Knowledge Engineering for Urban Planning

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Academics Without Borders

Can be downloaded from
www.laurini.net/ftp/Pompei.pdf

Dr. Robert Laurini

- Doctorates in computing (1973 and 1980), University of Lyon, France
- Distinguished professor at INSA-Lyon
- Extra positions
  - University of Cambridge, UK; University of Maryland CP, USA; University of Venice, Italy.
- Research specialty:
  - computing (AI) for urban planning
  - 10+ books, 250+ papers
  - (co)-supervisor of 44 PhD; Member of PhD committees in 19 countries
- Now,
  - Professor Emeritus at KSI,
  - IARIA fellow
  - Honorary president of « Urban Data Management Society »
  - Honorary president of « USF/Academics Without Frontiers »
  - Volunteer in an association for helping international students in Lyon

Knowledge Engineering for Urban Planning

1 – Introduction

Generalities, Objectives,

Smart cities, City Digital Twins

2 – Structure of a UKB

Geographic objects, relations, ontologies, rules, gazetteers

Multimedia documents, graphs

3 – Modeling Urban knowledge

Urban objects, rules and feedforward rules

Projects and knowledge

4 – Conclusions

1 – Introduction

Characteristics of urban planning

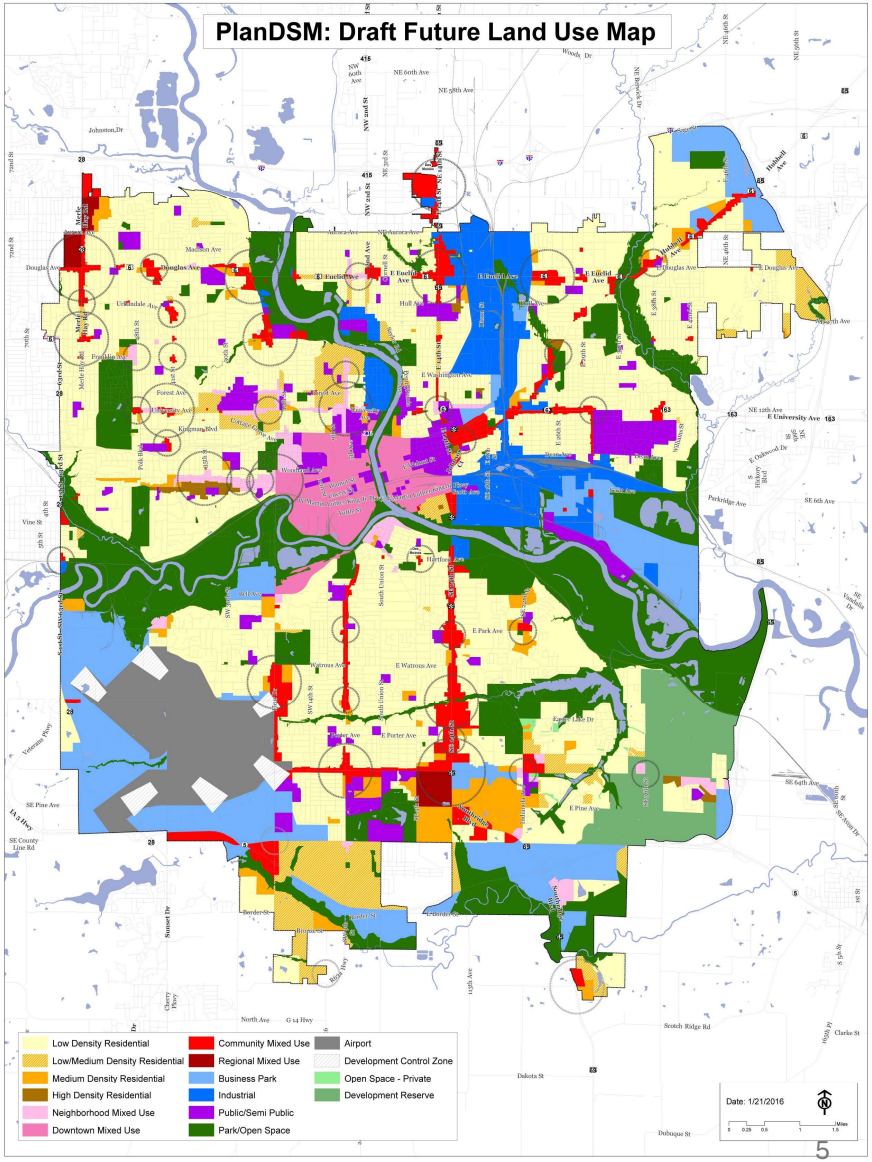
Objectives of this talk

Smart cities

City Digital Twins

Knowledge engineering

Example of Land Use Plan



https://plandsm.dsm.city/future-land-use-map-designations-draft

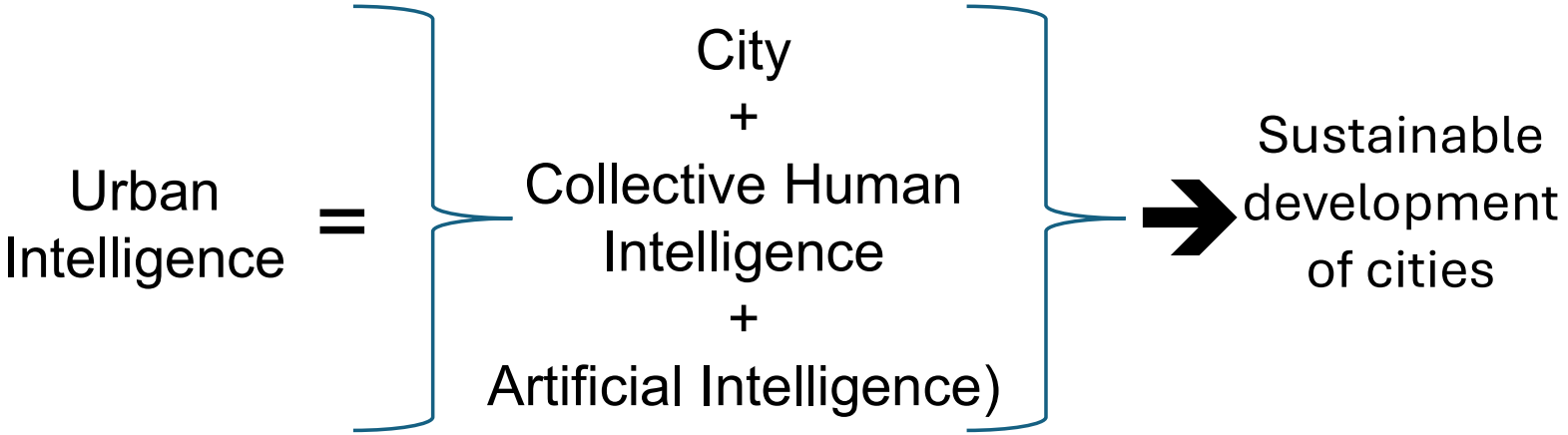
