Territorial intelligence

- Extension of business intelligence to the governance of territories
  - Urban and regional planning
- Based on
  - geographic data
  - knowledge management
  - visual analytics
  - best practice modeling

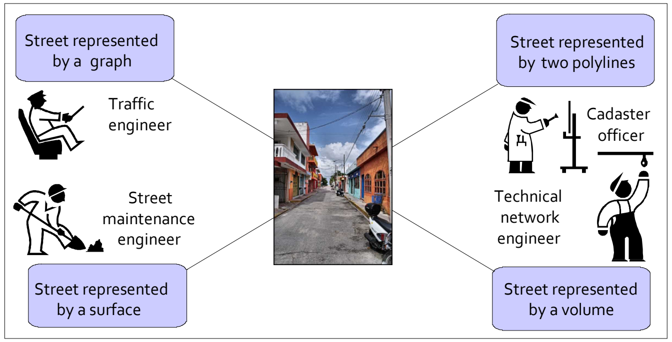
Modeling geographic knowledge

1. Geographic objects
2. Principles of modeling
   - Prolegomena
   - Principles
3. Visual representations
4. Conclusions

1 – Geographic Objects

- Geometric objects
- Types
- Spatial vs geographic relations

Multiplicity of representations



Geometric Objects

- Dimensions
  - 0D, 1D, 2D, 3D
- Dominant geometry
  - 2D, but eyes in the 3rd dimension
  - Plan - sphere
- Importance of non-connected polygons
  - ex. « Italy »
- Importance scale/resolution
  - multi-representation

Type of geographic objects

- Geodetic objects
- Administrative objects
- Manmade objects (crisp boundaries)
- Natural objects
  - With fuzzy boundaries
  - Fractal geometry
  - Continuous fields

Geodetic Objects

- Theoretical objects on the globe
  - Equator
  - North and south poles
  - Meridians
  - Parallels
- Modeled with points, lines and circles
- Basis for definition of coordinates
- Cannot disappear

Administrative objects

- Without considering disputes at borders
- Non-connected polygons
- Often organized in hierarchical tessellations
  - Countries, regions, provinces, municipalities
  - Parks
- Total coverage of the Earth
- A some scales, they can disappear

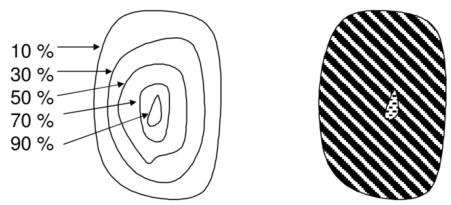
Manmade Objects

- Manmade
  - Buildings, bridges, streets, etc.
- Usually Euclidean objects
- Modeled as non-connected polygons
- At some scales
  - Roads can become linear
  - They can disappear

Natural Objects

- Shape can evolve
  - River, minor and major bed
- Boundary not easy to define
- Fractal geometry can be useful
  - Multi-scale
- Fuzzy sets
  - Egg-yolk

Fuzzy modeling



Continuous Fields

- Temperature, pressure, wind, sea salinity, land use, rain, etc.
- Meteorology
- Infinity of points in space
  - Impossibility to store all points
  - Sampling points and interpolation

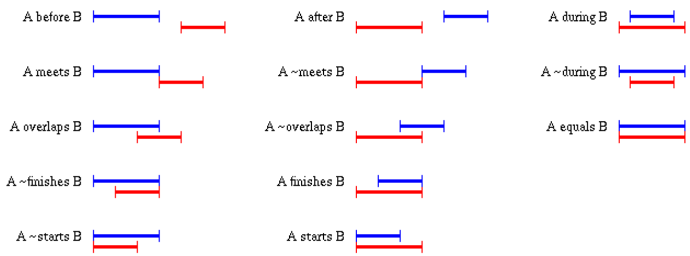
Object Geometry

- Storing only one geometric description
- Several visualization geometries generated by on-demand generalization algorithms
- If geometric visualization size < threshold then the GO disappears

