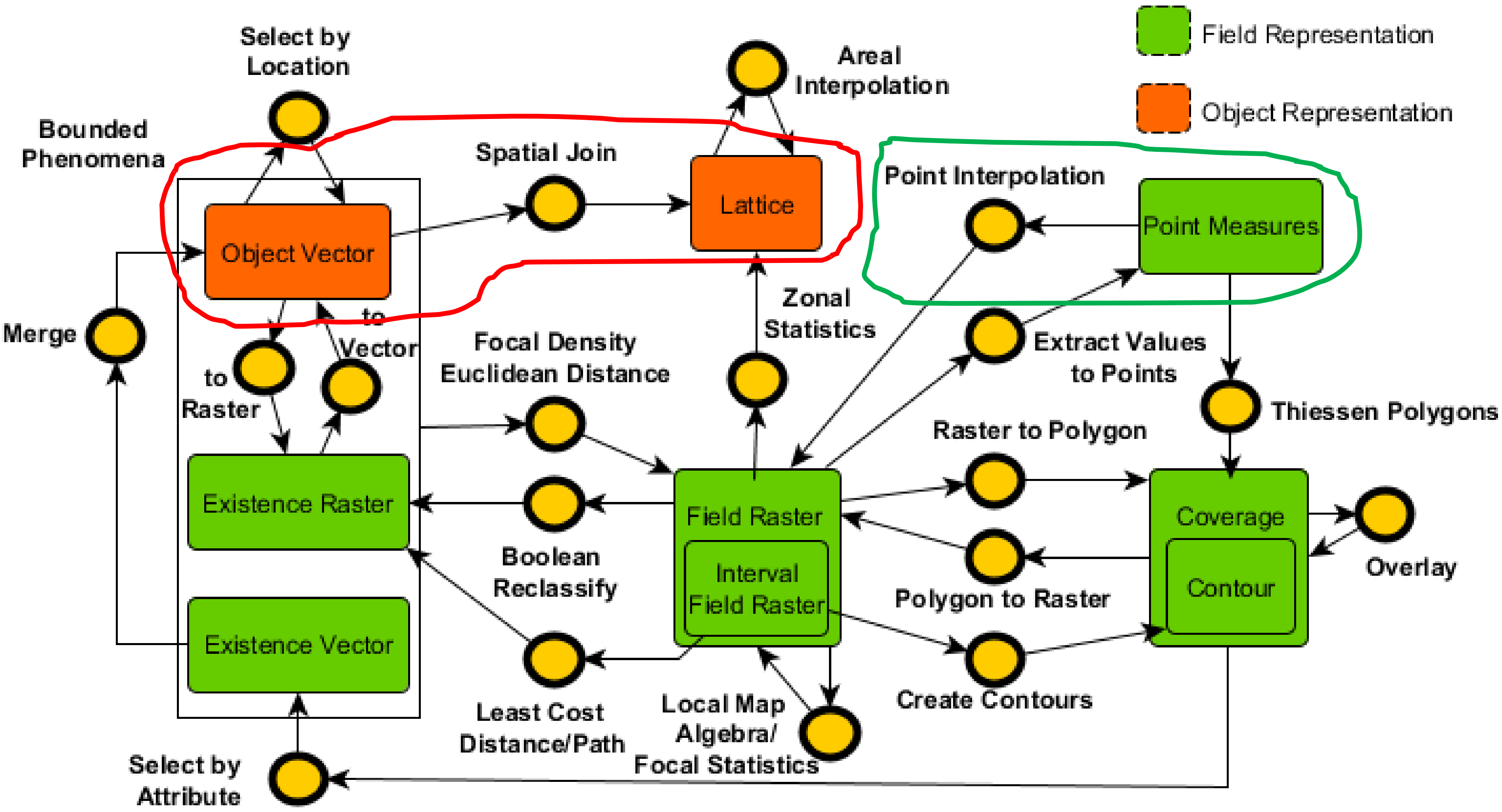




PointMeasures



In which ways can geodata be transformed?



Questions?
(Q&A session)

References

- Mandatory readings:
  - Chapter 2 “Measurement frameworks” in Chrisman 2002: Exploring geographic information systems, 2nd edition)
  - Chapter 7: Manipulations (interpolations, geometric operations, transformations) in Laurini and Thompson 1992: Fundamentals of Spatial Information Systems
- https://www.ogc.org/standards/sfa

- Kuhn, W. (2012). Core concepts of spatial information for transdisciplinary research. International Journal of Geographical Information Science, 26(12), 2267-2276.
- Scheider, S., Meerlo, R., Kasalica, V., & Lamprecht, A. L. (2020). Ontology of core concept data types for answering geo-analytical questions. Journal of Spatial Information Science, 2020(20), 167-201 (http://www.josis.org/index.php/josis/article/viewArticle/555)