Geographic Knowledge Engineering for Smart Planning

Robert Laurini
Knowledge Systems Institute

Geographic Knowledge Engineering for Smart Planning

1 – Introduction

2 – Components of a GKB

3 – Knowledge-base planning → Tuesday Afternoon

4 – Conclusions

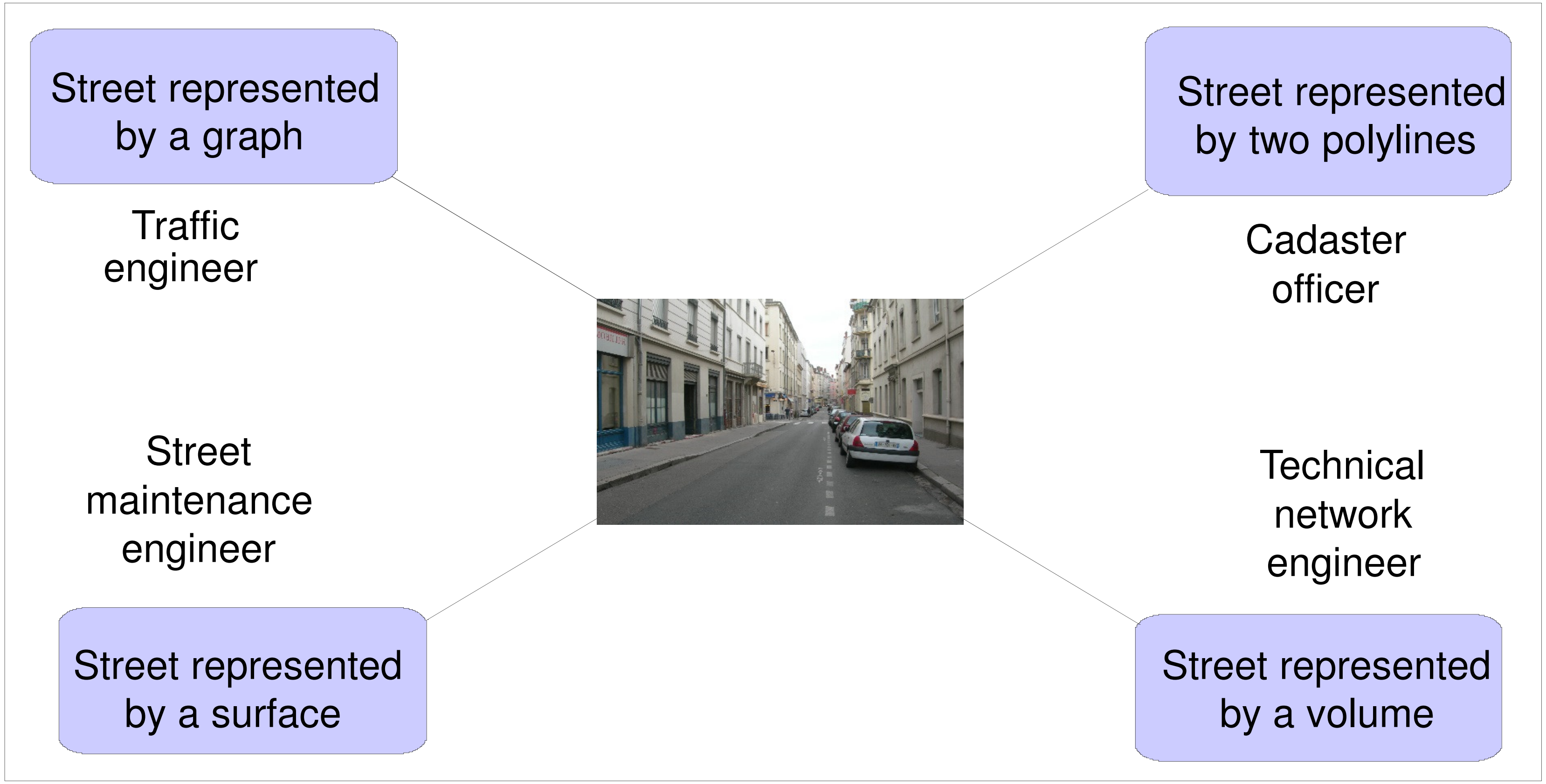
1 – Introduction

- Dataless urban planning
- Statistical analysis (Baxter, 76)
- Computer-Assisted Cartography
- Urban Data Bases (80s)
- Information
  - Geographic information systems (80s)
  - Fundamentals of Spatial Information Systems (Laurini-Thompson, 91)
  - “Information Systems for Urban Planning” (Laurini, 01)
- Now Knowledge
  - Business intelligence to Territorial Intelligence
  - Knowledge society

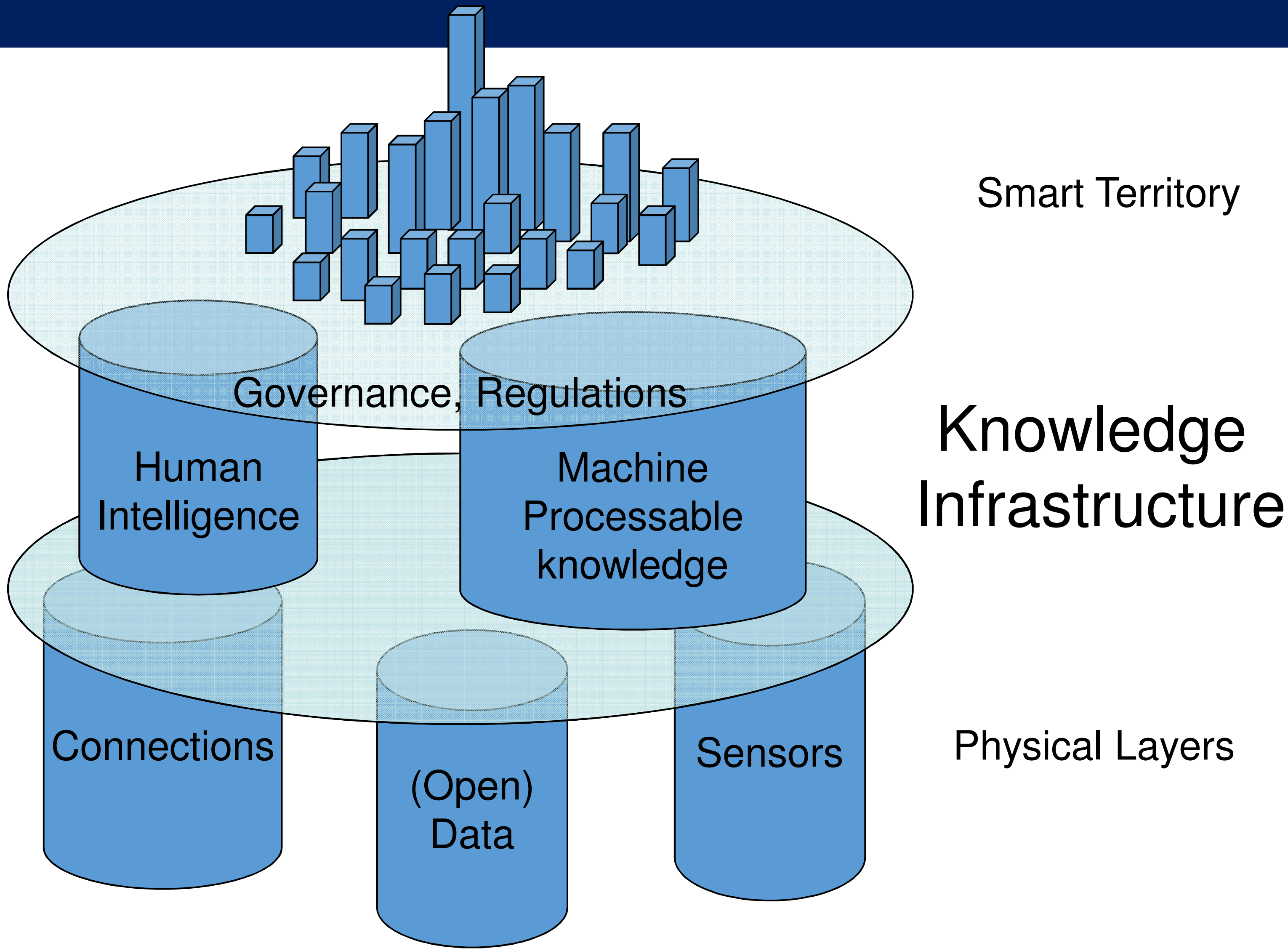
Specific characteristics

- Space 2D, 3D, 3D+T ➔ coordinates
- Computational geometry, topology
- Cartography and geovisualization
- Spatial analysis
- Features and geographic objects
    - Measurement accuracy
    - Multiple representations
    - Acquisition devices