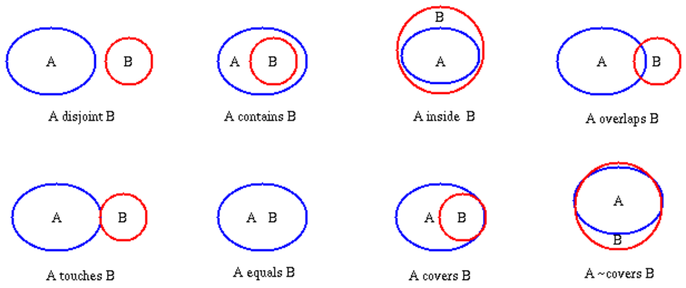
Conventional Spatial Relations

- Topological (Allen, Egenhofer, Clementini, etc.)
- Projective
- Distance

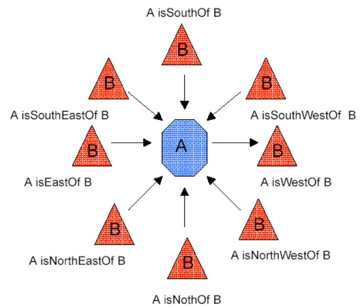
Allen's relations



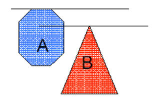
Egenhofer's relations



Projective relations (1/2)



e.g. "*A isNorthOf B*"



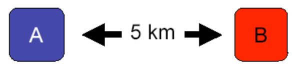
True if northern most point of A is north of the northern most point of B

Projective relations (2/2)

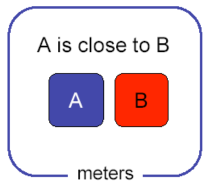
- Truly geographic relations
- Attention to the sphere:
  - Limited transitivity
    - *Beijing is east of London*
    - *Washington is east of London*
    - ==> *Washington is east of Brighton !!*
  - Nothing to the North of the North Pole
  - When you are at the South Pole, all directions bring you the North Pole

Distance relations

- **Quantitative Distance**



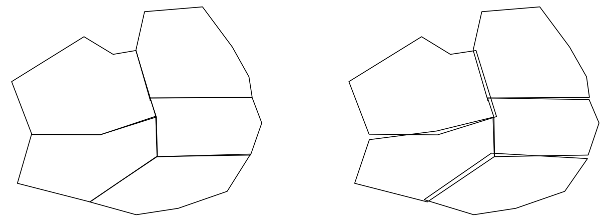
- **Qualitative Distance**



Geographic relations

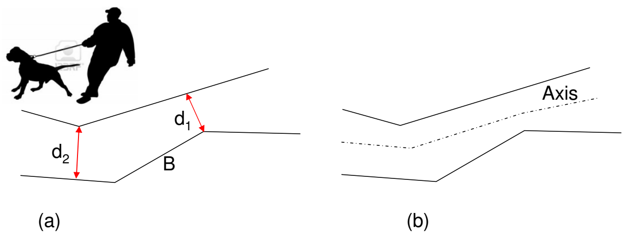
- In addition to spatial relations
  - Tessellations for administrative objects
  - Networks
  - Ribbon relations
  - Geographic ontologies with Geo Relations
  - Gazetteers