Planning as a feedforward activity

- Feedforward refers to using predictions, projections, and future-oriented data to guide present actions. In contrast to feedback, which reacts to past outcomes, feedforward is about shaping the future by anticipating it.
- Urban planners use this principle when they design cities or neighborhoods not just for current needs, but for how populations, technologies, climates, and economies are likely to evolve.
- **Knowledge and feedforward**

About Knowledge

- Knowledge Society
- Basis for governance
  - Smart Cities
  - Territorial Intelligence
- Difference between data, information and knowledge
- Neighboring concepts
  - Smart People
  - Smart Governance

Definition of Urban Intelligence



Definition of Geographic Knowledge

- Geographic knowledge corresponds to information potentially useful to
  - explain
  - manage
  - monitor
  - and plan a territory.

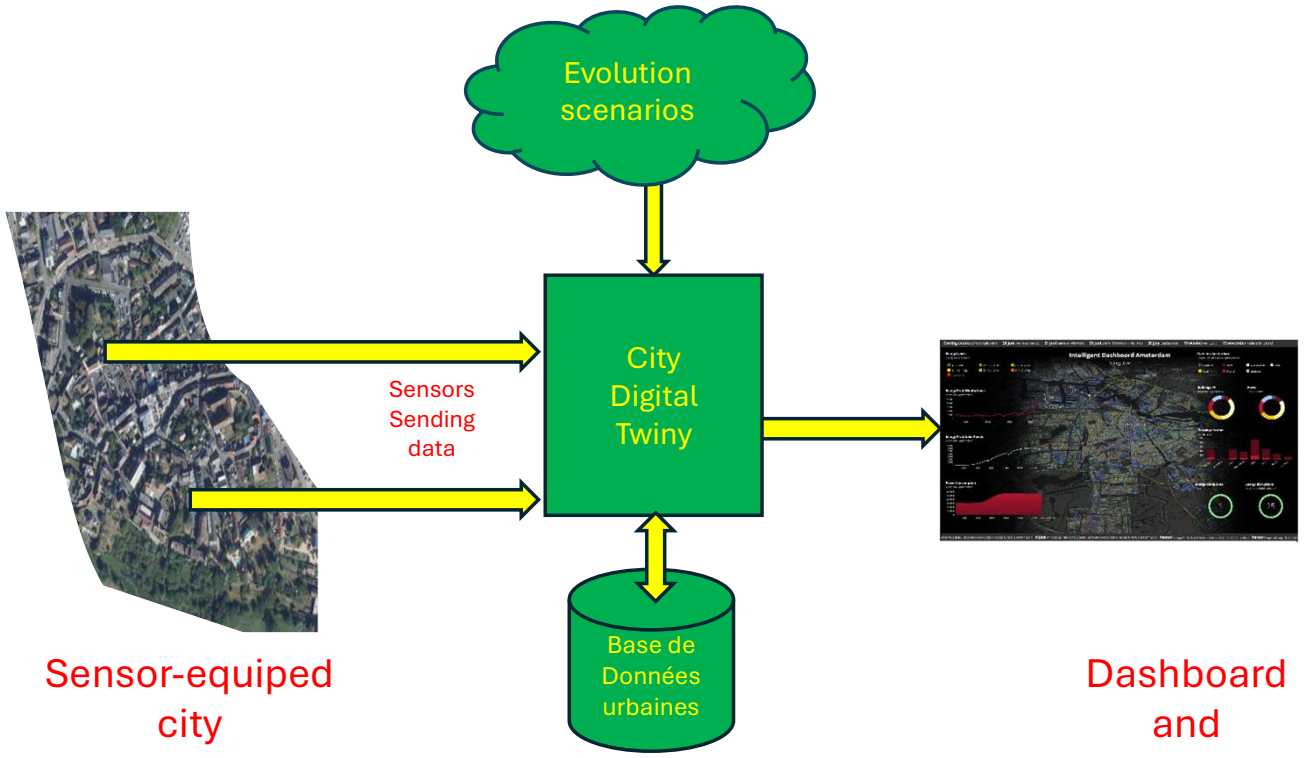
Geographic Rules

- RULES as first-class citizens in IT
  - IF-THEN-Fact
  - IF-THEN-Actions
- Business intelligence (1st order logic)

- Territorial Intelligence
  - Rewrite geoprocessing based on rules
  - Renovate concepts
  - Feedforward Knowledge

- New types for geographic rules

Principle of City Digital Twin Systems



Own elaboration

2 – Structure of an Urban Knowledge Base

- Objects
  - geographic shape
  - coordinates
- Relations
  - topology
- Complex structures
- Ontologies
- Rules