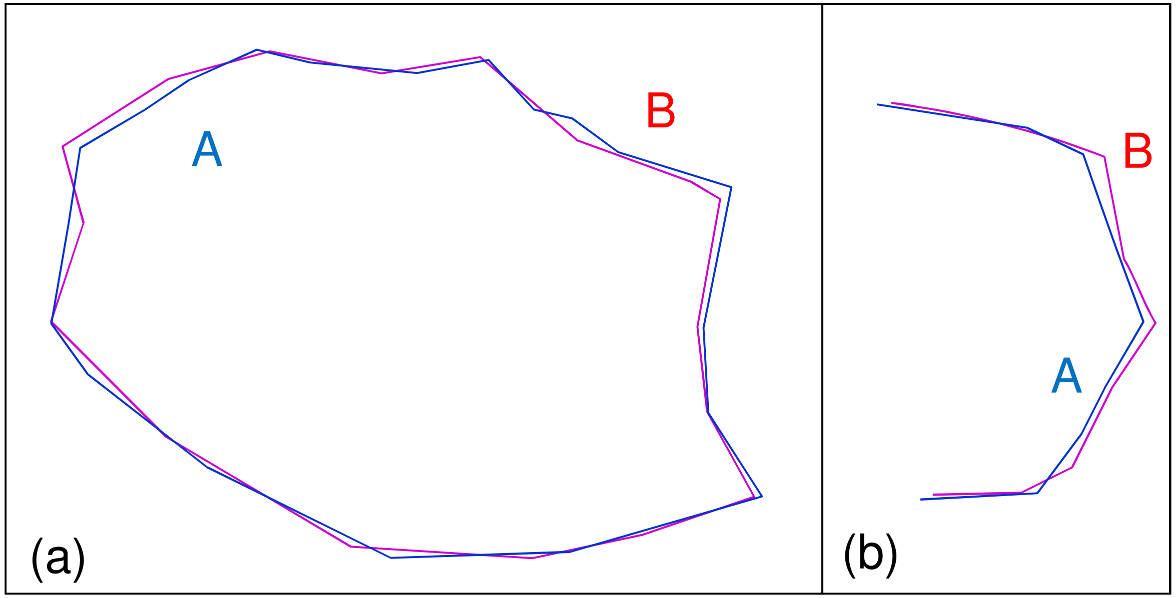
Example of a street



Infrastructure organization



Geometric Homology



$$Geom(A) \text{ ₪ } Geom(B)$$

Reflexive, associative

But non-transitive

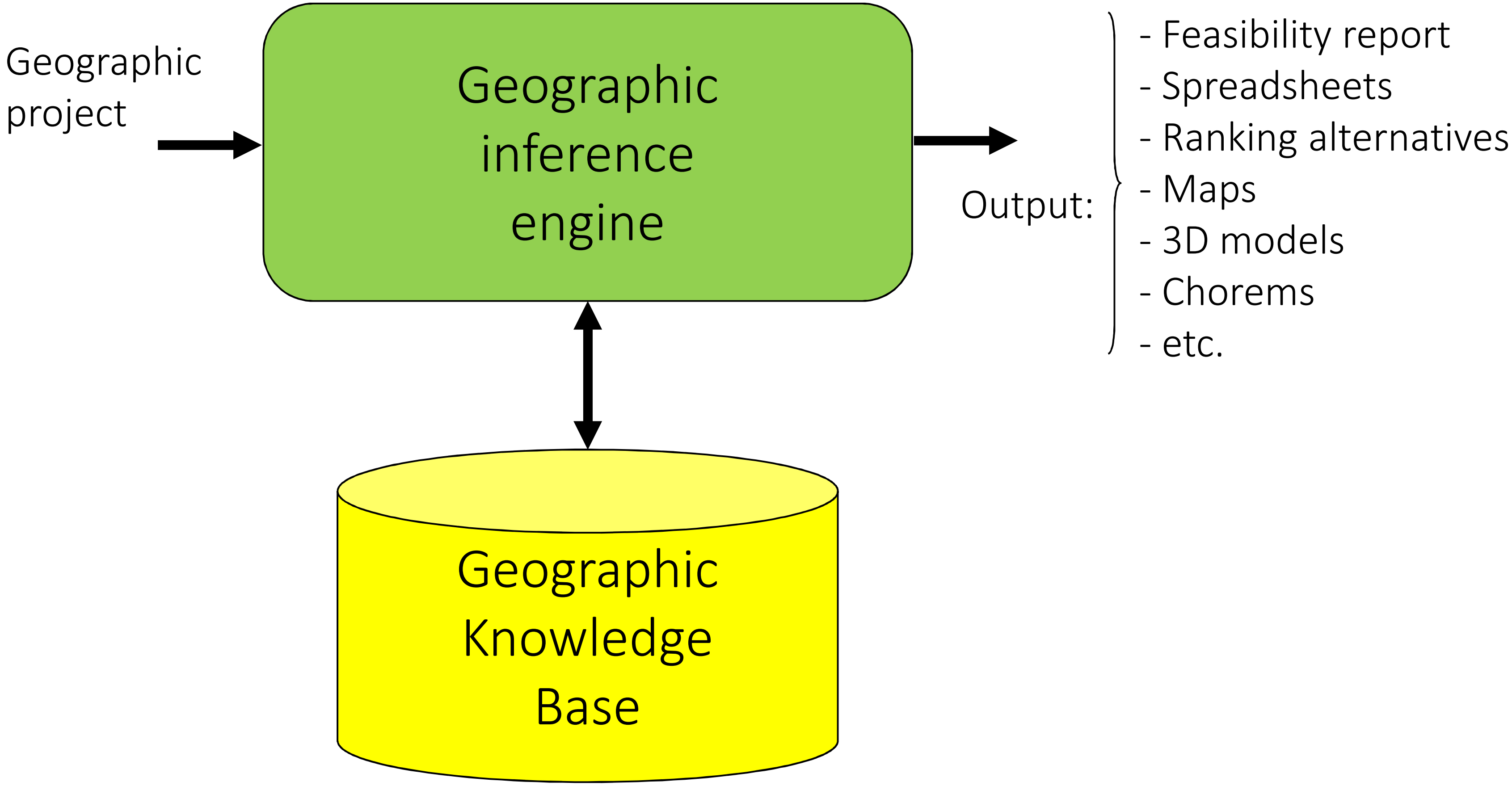
Generic and Applicative Knowledge

- **Generic knowledge**
  - valid everywhere and
  - linked to acquisition devices
  - and linguistics aspects
- **Applicative knowledge** linked to applicative domains such as
  - urban planning,
  - environmental planning,
  - transportation, etc.

Geographic Projects

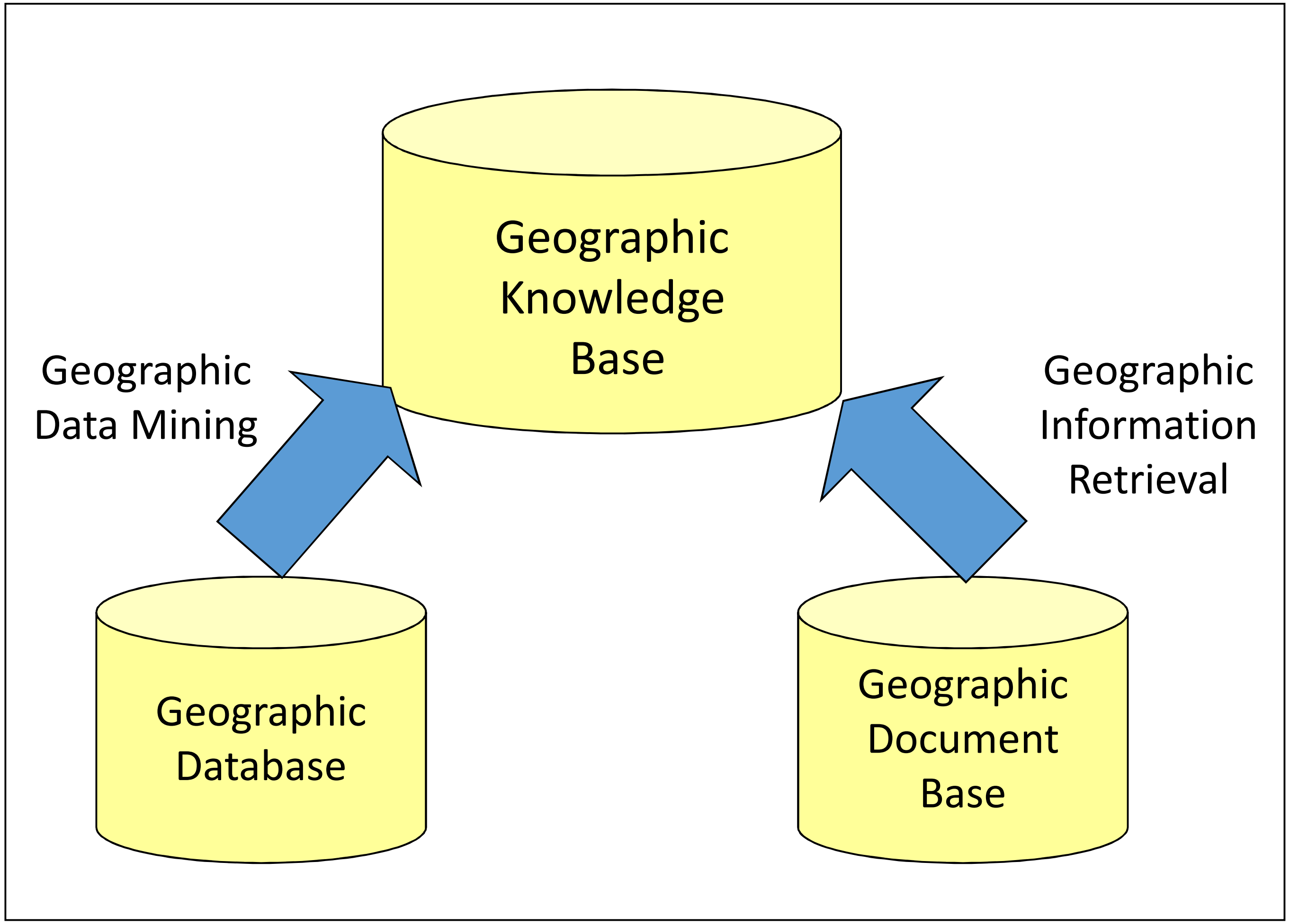
- Where to put a new airport, a new hospital, a new stadium, etc.?
- Is this new construction project compliant with planning rules?
- What is the best mode or the best way to get from *A* to *B*?
- How to organize a plan for green spaces in a city?
- How to reorganize common transportation?
- etc.

Usage

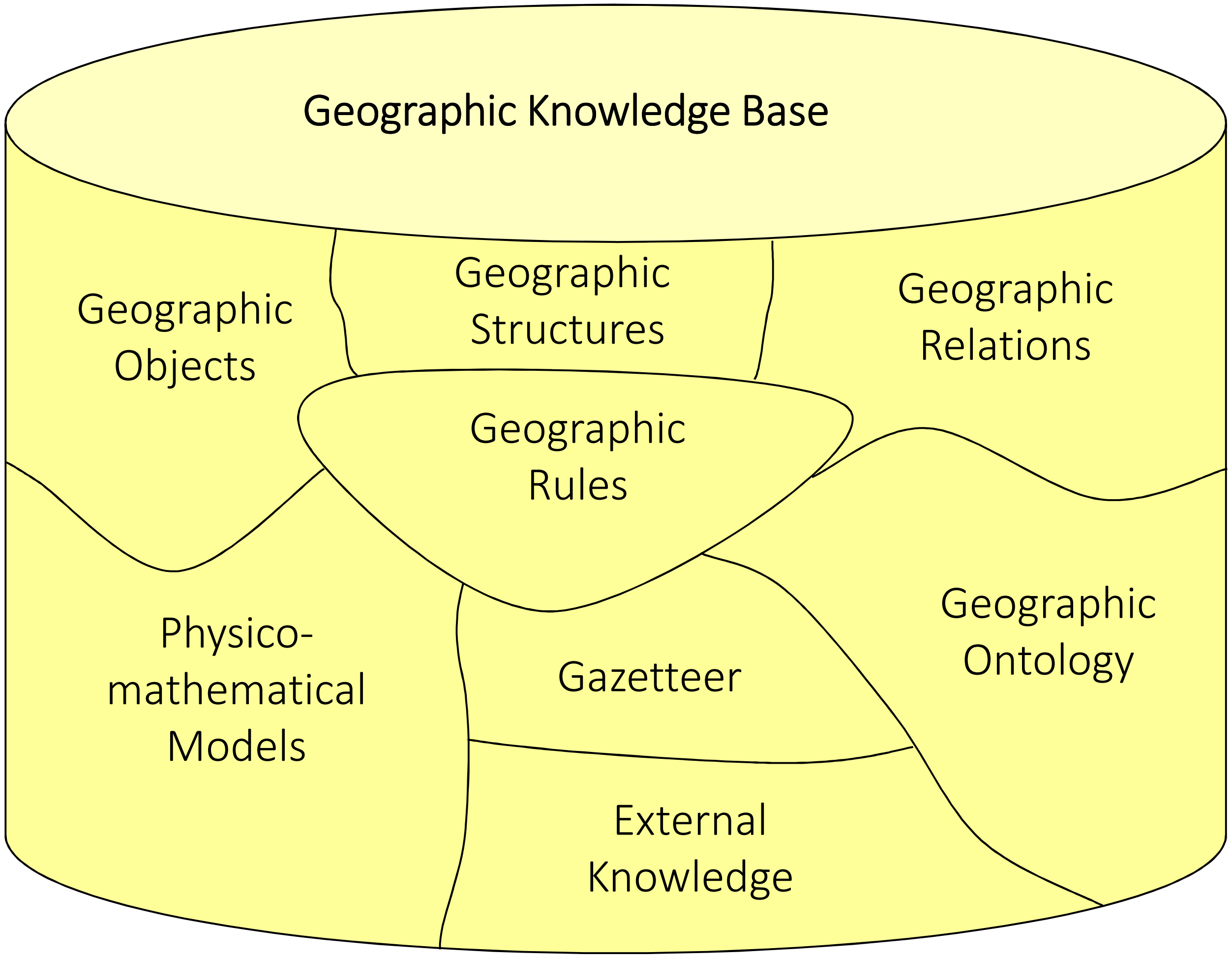


Geographic project
Geographic inference engine
Output:
- Feasibility report
- Spreadsheets
- Ranking alternatives
- Maps
- 3D models
- Chorems
- etc.
Geographic Knowledge Base