Tessellations



(a) good-standing tessellation (b) loose tessellation with sliver polygons

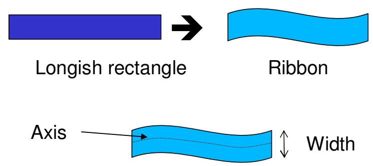
Frechet distance



$$F = \underset{a \in A}{Max}(\underset{b \in B}{Min}(dist(a,b)))$$

Ribbons

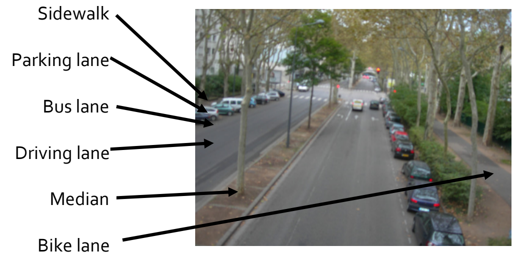
- Homeomorphism of a longish rectangle



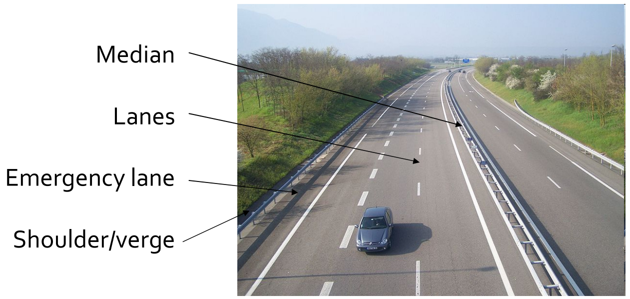
Ribbon relations



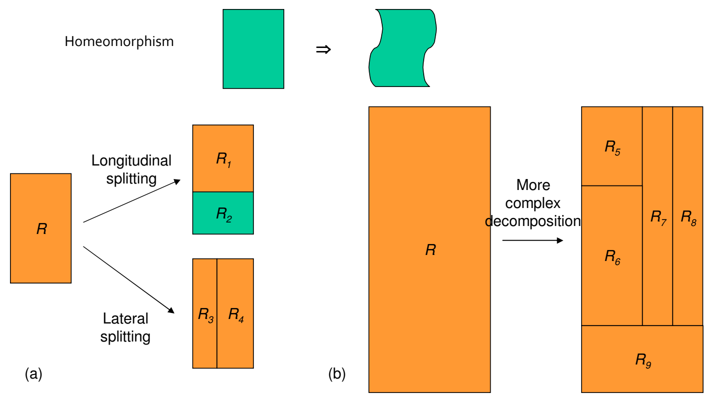

Urban example



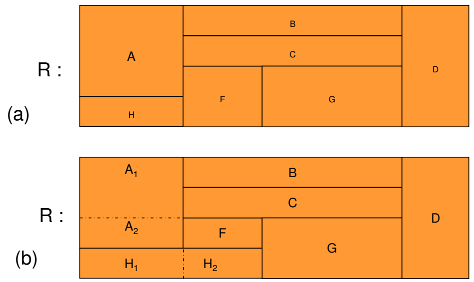
Motorway



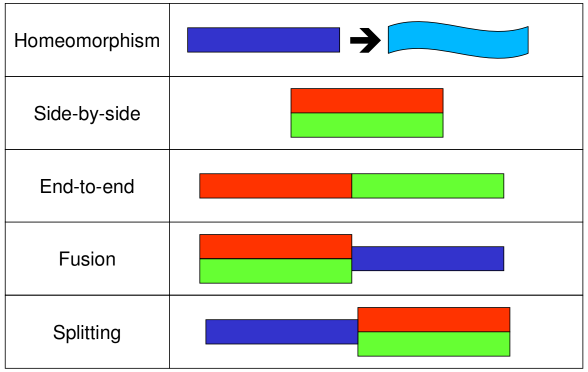
Ribbon topology



Ribbon arrangement



Some ribbon relations



Visual acuity

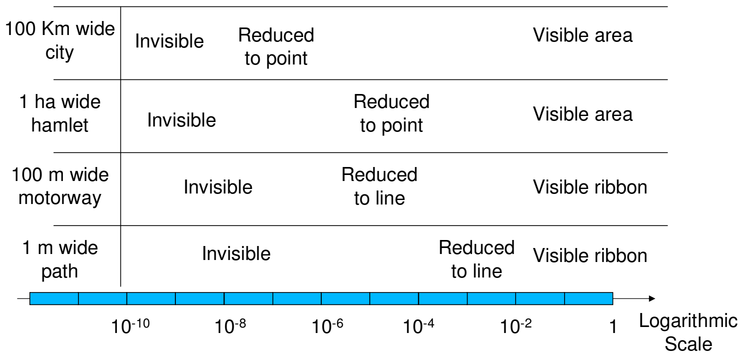
- According to scale, objects are present or not.
- Cities: area, then point, then nothing
- River: ribbon, then line, then nothing
- Threshold for visual acuity
  - 0.1 mm (object no more visible)
  - 1 mm (ribbon is transformed into a line)