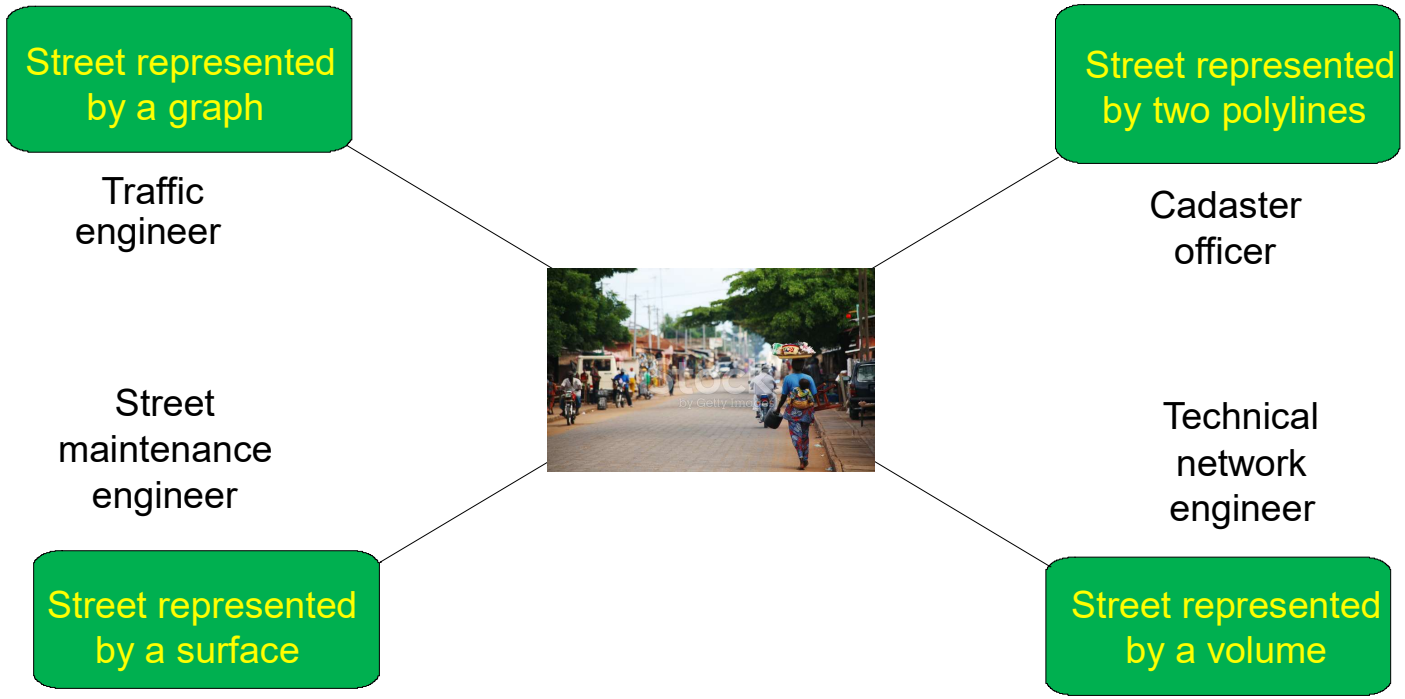
- Gazetteers
  - sometimes multilingual
- Multimedia documents
  - aerial photos
  - satellites images
- Knowledge graphs

➔ Reasoning

Specific Characteristics of Urban Objects

- 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



Own elaboration

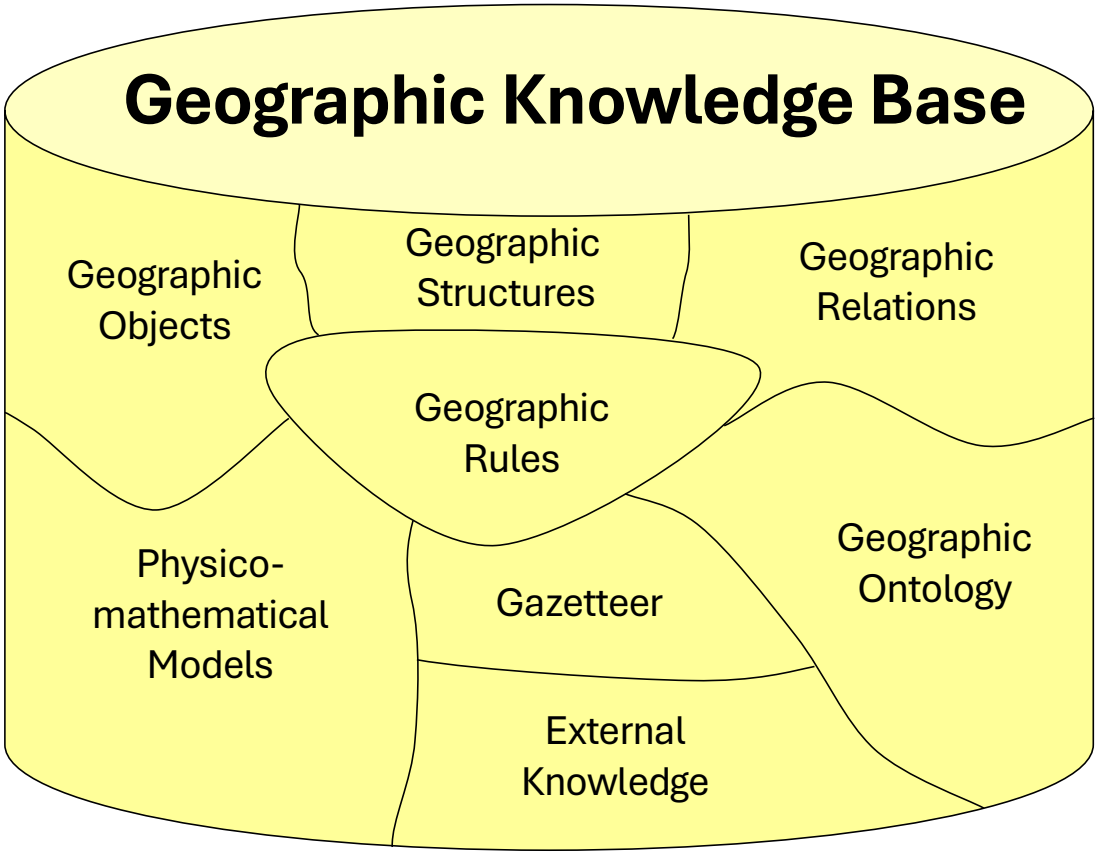
Geographic Projects

- 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.