Origin of Geographic Knowledge



2 – GKB components



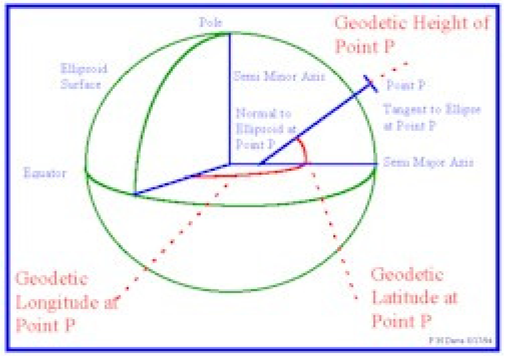
GKB Formalization

- *GKB ≡ (Terr, λ,Ω, GO,Γ,REL, Σ,RULES, PROJECTS)*
  - *Terr* defines a territory, which is a part of *Earth*,
  - λ a language,
  - *GO* is the set of all geographic objects stored in *GKB*,
  - Γ a gazetteer,
  - Ω an ontology,
  - *REL* a set of relationships between geographic objects,
  - Σ a set of structures linking some geographic objects,
  - *RULES* a set of rules and
  - *PROJECTS* a set of old and ongoing projects.

2.1 – 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

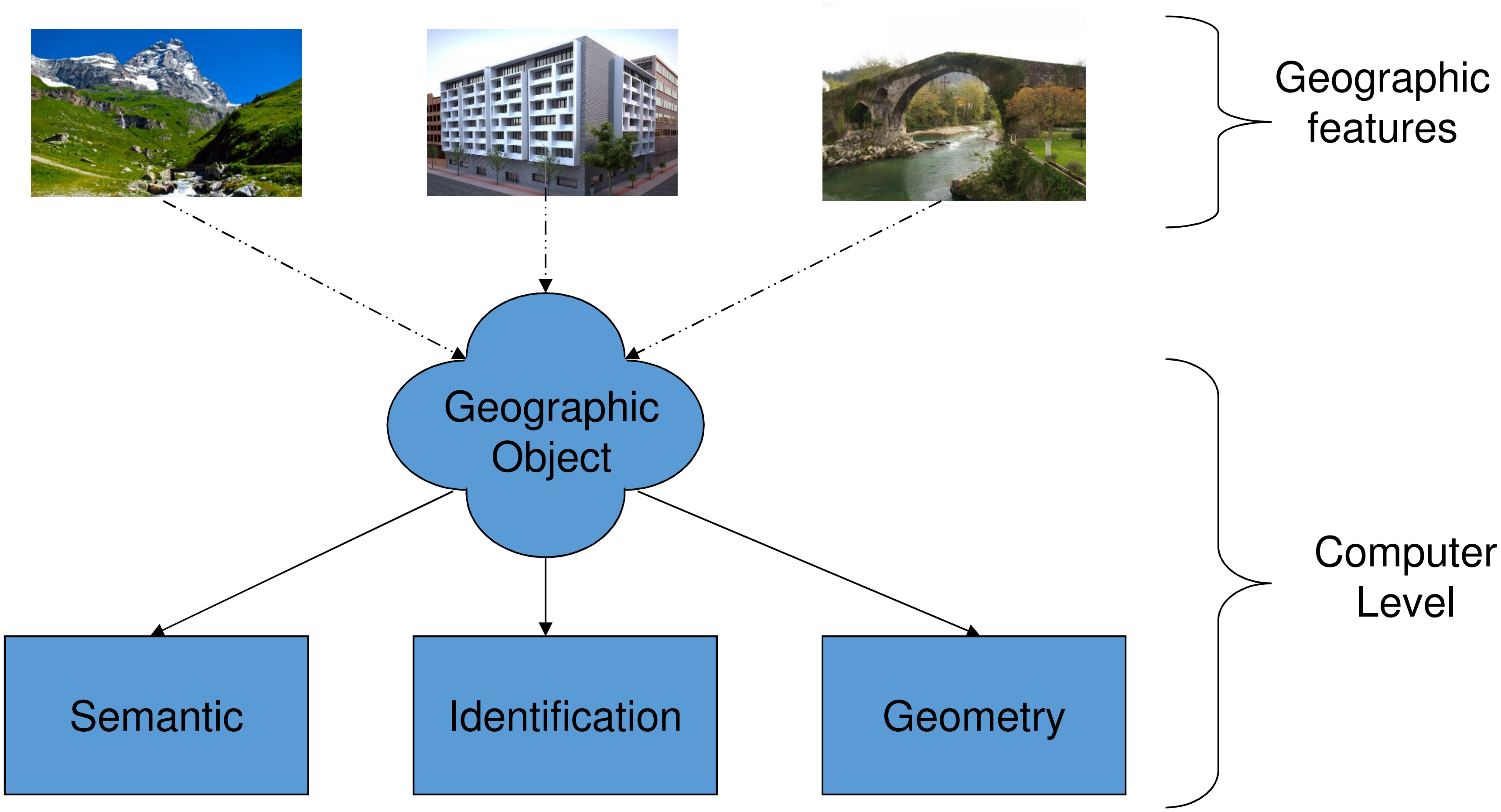
Manmade Objects

- 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

Characteristics of Geo Objects



What is it?

	
(a) A car park? No, the roof of a small used as a car park.	(b) A meadow? No, a water catchment area

Geometric types

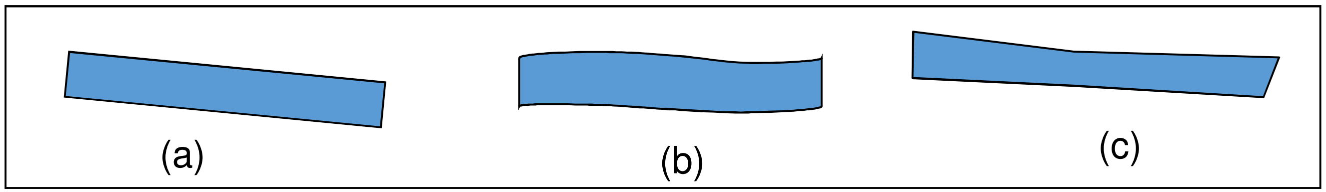
- Math tradition
  - Points
  - Lines
  - Areas
- Proposition
  - Ribbons
  - Areas

For mathematical modeling

For geographic modeling

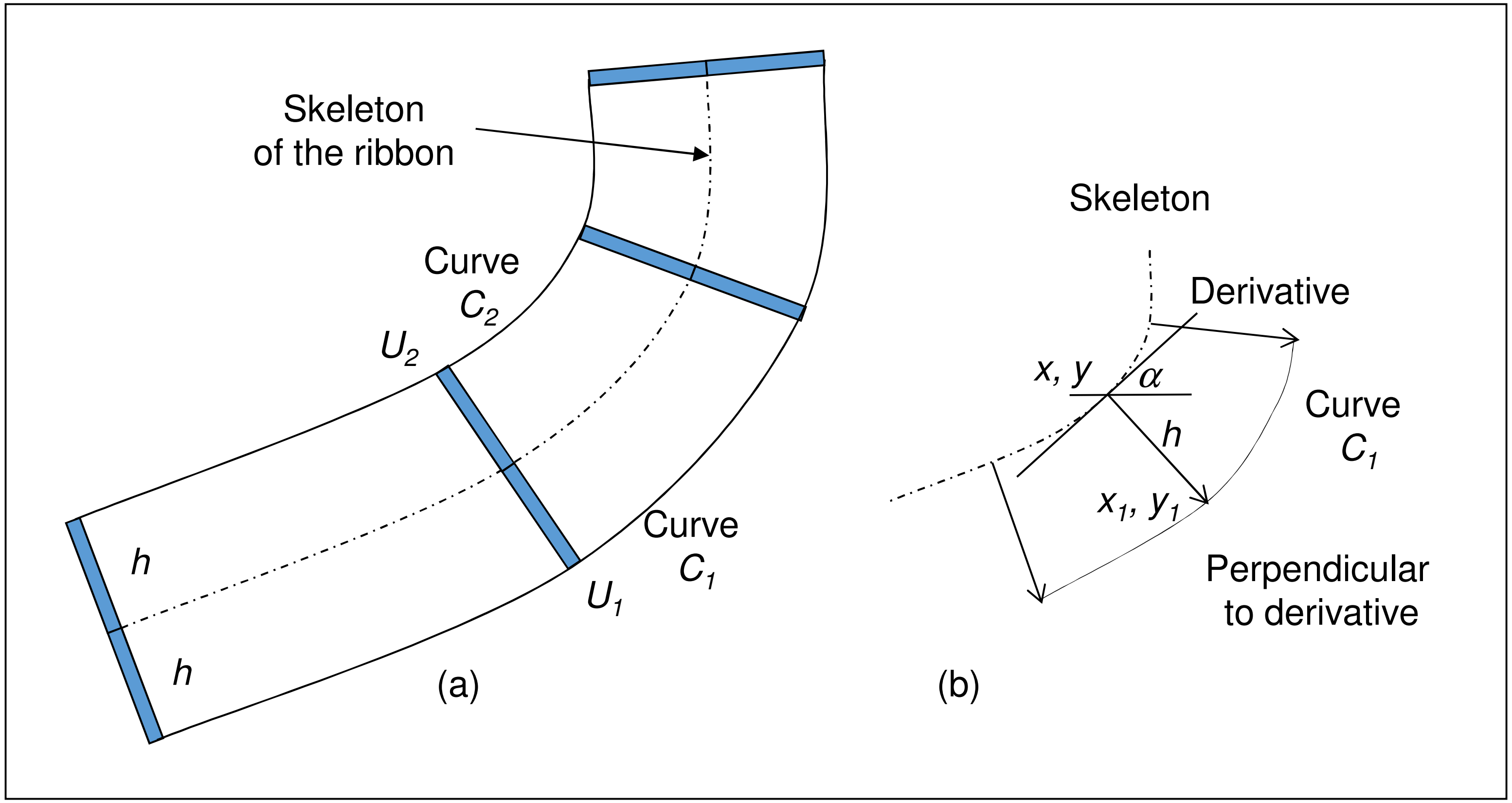
From Lines to Ribbons

- Ribbon = line with a width
- Rectangular Ribbons
- Loose Ribbons



Construction of a ribbon

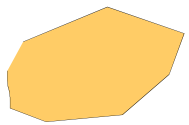
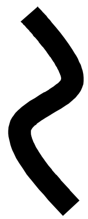
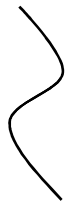
- Line as a starting skeleton



Modeling a street with ribbons

Sidewalk
Parking lane
Bus Lane
Driving lane
Median
Driving lane
Bike lane
Sidewalk

General Process

Some scale	 Area	 Ribbon
Smaller scale	 Point	 Line
Smaller and smaller scale	Void	Void