Granularity of interest

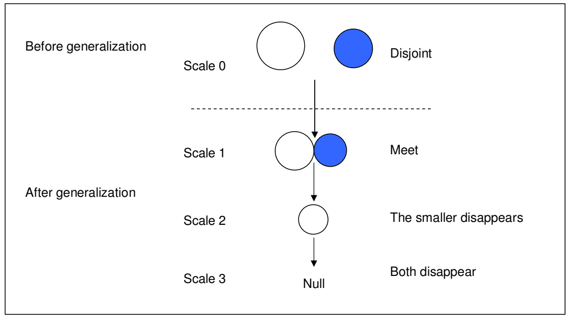
- A statewide politician vs a citywide politician
- A statewide planner vs an urban planner

- → Perimeter of interest
- → Minimum level of details
- → Granularity of interest (similarity with visual acuity, but for reasoning)

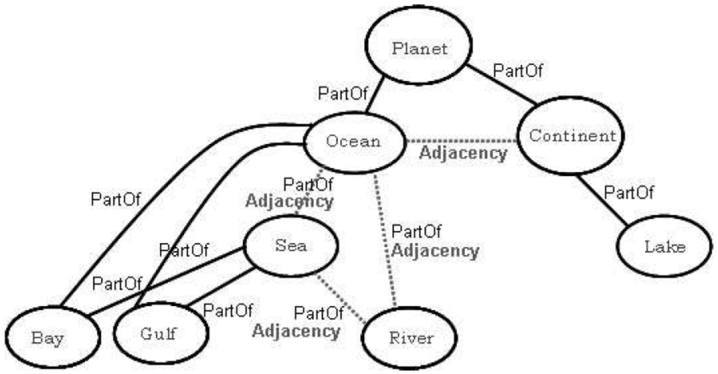
Geographic objects and scales



Generalized Topological Relations



Ontology with geographic relations



Gazetteers

- Placename database (toponyms)
- A place can have different names
  - London, Londres, Londra, etc.
- Same name for different places
  - Mississippi river, Mississippi State
- Different shapes
  - Roma (Romulus' time, now)
- Different names over time
  - Byzantium, Constantinople, Istanbul

2 – Modeling principles

- Theoretical bases for modeling geographic knowledge
- 12 principles and 12 prolegomena
- Prolegomena: preliminary considerations

Construction of this framework

- More than 30 years of teaching GIS
- Necessity to reorder GIS concepts
- Necessity of testing this framework
  - Expert consensus
- First presentations
  - Belluno (2/2012), Salerno (3/2012), Sousse (6/2012), Dublin (2/2013),
- Brighton (7, 2013)
  - Kuala Lumpur (9, 2013)

Prolegomenon #1 (3D +T objects)

- ***"All existing objects are tridimensional and can have temporal evolution; lower dimensions (0D, 1D and 2D) are only used for modeling (in databases) and visualization (cartography)".***
- Unlike geodetic objects which were created by man, all features are 3D, can move, can change their shape and can be destroyed.

Prolegomenon #2 (acquisition by measurements)

- ***"All basic attributes (spatial or non-spatial) are obtained by means of measuring apparatuses having some limited accuracy".***
- Now more and more data come from sensors;
- More, citizens can be seen as sensors

Prolegomenon #3 (Continuous fields)

- ***" Since it is not possible to store the infinite number of value points in a continuous field, some sampling points will used to generate the whole field by interpolation.***

Prolegomenon #4 (Raster-vector and vector-raster transformations)

- ***"Procedures transforming vector-to-raster data and raster-to-vector data must be implemented with loosing less accuracy as possible".***

Prolegomenon #5 (From Popper's falsifiability principle):

- ***"When a new apparatus delivers measures with higher accuracy, these measures supersede the previous ones".***
- The practical consequence is that as a new generation of data comes, geographic data and knowledge basis must integrate those data. But alas, due to the acquisition cost, a lot of actual systems are based on "obsolete" data.

Prolegomenon #6 (Permanent updating)

- ***"Since objects are evolving either continuously (sea, continental drift) or event-based (removing building), updating should be done permanently respectively in real-time and as soon as possible".***

- Sensor-based updating
- Data cleaning / Data quality

Prolegomenon #7 (Geographic metadata)

- ***"All geographic databases or repositories must be accompanied with metadata".***
- International Standard ISO 19115 "Geographic Information - Metadata" from ISO/TC 211 provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.
- Practically, many geographic databases do not implement the whole standard, but only the more important aspects, because it is very time-consuming.