Repository for Multimedia Documents

- Text (urban planning laws, legal written statements, other reports, etc.)
  - Metadata
  - Key-words
- Maps
  - Working maps
  - Legal maps
- Images
  - Satellite images
  - Aerial photos

Structure of a Geographic Knowledge Base

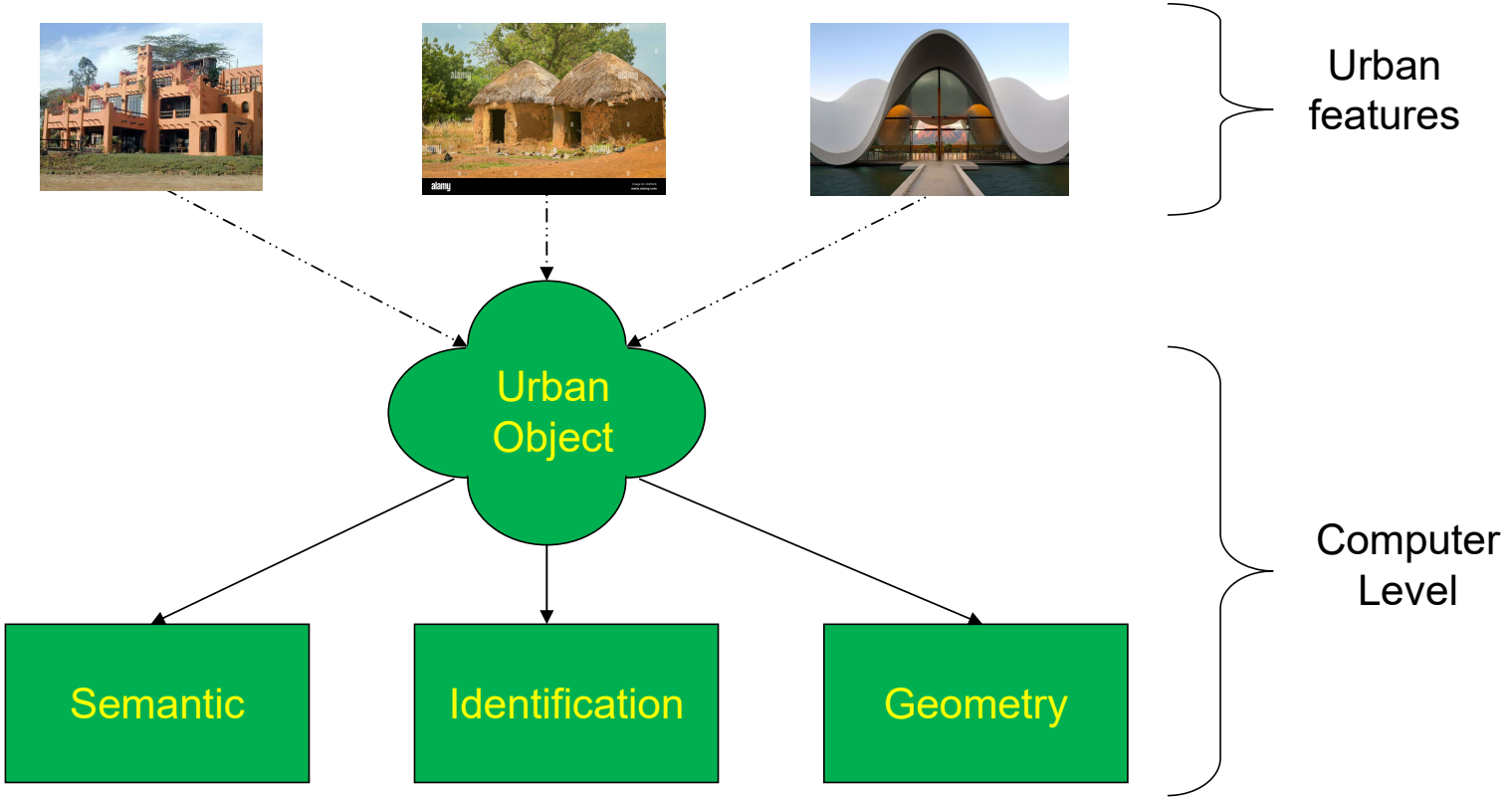


Own elaboration

Urban Objects

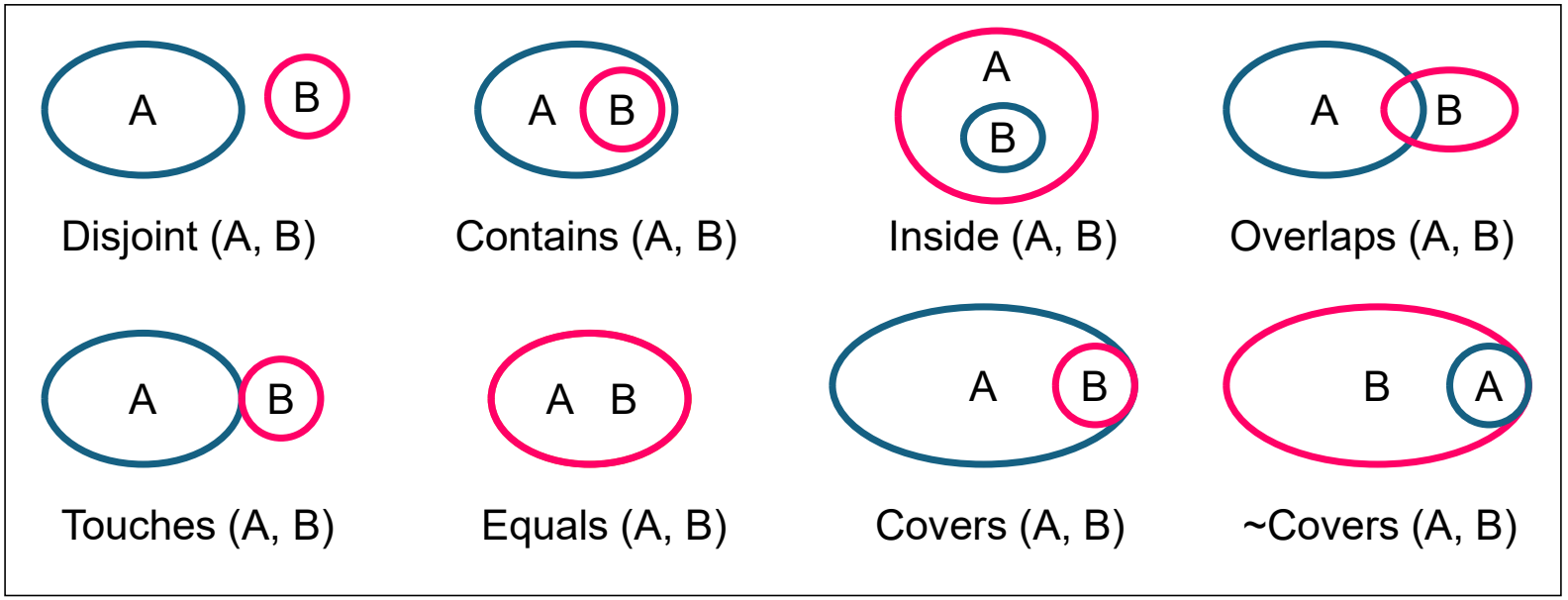
- Administrative divisions, buildings, streets, etc.
  - Manmade objects (crisp boundaries)