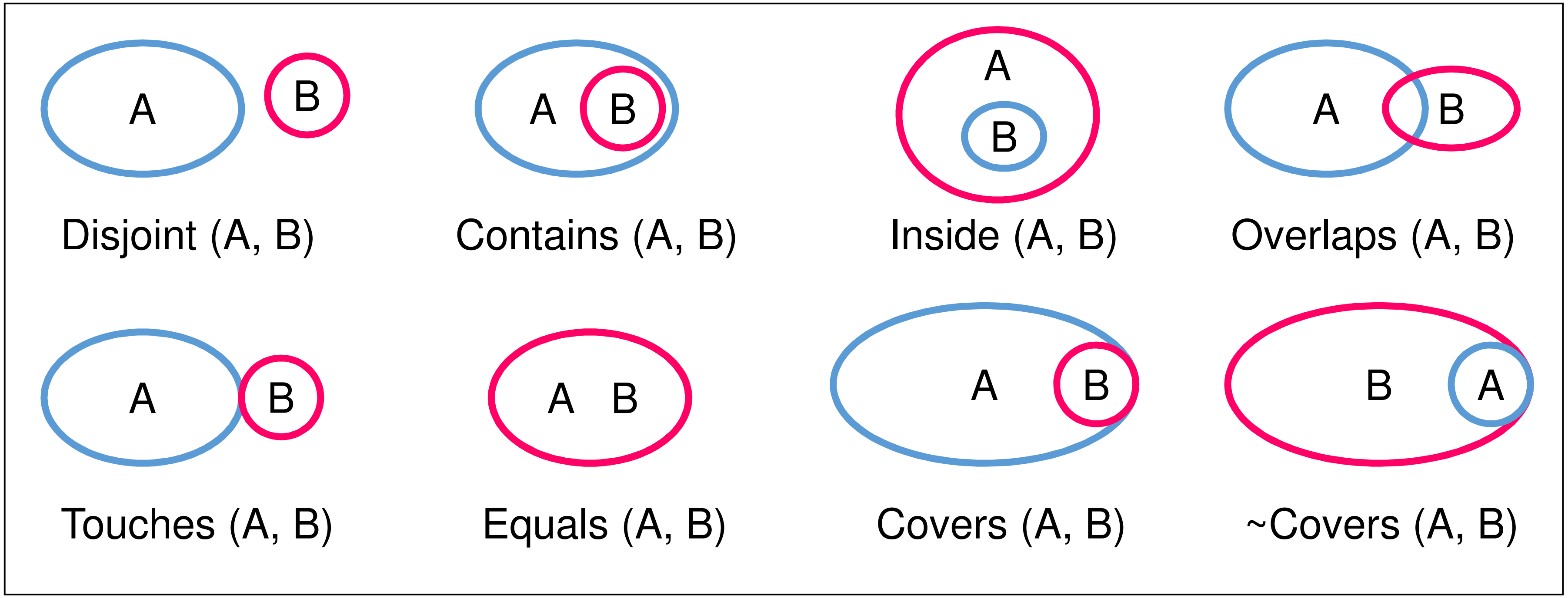
Final Remarks Concerning Geographic Objects

- $GO \equiv \{O_1, O_2, \ldots O_n : n \in N\}$.
- $O_i \equiv (GeoID_i$, G-$Type_i$, $Topo_i$, $Geom_i$, Ω-*Type, (Attribute, Value)*)*
- G-*Type* $\in$ {*Point*, *Line*, *Area*, *Ribbon*, *Void*, *Null*}.
- Modifiers
  - *Crisp* and *Fuzzy* for points, lines, ribbons and areas
  - *Oriented* or *Not_Oriented* for lines and ribbons.

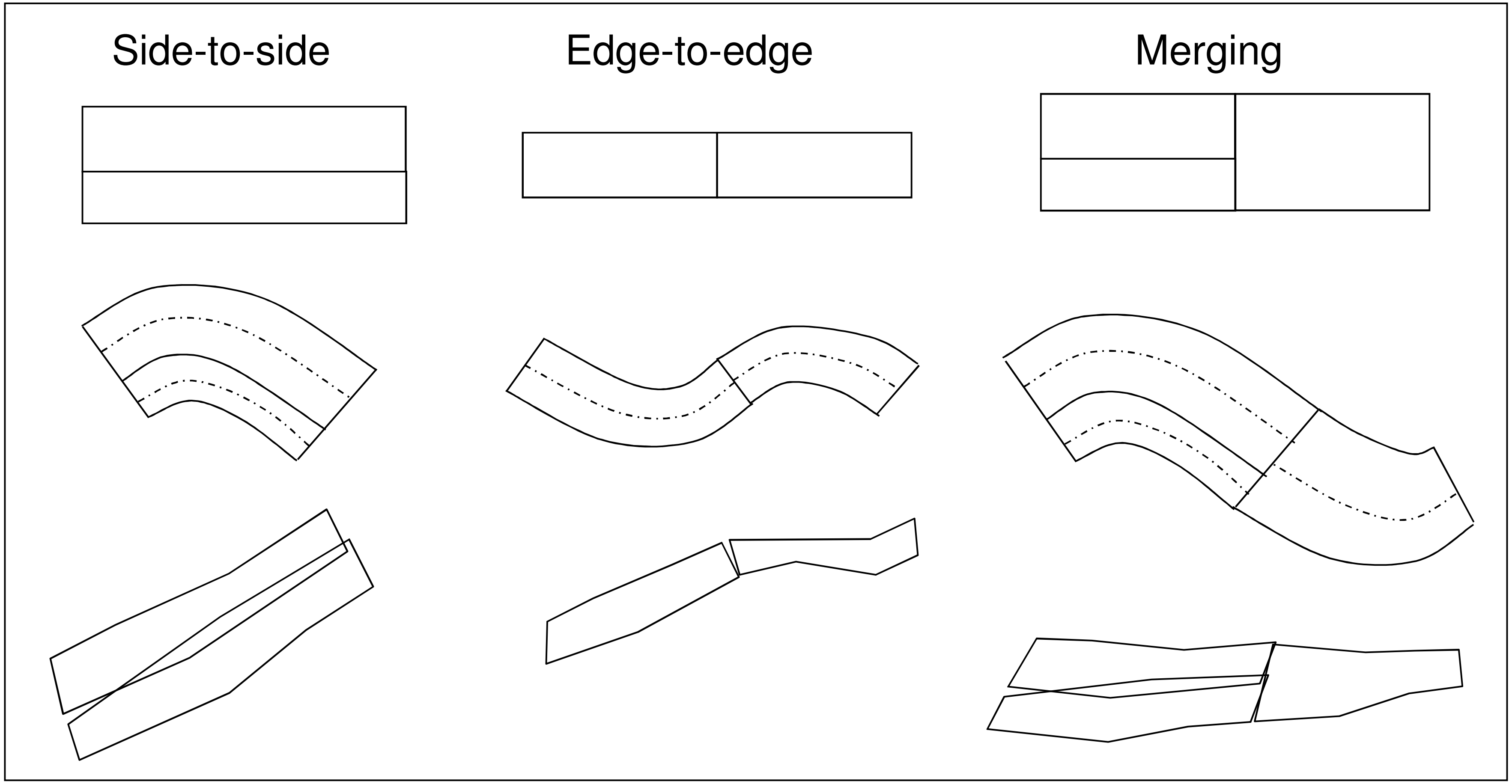
2.2 – Geographic relations

- Not only spatial relations (Egenhofer)
- Geographic relations can vary according to scale
- Ribbon relations