Prolegomenon #8 (Cartographic objects)

- ***"In cartography, it is common to eliminate objects, to displace or to simplify them".***
- This is due to ensure a maximal readability of maps.

Prolegomenon #9 (One storing, several visualizations)

- ***"A good practice should be to store all geographic objects with the highest possible accuracy and to generate other shapes by means of generalization".***
- This can be seen also as a consequence of Prolegomenon #3.

Prolegomenon #10 (Place names and gazetteers)

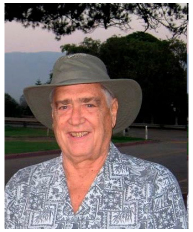
- ***"Relationships between places and place names are many-to-many".***
- Mississippi is the name of a river and the name of a state. The actual city of Rome, Italy, is larger than the same Rome in Romulus's time.
- The main consequence is that unique feature identifiers are not so easy to define.

Prolegomenon #11 (Geographic ontologies)

- ***"All geographic object types are linked to concepts organized into a geographic ontology based on topological relations".***

Prolegomenon #12 (Tobler's law):

- ***"Everything is related to everything else, but near things are more related than distant things".***
- .This statement may be seen as a key-concept also for geographic data mining



Principles

- Prolegomena: preliminary considerations
- Principles
  - Basis for modeling geographic knowledge
  - Basis for transforming it

Principle #1 (Origin of geographic knowledge):

- ***"Spatial knowledge is hidden in geometry whereas geographic knowledge comes in addition from non-spatial attributes".***

Principle #2 (Knowledge cleaning)

- ***"All geographic data, once captured, must be cleaned to remove errors and artifacts".***
- All automatic acquisition system may include errors or anomalies.
- Be aware when generating knowledge!

Principle #3 (Knowledge enumeration)

- ***"It is not necessary to enumerate all possible chunks of geographic knowledge".***
- if one has *n* object, then $(n-1)^2$ North-South relationships can be also derived accordingly.

Principle # 4 (From geoid to plane):

- ***"On small territories, a planar representation is sufficient whereas for big territories, Earth rotundity must be taken into consideration".***
- But the question is "how to define a small or a big territory"?
- A solution can be to define a threshold, for instance a 100 km wide square.

Principle #5 (Visualization and visual acuity)

- ***"Cartographic representation is linked to visual acuity".***
- Thresholds must be defined. In classical cartography, the limit ranges from 1 mm to 0.1 mm.
- Reasoning is linked to the granularity of interest

Modification

- Disappearance
  - $\forall O \in$ *GeObject*, $\forall \sigma \in$ *Scale*
  - $\wedge O_\sigma$ =2Dmap(O, σ)
  - $\wedge$ Area $(O_\sigma) < \varepsilon_2$
  - => $O_\sigma = \varnothing$.
- Transformation into point
  - $\forall O \in$ *GeObject*, $\forall \sigma \in$ *Scale*
  - $\wedge O_\sigma$ =2Dmap(O, σ)
  - $\wedge \varepsilon_1$ Area $(O_\sigma) < \varepsilon_2$
  - => O_σ = Centroid(O).

Principle #6 (Sharpification)

- ***"At some scales every fuzzy object becomes sharp".***
- Egg-yolk representation
  - When the mean distance between egg and yolk is less than a threshold
  - Its geometry can be taken midway

Principle #7 (Relativity of spatial relations)

- ***"Spatial relation varies according to scale".***
- $\forall O^1, O^2 \in$ *GeObject*, $\forall \sigma \in$ *Scale*
- $\wedge O^1_\sigma$ =2Dmap$(O^1, \sigma) \wedge O^2_\sigma$ =2Dmap(O^2, σ)
- $\wedge$ Disjoint (O^1, O^2)
- $\wedge$ Distance $(O^1, O^2) < \varepsilon_1$
- => Touch (O^1_σ, O^2_σ)