  - Euclidean Geometry
- Natural objects (mountains, rivers, etc.)
  - With fuzzy boundaries
  - Fractal geometry
- Continuous fields (temperature, pollution, etc.)

Characteristics of Geo Objects



Own elaboration

Egenhofer Topological Relations

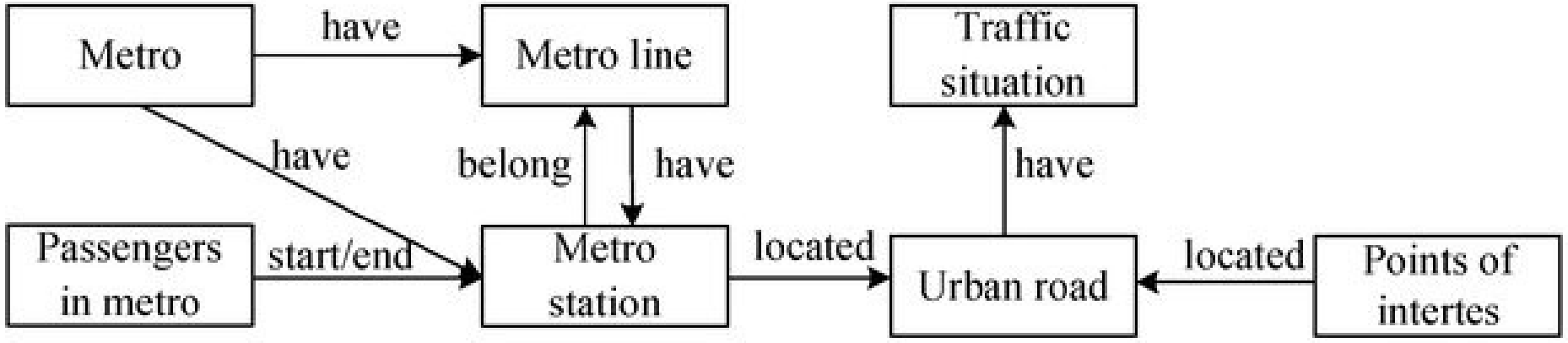


Own elaboration

Urban Ontologies

- Organizations of geo features
- In addition to relations “*is_a*”, “*has_a*”, “*whole_part*”
  - Necessity of spatial relations
- The Towntology project