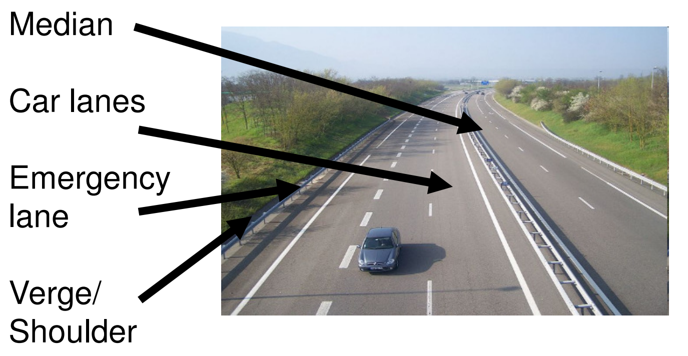
Egenhofer Relations



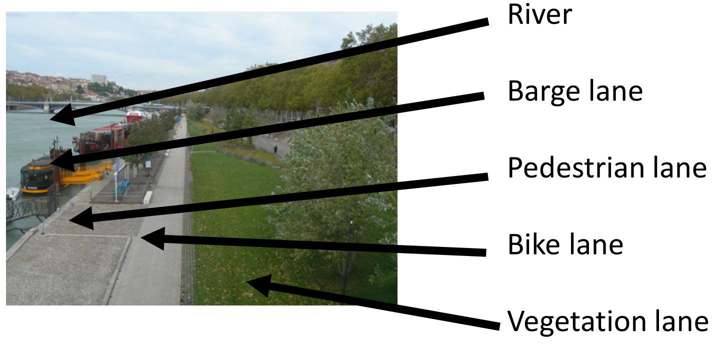
Ribbon relations



Examples



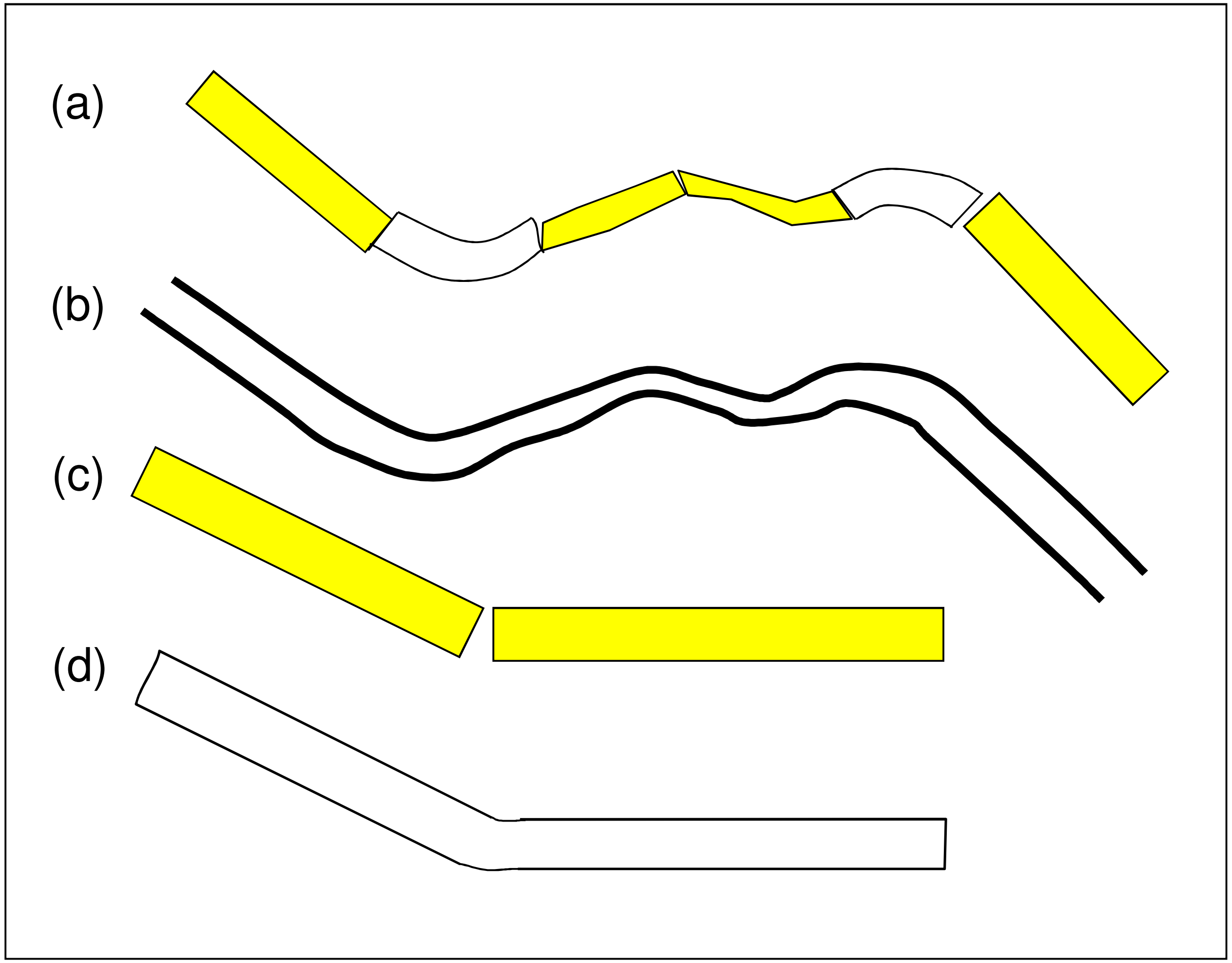
(a) A street decomposed into ribbons



(b) Along a river

SIDE_BY_SIDE (*Platform, railways*)
SIDE_BY_SIDE (*Bus_stop, Bus_lane*)
SIDE_BY_SIDE (*Levee, River*)
SIDE_BY_SIDE (*Towpath, River*).

Chaining ribbons



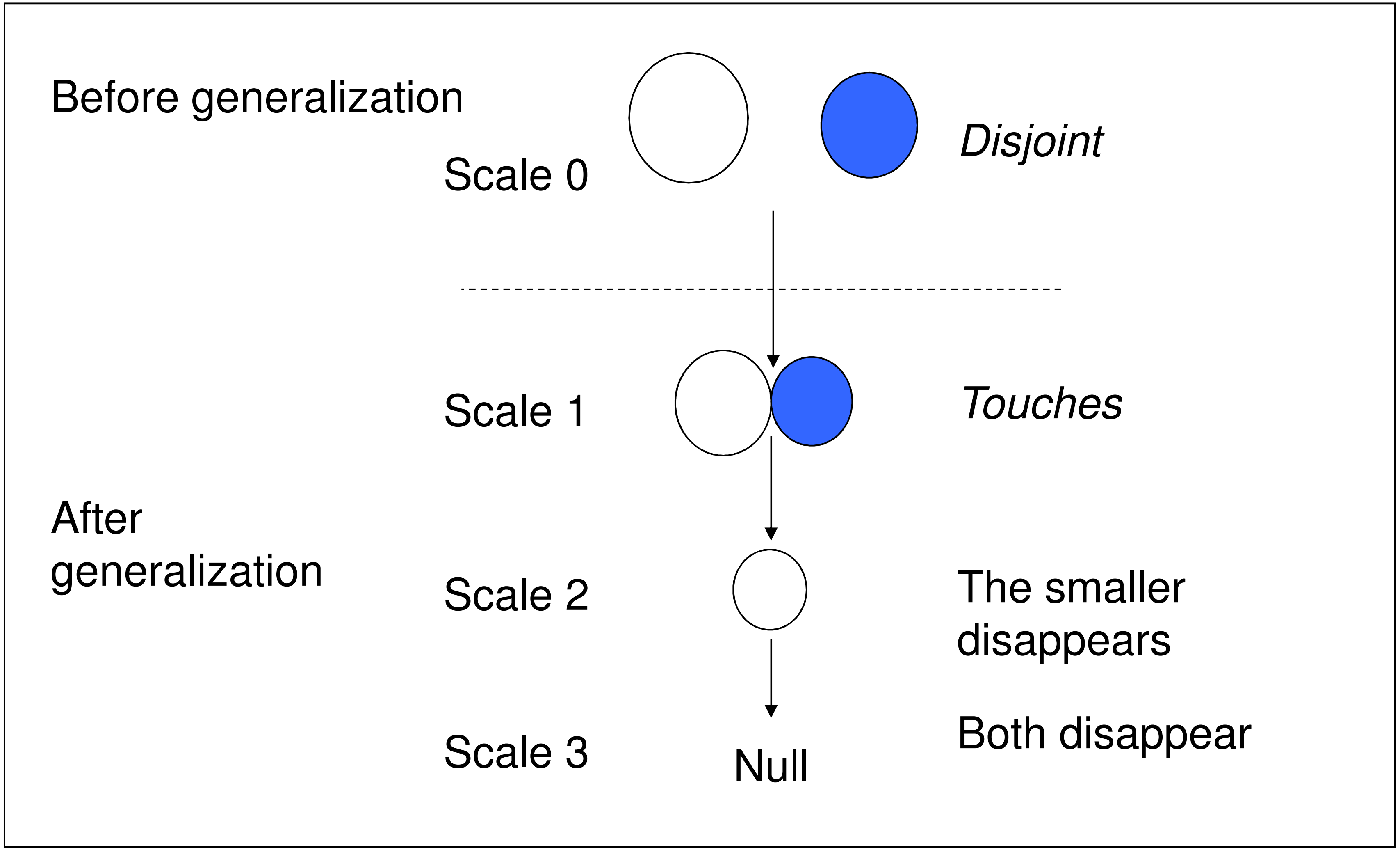
Scales

- According to scale, relations vary

(a) (b)

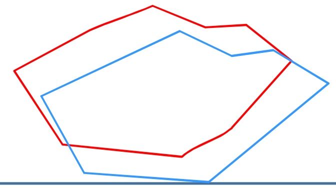
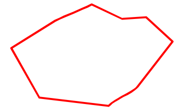
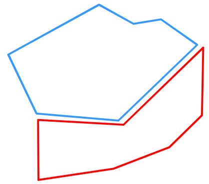
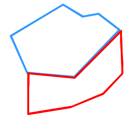
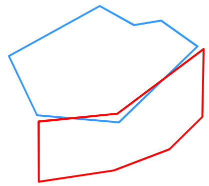
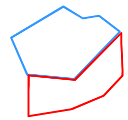
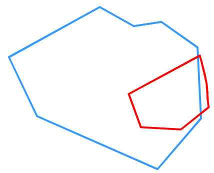
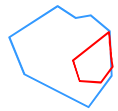
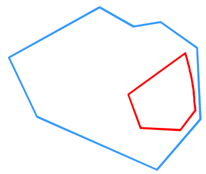
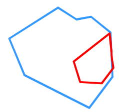
- Touches or Disjoint?

Example of mutation



Disjoint-to-touches Rule

$\forall O^1, O^2 \in GO, \forall \sigma \in Scale,$ $O_\sigma^1 \equiv Dmap(O^1), O_\sigma^2 \equiv 2Dmap(O^2), Disjoint(O^1, O^2):$ $Dist(O^1, O^2) < \varepsilon^2$ $\Rightarrow$ $Touches(O_\sigma^1, O_\sigma^2).$	Rule 5.12

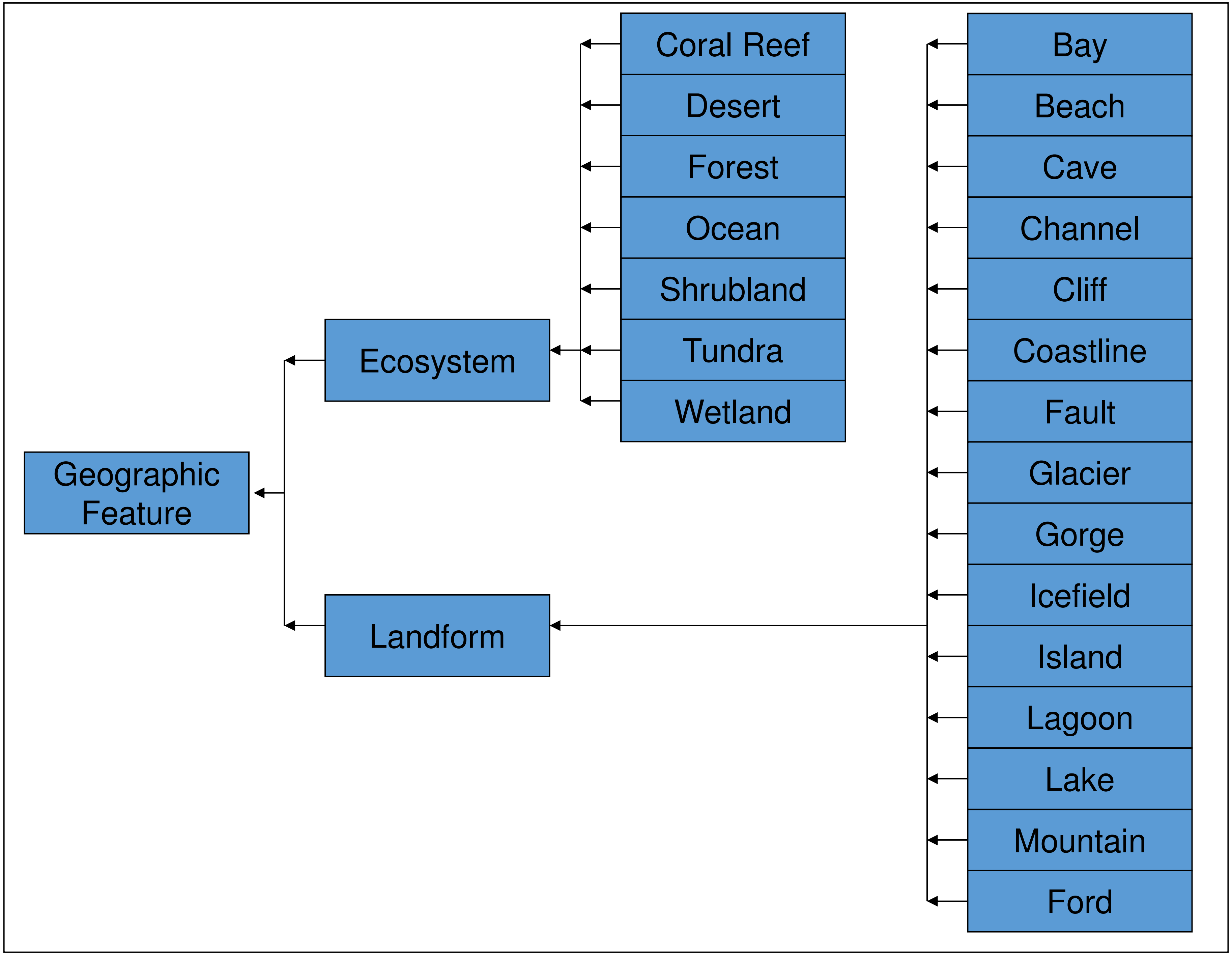
From-to mutation	Initial scale	Smaller scale
Overlap $\wedge$ *C1* $\Rightarrow$ *Equal*		
Disjoint $\wedge$ *C2* $\Rightarrow$ Touches		
Overlap $\wedge$ *C3* $\Rightarrow$ *Touches*		
Overlap $\wedge$ *C4* $\Rightarrow$ *Covers*		
Contains $\wedge$ *C5* $\Rightarrow$ *Covers*		