Principle #8 (Transformation into graphs)

- ***"Every set of linear objects can be transformed into a graph".***
- For instance from
  - Roads to road networks
  - Rivers to river graphs

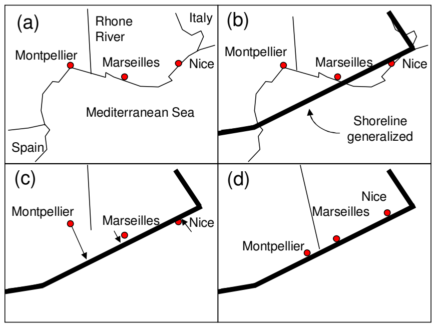
Principle #9
(From pictorial to geographic objects)

- ***"Any group of pixels having same characteristics can be regrouped into a pictorial object; this pictorial object can be conferred a geographic type possibly using an ontology".***
- Indeed as soon as a pictorial object is recognized, its type will be identified and it can be a part of a geographic object.

Principle #10
(Visualization constraints)

- ***"The spatial relations between objects must hold after generalization".***
- Ex. Mediterranean coastline

Example



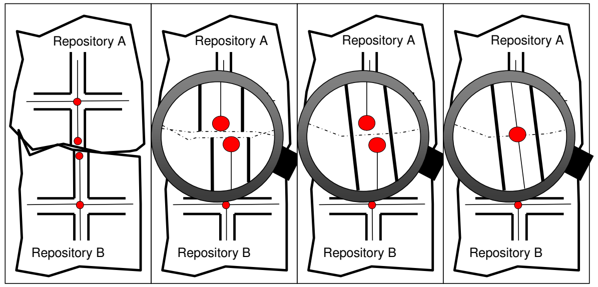
Principle #11
(Influence of neighbors)

- ***"In geographic repositories, do not forget that objects at the vicinity (outside the jurisdiction) can have an influence".***
- Ex. Geneva and French Region Rhône-Alpes

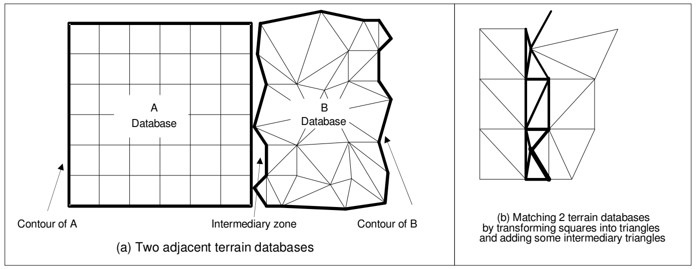
Principle #12 (Cross-boundary interoperability)

- ***"Any geographic repository must provide key-information to ensure cross-boundary interoperability".***
- Two cases:
  - Network continuity
  - Terrain continuity

Road continuity



Terrain continuity

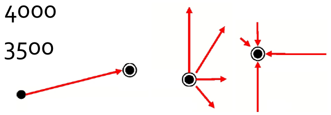


Where to find GK?

- Discussions with experts
- Spatial data mining
- Analyzing web documents
  - Gazetteers
  - Ontologies

Elementary knowledge (1/2)

- Facts
  - Italy.population= 60 000 000
  - Touch (Italy, Switzerland)
- Flow
  - Bi-directional flow
    - Flow (Dublin, Limerick) = 4000
    - Flow (Limerick, Dublin) = 3500
  - Converging flows
  - Diverging flows



Elementary knowledge (2/2)

- Clusters
  - UK= Union (England, Scotland, Wales, NorthenIreland, etc)
- Co-location relation
  - Co-location (CityHall, Church)

3 – Visual representations

- Four types:
  - Natural Language (classic geography)
  - Mathematics (description logic, etc.)
  - XML dialects
  - Visual