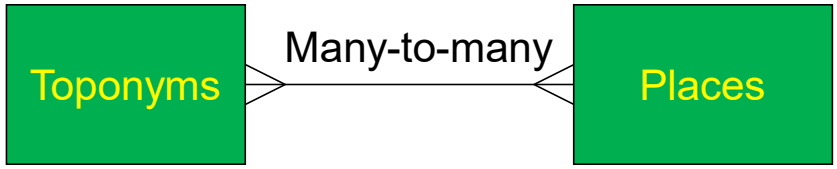
Example of an Urban Ontology



https://www.mdpi.com/2071-1050/13/6/3191

Gazetteers

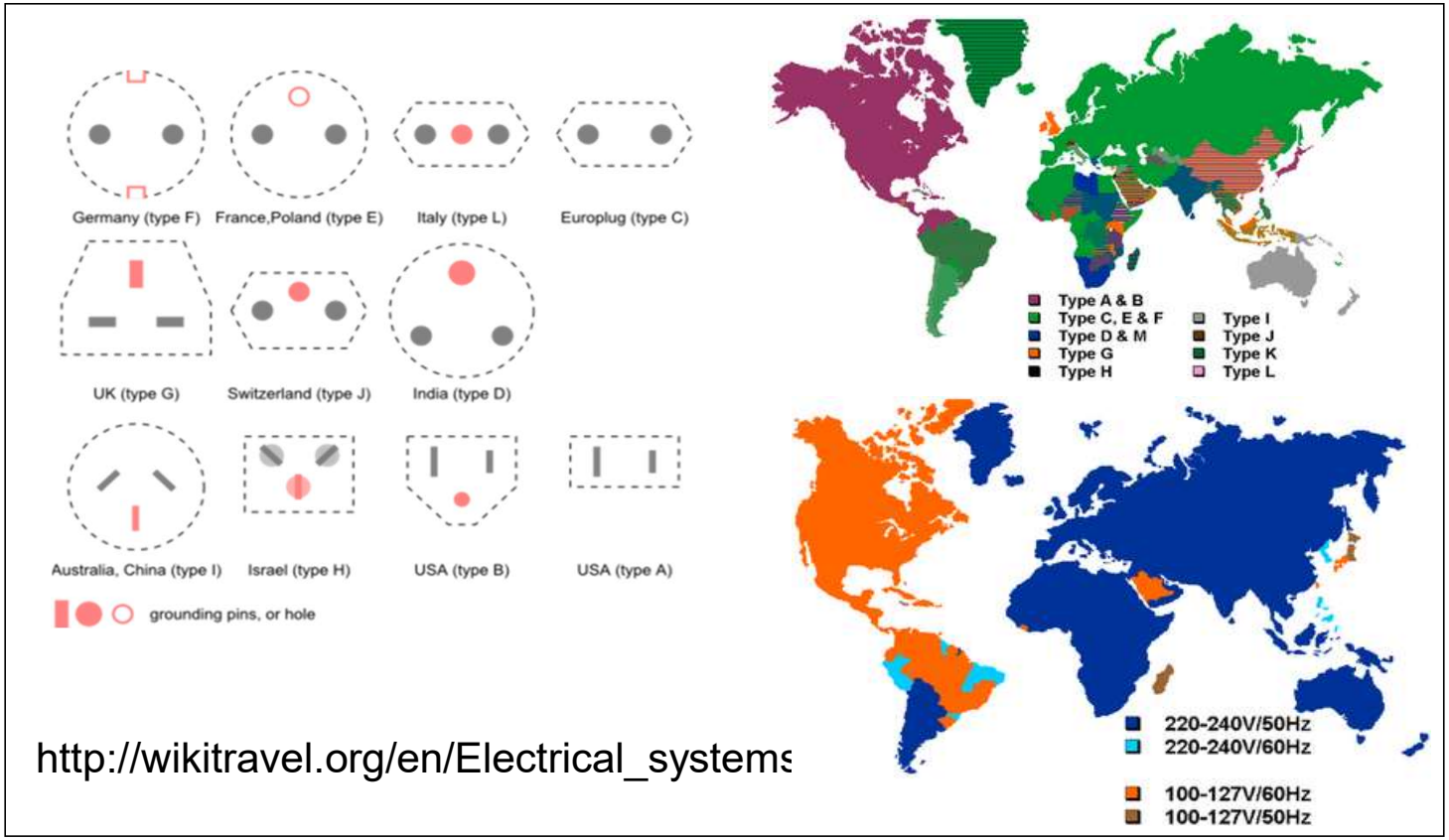
- Placenames / toponyms
- Can change over time
- Multiple translations
- Different places can have same name



- Not only city's names, but also streets and landmarks

Own elaboration

Example of multimedia located rules



http://wikitravel.org/en/Electrical_systems

Geographic and Urban 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).