2.3 – Geographic Ontologies

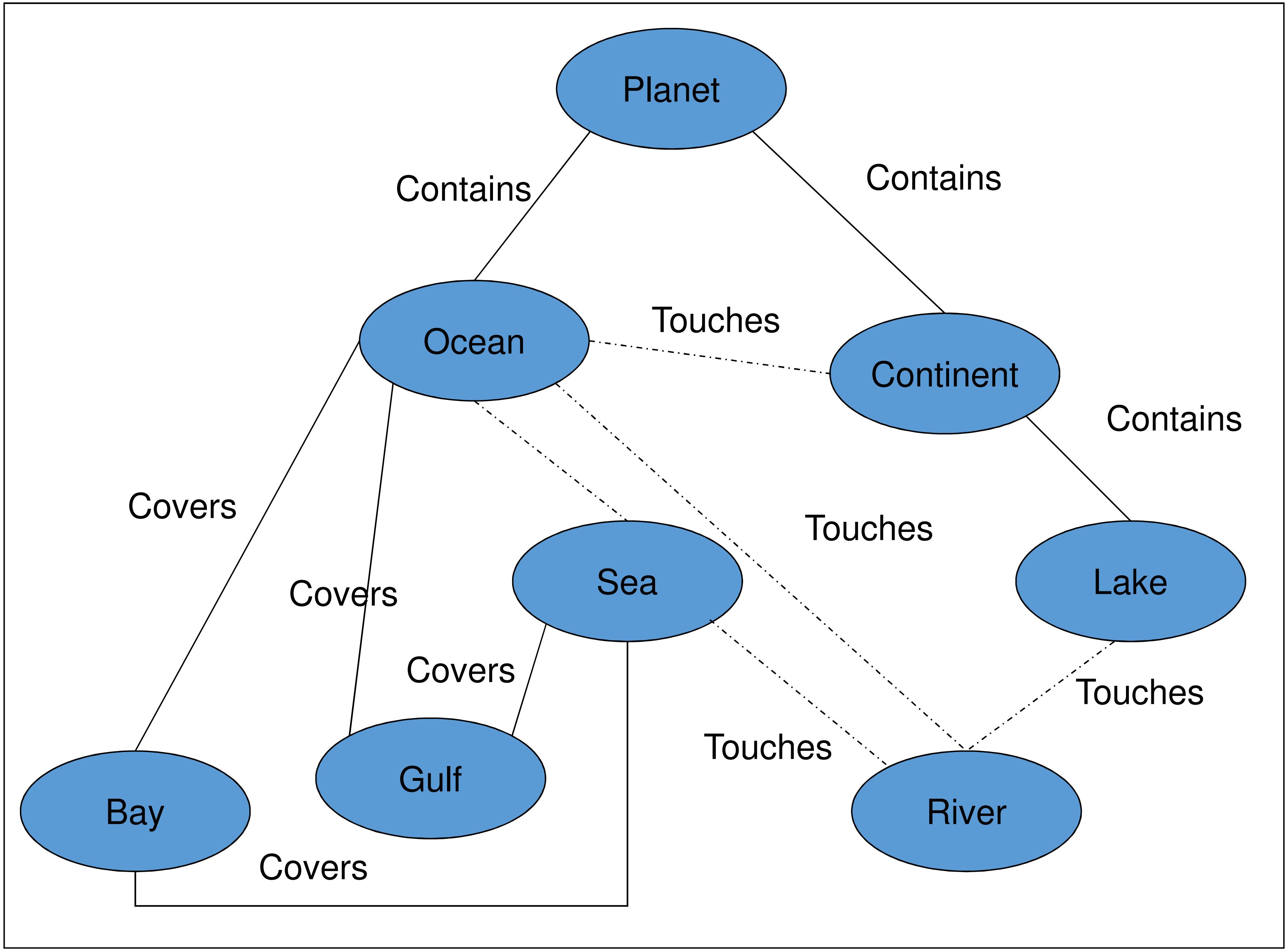
- Organizations of geo features
- In addition to relations "*is_a*", "*has_a*", "*whole_part*"
  - Necessity of spatial relations

Example of ambiguities

French	Picture	English	Spanish	Italian
Quai		Warf	Muelle	Molo
		Riverside	Avenida a lo largo de un río	Lungofiume
		Platform	Andén	Binario

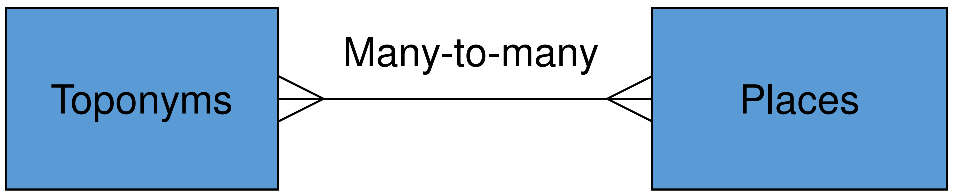


Geographic Feature
Ecosystem
Landform
Coral Reef
Desert
Forest
Ocean
Shrubland
Tundra
Wetland
Bay
Beach
Cave
Channel
Cliff
Coastline
Fault
Glacier
Gorge
Icefield
Island
Lagoon
Lake
Mountain
Ford


Planet
Contains
Contains
Ocean
Touches
Continent
Contains
Covers
Touches
Sea
Lake
Covers
Covers
Touches
Touches
Gulf
Bay
River
Covers

2.4 – Gazetteers

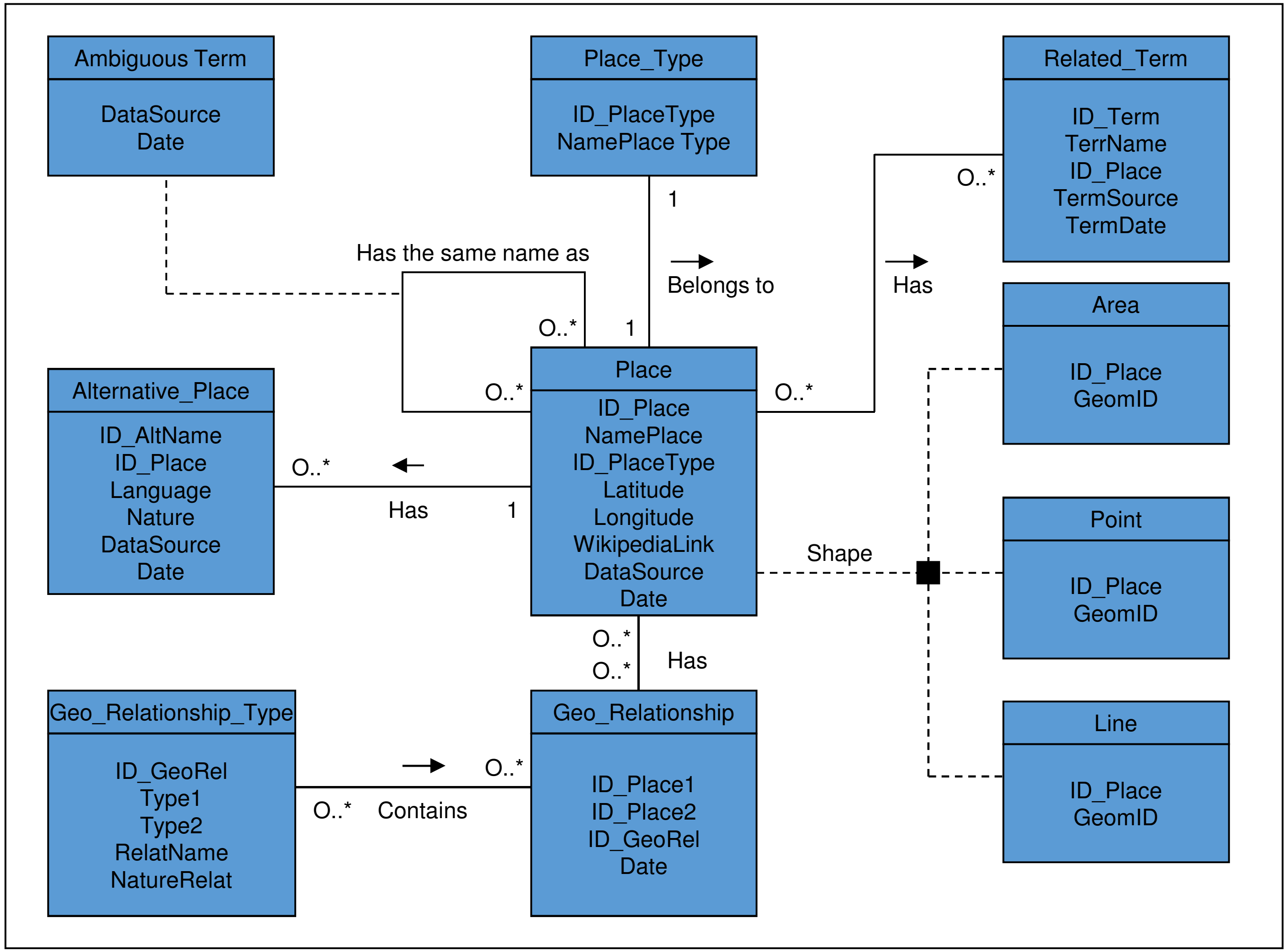
- Placenames / toponyms
- Can change over time
- Multiple translations
- Different places can have same name



- Not only cities, but also streets and landmarks

Some problems regarding toponyms

- “Mississippi” can be the name of a river or of a state.
- The city, “Venice”, Italy, is also known as “Venezia”, “Venise”, “Venedig”, respectively, in Italian, French and German.
- The local name of the Greek city of “Athens” is “Αθήνα”; read [a’θina].
- “Istanbul” was known as “Byzantium” and “Constantinople” in the past.
- The modern city of Rome is much bigger than in Romulus’s time.