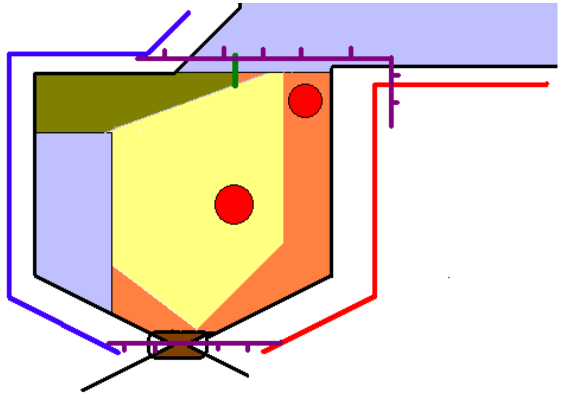
Example

- If
  - Lake
  - Road going to the lake
- Then
  - Restaurant

Logic

- $\forall l \in Lake \wedge \forall s \in Road \wedge (touches\ (l, s))$
- $\Rightarrow$
- $\exists r \in Restaurant \wedge (distance\ (r,l) < 100 \wedge (distance(r,s) < 100$

Guess!

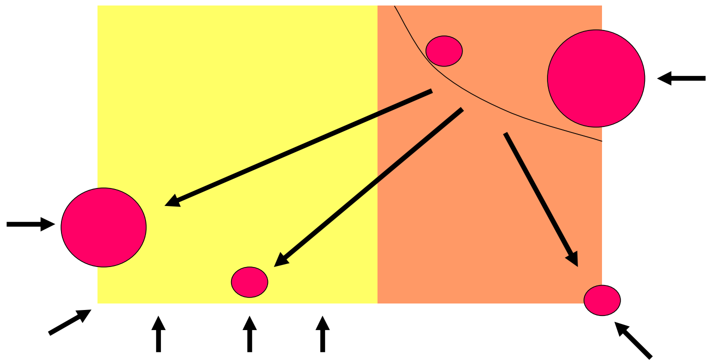


What are Chorems?

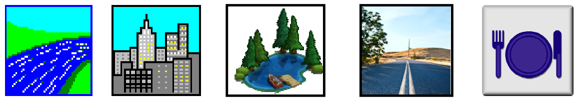
- Invented by Pr. Roger BRUNET (University of Montpellier)
- Schematized representation of a territory

- Usage:
  - Understand salient features
  - Geographic knowledge representation
  - Visual access to geo DB

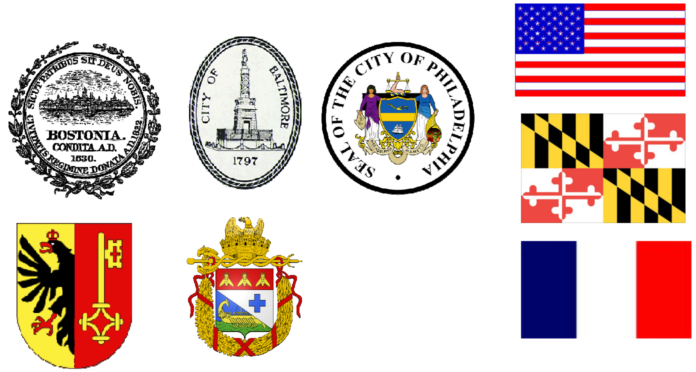
Demography of the USA



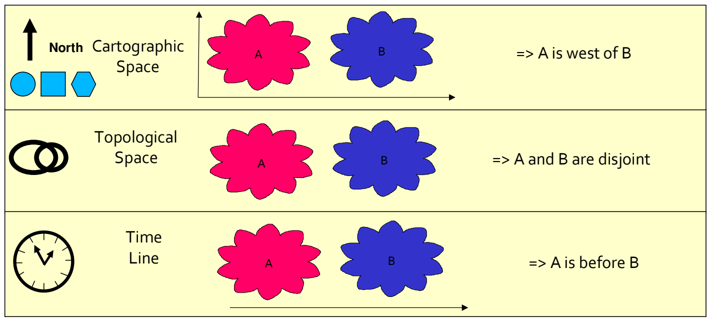
Vocabulary (generic objects)