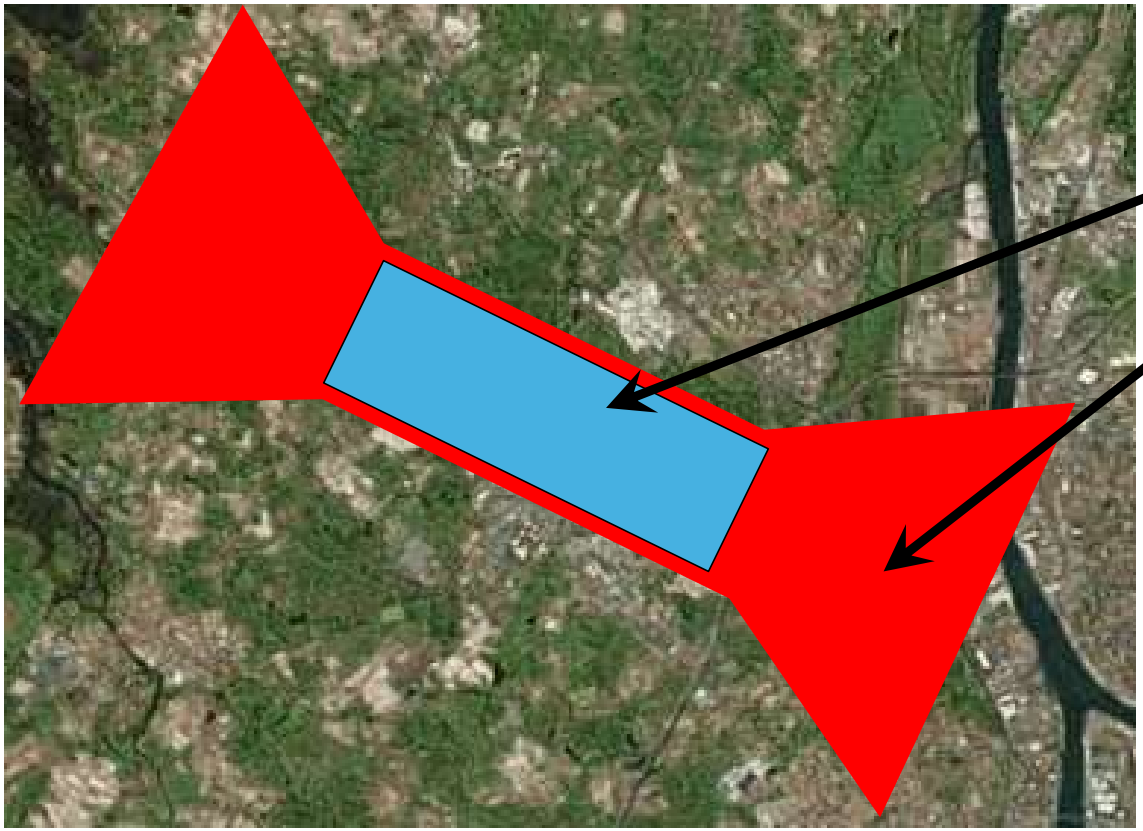
Other Examples of Geographic Rules

- 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

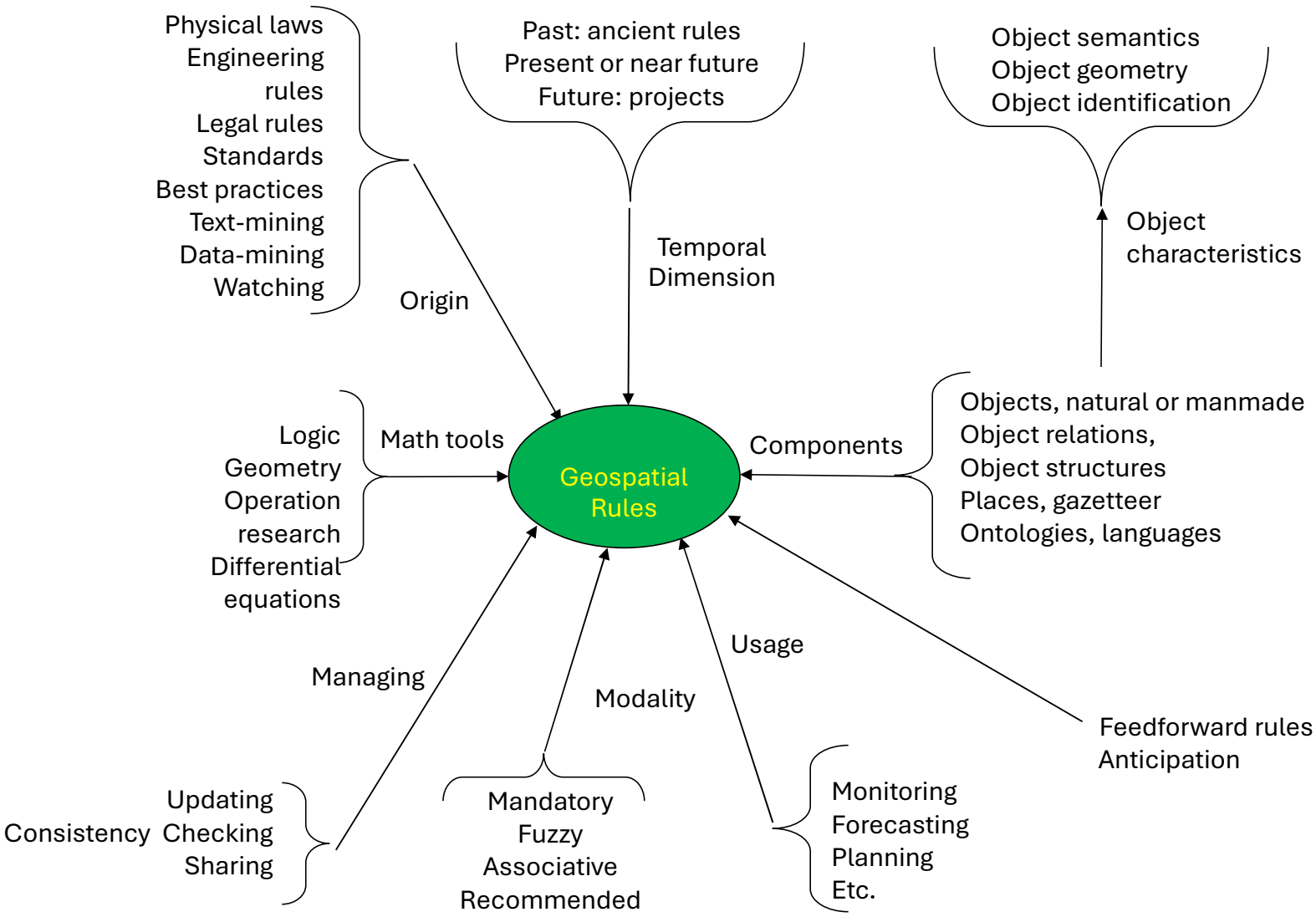
Different Applications of Spatial Rules

- Applicative rules once planning decision are made
  - Urban and Environmental Planning
  - Residential activities
  - Economic development
  - Commerce
  - Transportation
  - Tourism,
  - etc