Ambiguous Term
DataSource
Date
Place_Type
ID_PlaceType
NamePlace Type
Related_Term
ID_Term
TerrName
ID_Place
TermSource
TermDate
Has the same name as
1
Belongs to
Has
O..*
O..*
1
Area
ID_Place
GeomID
Alternative_Place
ID_AltName
ID_Place
Language
Nature
DataSource
Date
O..*
Place
ID_Place
NamePlace
ID_PlaceType
Latitude
Longitude
WikipediaLink
DataSource
Date
O..*
O..*
Has
1
Shape
Point
ID_Place
GeomID
O..*
O..*
Has
Geo_Relationship_Type
ID_GeoRel
Type1
Type2
RelatName
NatureRelat
O..*
O..*
Contains
Geo_Relationship
ID_Place1
ID_Place2
ID_GeoRel
Date
Line
ID_Place
GeomID

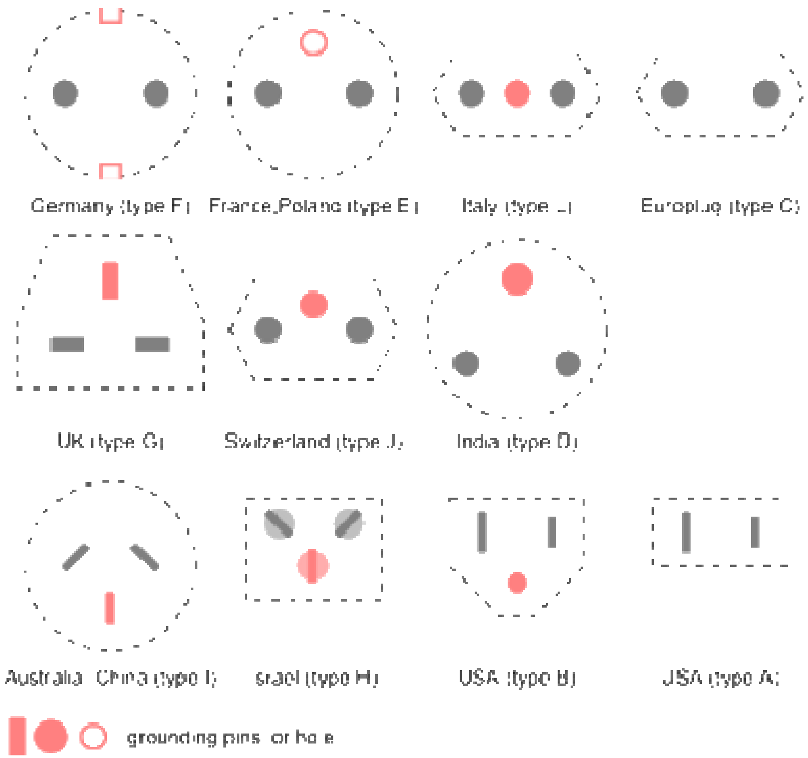
2.5 – Geographic Rules

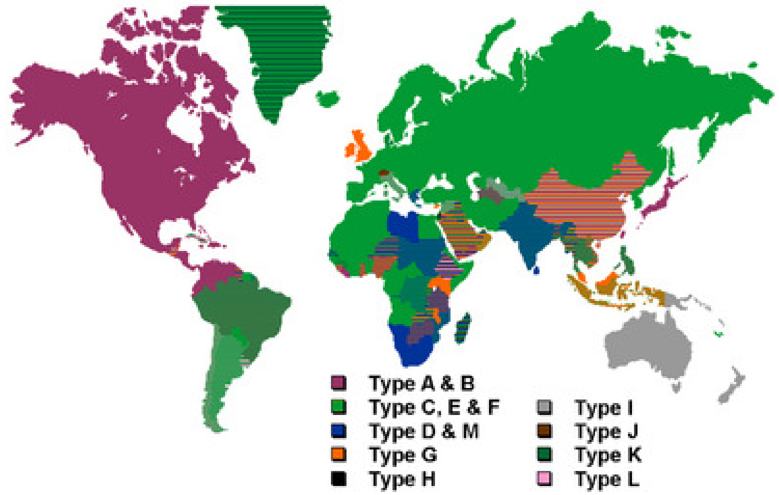
- in the United Kingdom, we drive on the left;
- in Canada, the majority of the population lives along the border with the United States;
- each capital city has an international airport nearby;
- between the two capital cities, in general, there are direct flights;
- in the Northern Hemisphere, the more you are going to the north, the colder (but locally this is not always true).

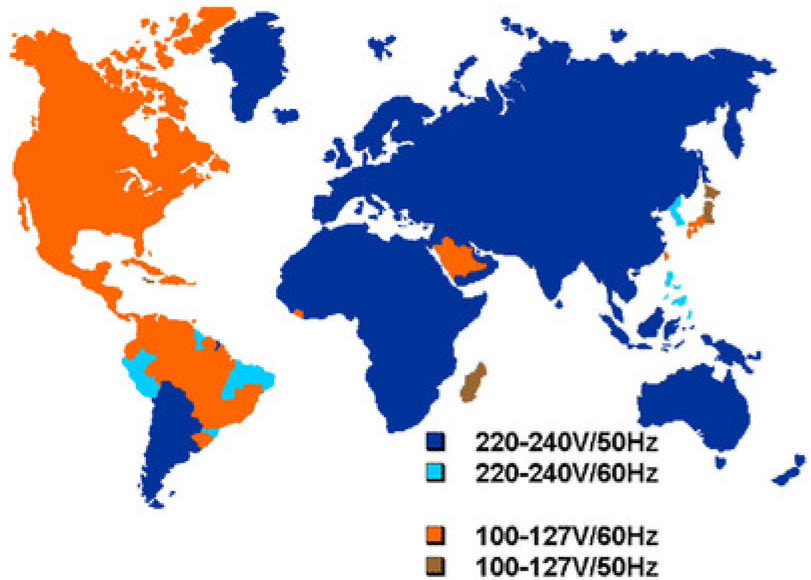
Examples of Geographic Rules

- the more you climb a mountain, the colder;
- heavy rain upstream, downstream flooding.
- mosques are oriented towards Mecca;
- if a zone is a swamp, it is necessary to prohibit construction;
- if there is unemployment, the creation of companies or industrial areas must be encouraged;

Decision trees, tables and maps





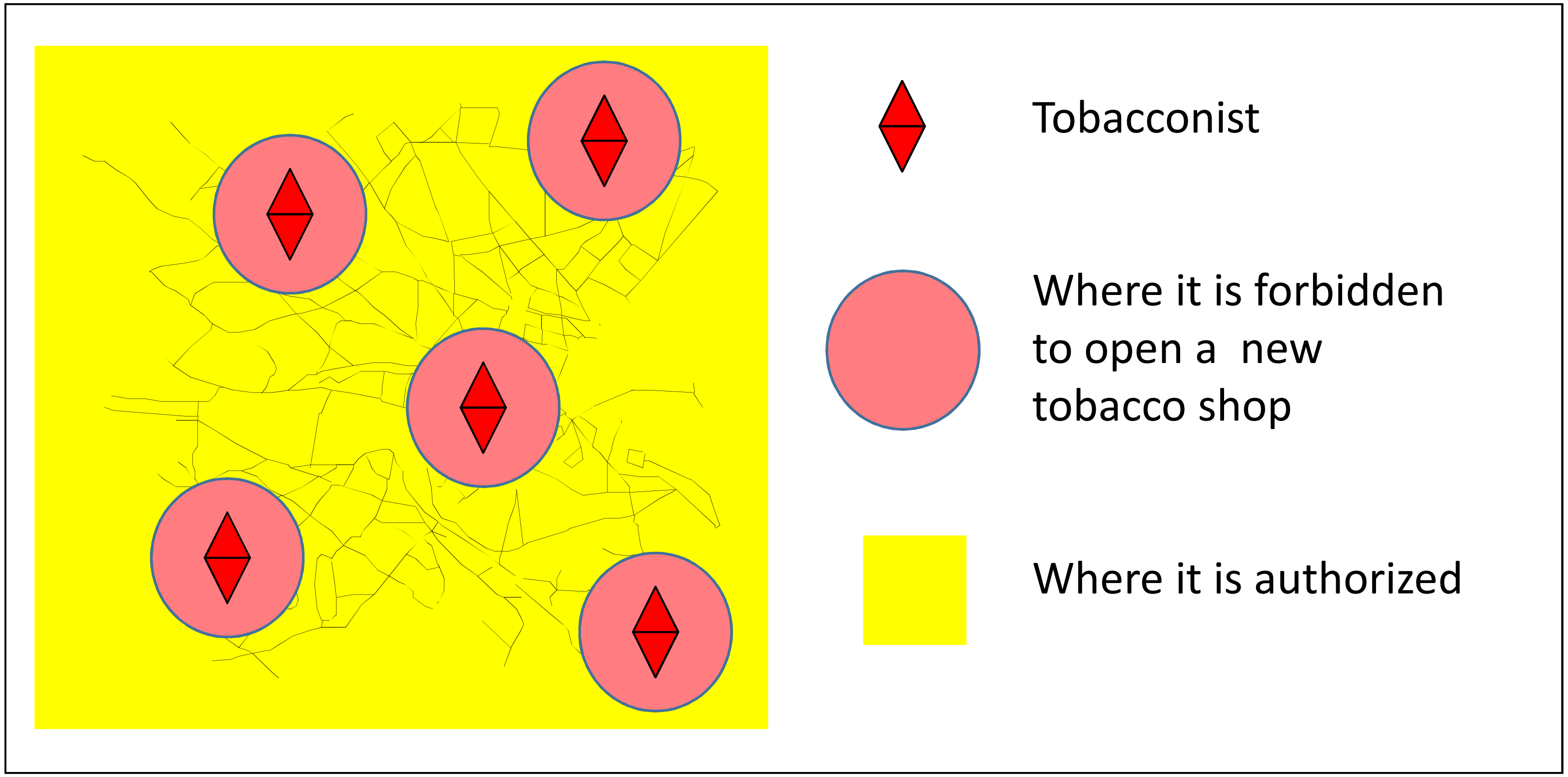


http://wikitravel.org/en/Electrical_systems

Different Types of Geographic Rules

- Applicative rules
  - Urban and Environmental Planning
  - Transportation
  - Tourism, etc
- Generic rules (to ensure reasoning robustness)
  - Quality control
  - Independence from data acquisition devices
  - Taking human languages and reasoning into account
  - Variation according scales (mutation of shapes, relations, etc.)