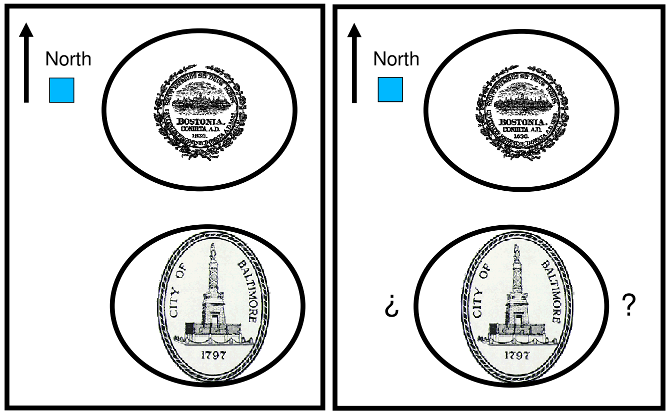
Visual Gazetteer



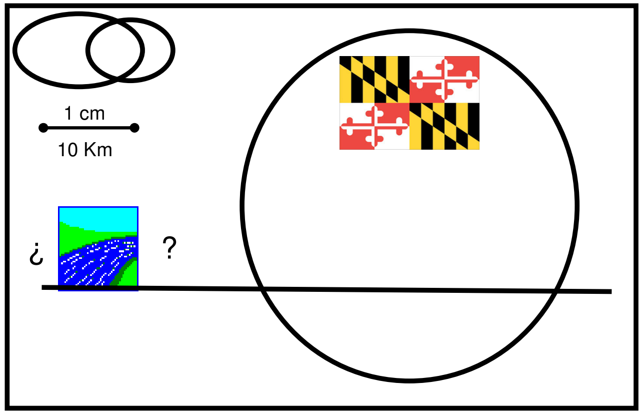
Contexts of interpretation



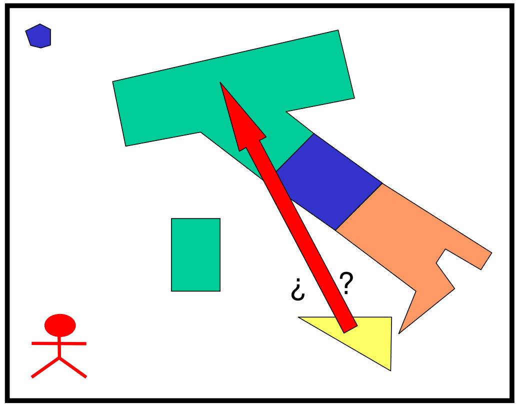
Fact statement and query



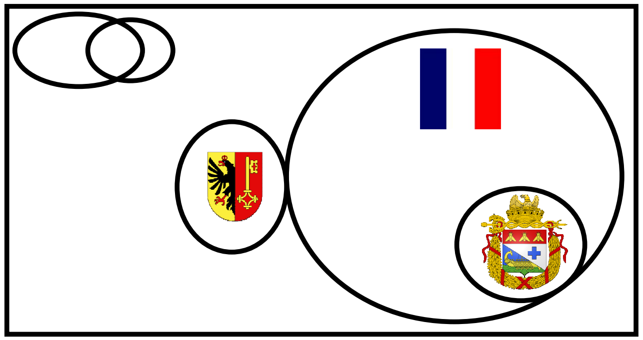
Topological query



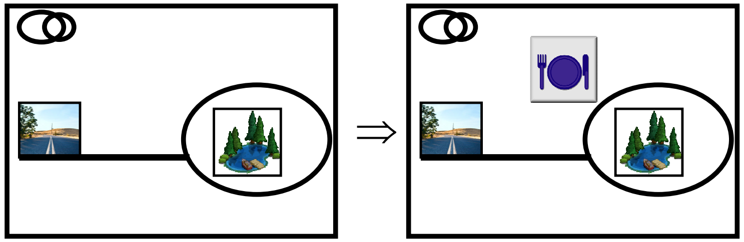
Chorem, cluster, area and query



Topological constraint



Co-location rule



4 – Conclusion (1/2)

- A general framework is proposed
  - 12 prolegomena
  - 12 principles
- Must be enhanced
  - Completeness, no redundancy, consistency
- Outlines of a visual language for geographic knowledge engineering

Conclusions (2/2)

- Other minor contributions
  - Ribbon
  - Ribbon topology
  - Generalization of topological relations
- Terms of references for the design of a Geographic Knowledge Management System for Territorial Intelligence