Tobacco shop rule in France



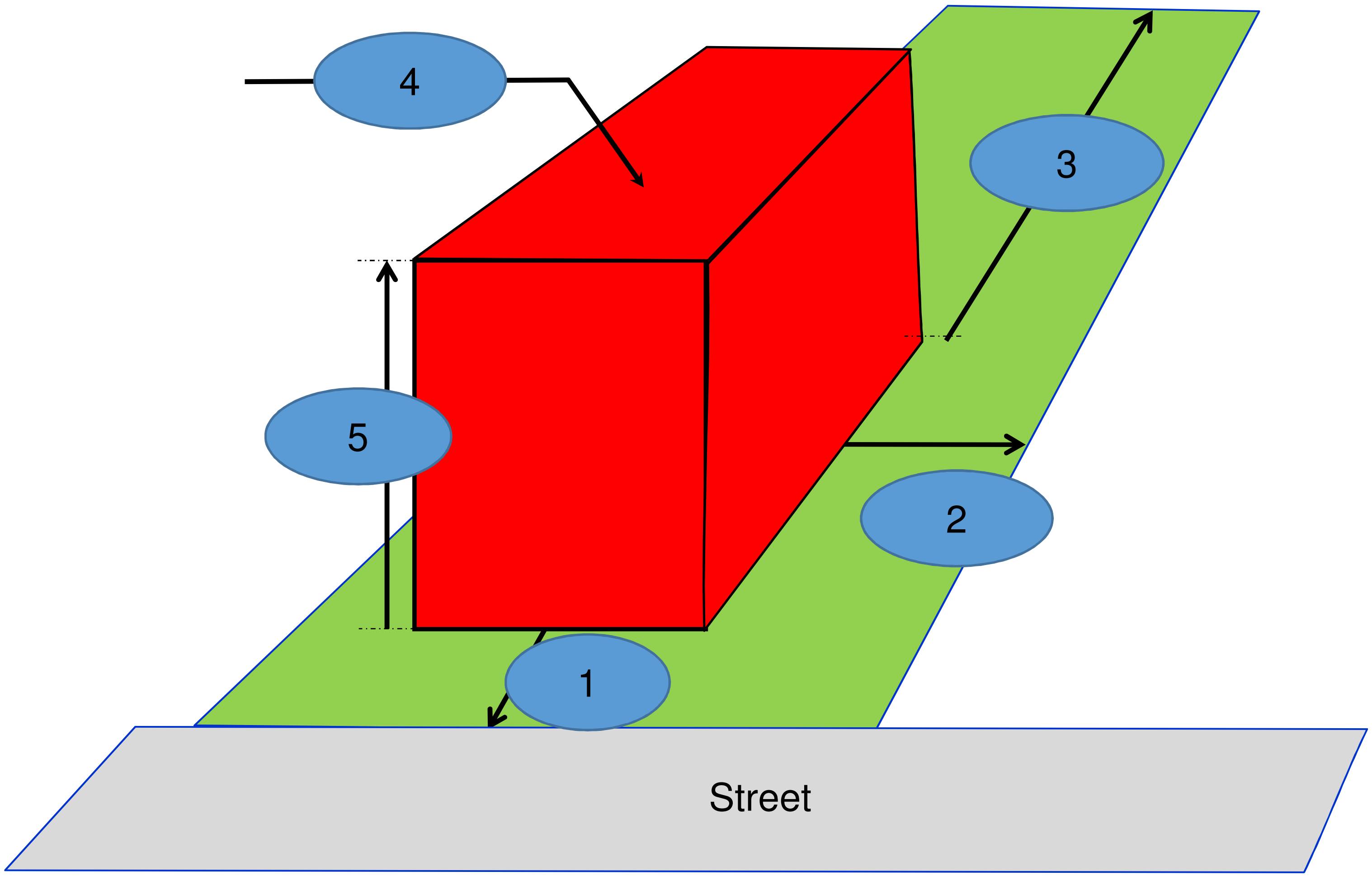
Zone Determination

$\forall F_i \in GO, \exists Z \in Terr,$ $G\text{-}Type\ (F_i) = Point,\ G\text{-}Type\ (Z) = Area,$ $\Omega\text{-}Type\ (F_i) = \text{“Tobacconist”},$ $Geom\ (F_i) \in Terr$ $\Rightarrow$ $Geom(Z) = Terr - Union\ (Buffer\ (F_i,\ 500))$	Rule 10.8

Urban Planning Rules

- Rule 1: If a zone is a marsh or floodplain then prohibit construction.
- Rule 2: If there is unemployment then support the creation of businesses and/or create industrial zones.
- Rule 3: If a plot is adjacent to an airport then limit the height of the building.

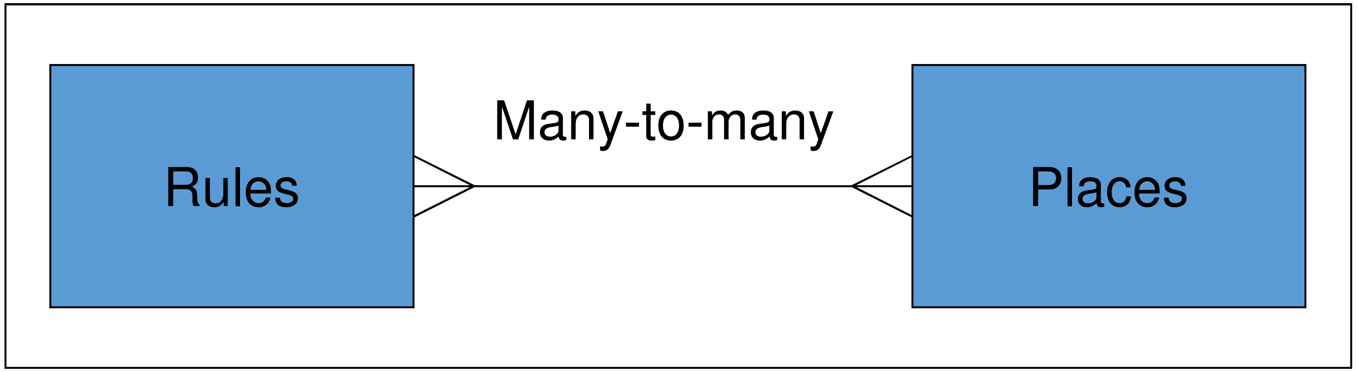
Urban Planning Rules



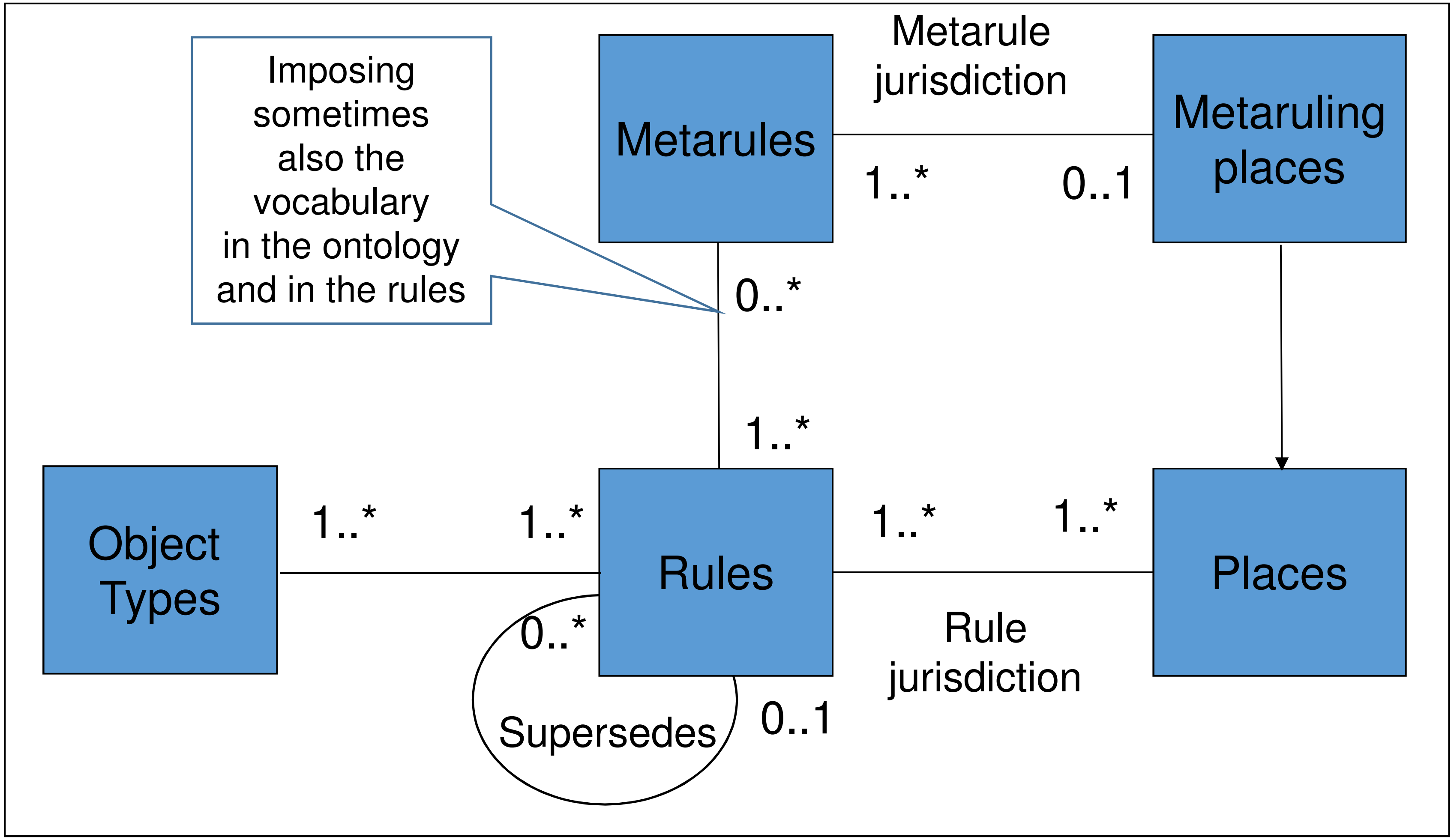
Encoding

$\forall\ B \in PROJECT, \exists\ P \in\ GO$ $\Omega\text{-}Type\ (B) =$ "Building", $\Omega\text{-}Type\ (P) =$ "Parcels", $Contains\ (Geom\ (P), Geom\ (B)) :$ $Height\ (B) < 10$ $\wedge Street\_distance\ (B, P) > 3$ $\wedge Neighbor\_distance\ (B, P) > 3$ $\Rightarrow$ $UP\text{-}Allowed\ (B, P)$	Rule 10.9- 10.13

Naïve relation between places and rules



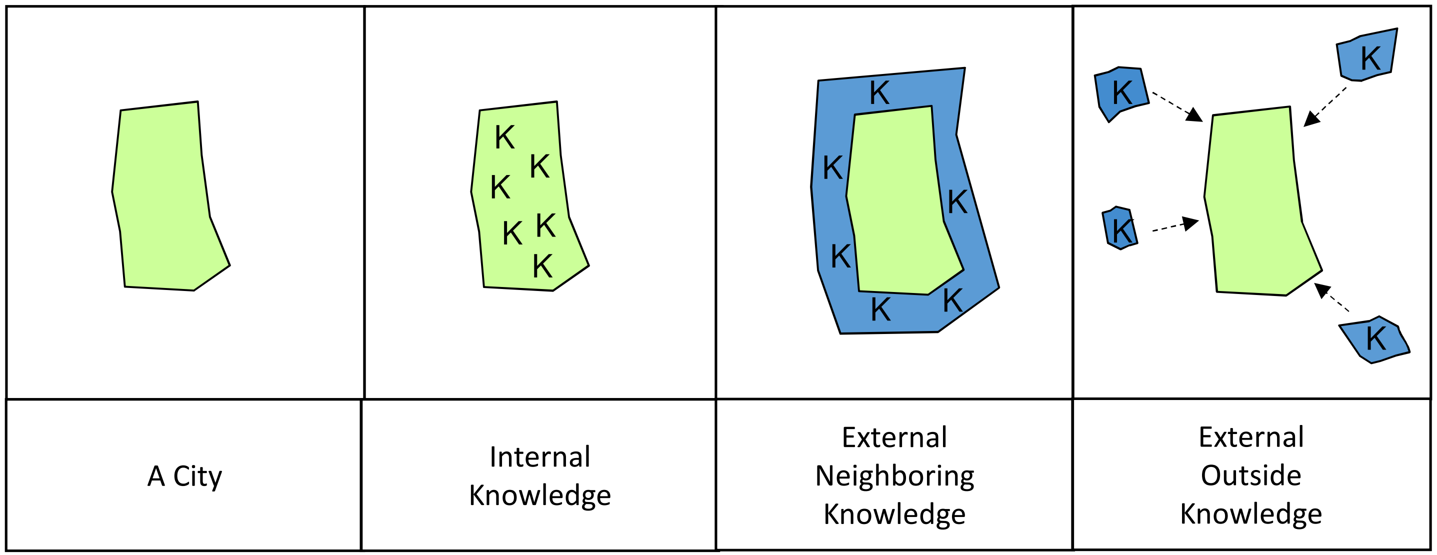
Relations between Rules and Locations



2.6 – External Knowledge

- In GIS, usually coverage = spatial extension of the jurisdiction of the owning entity
- Importance of the vicinity
- Two kinds of external knowledge
  - At the vicinity of the jurisdiction
  - Technology watching
- “intra muros” and “extra muros” knowledge

External Knowledge



3 – Conclusions (1/2)

- 80 % of data in the world have some geographic base
- Only a rapid presentation of geographic knowledge in urban planning
- Territorial intelligence more complex than business intelligence
- Many additional aspects must be developed

3 – Conclusions (2/2)

- <Roberto.Laurini@gmail.com>