At the Vicinity of an Airport



Own elaboration

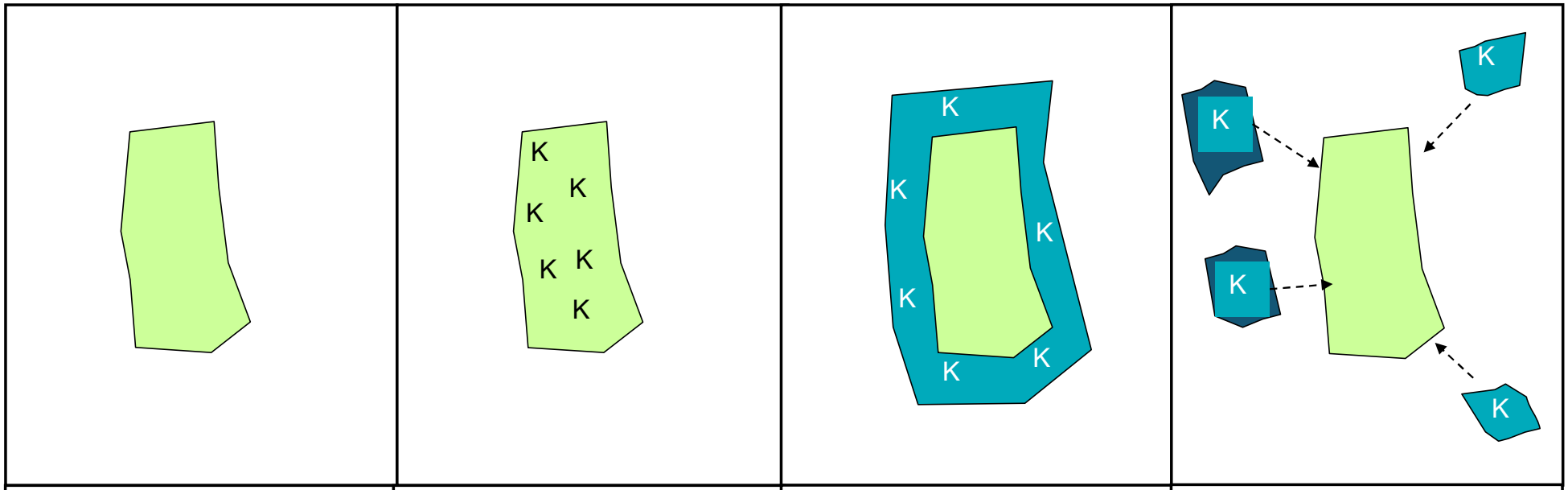


Own elaboration

External Knowledge

- In GIS, usually coverage = spatial extension of the jurisdiction of the owning entity
- Importance of the vicinity (sometimes outside objects have more importance than some inside objects)
- Two kinds of external knowledge
  - At the vicinity of the jurisdiction
  - Technology watching
- “intra muros” and “extra muros” knowledge

External Knowledge



Own elaboration

3 – Modeling Urban Knowledge

Rule modeling

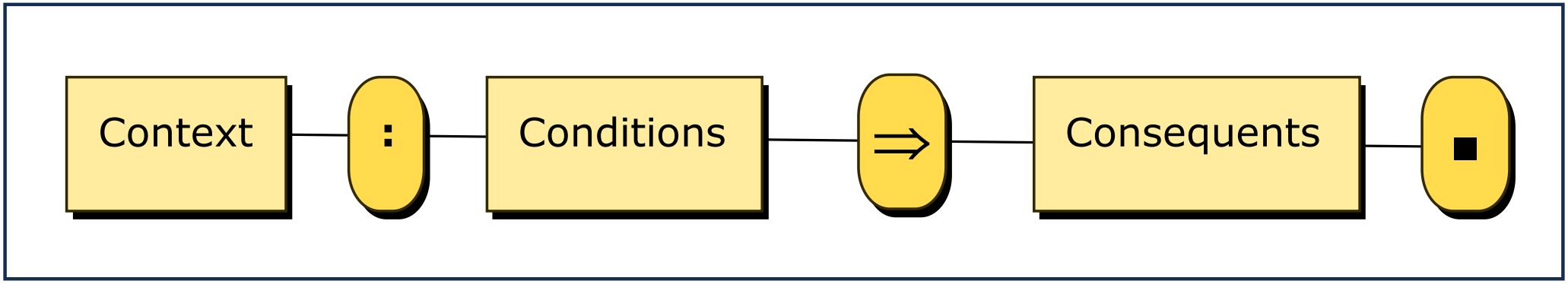
Knowledge Graph

Project repository

Geovisualization

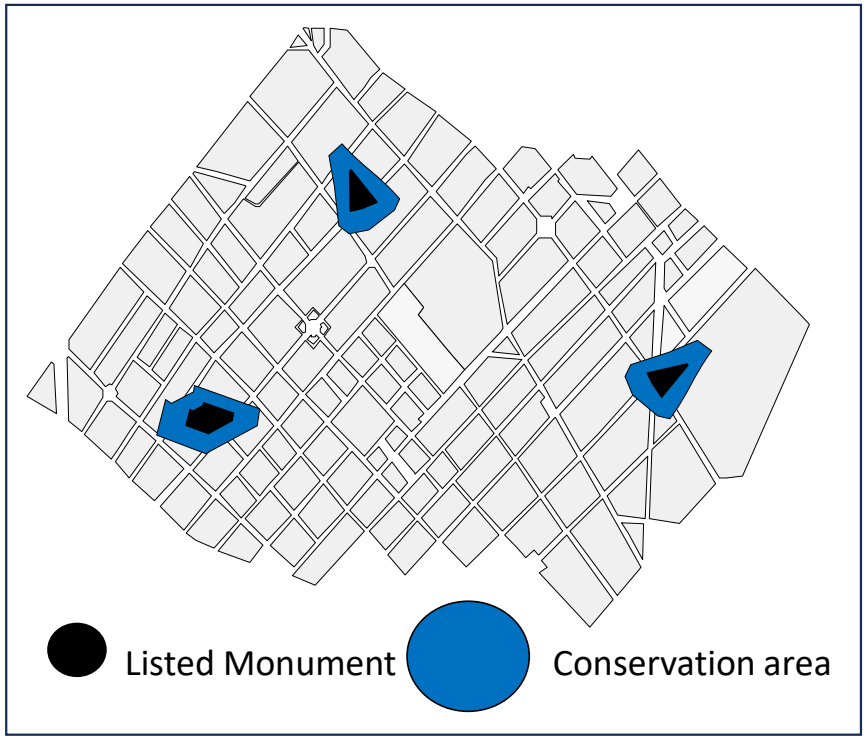
Grammar for Spatial Rule encoding

- Context (definitions of objects, relationships between them)
- Boolean conditions (including geometry and topology
- Consequence



Own elaboration

Example for Listed Monuments



Own elaboration

$\forall\ T \in Earth, \forall\ B \in PROJECT, \exists\ M \in Geo\text{-}Objects,$

Type (B) = “Building”,

Type (M) = “Listed_Monument”,

$\vDash$ *Inside* (*Geom* (B), T), *Inside* (*Geom* (M), T)

:

Disjoint (Geom(B), *Union* (*Buffer* (*Geom* (M), 100)))

$\Rightarrow$

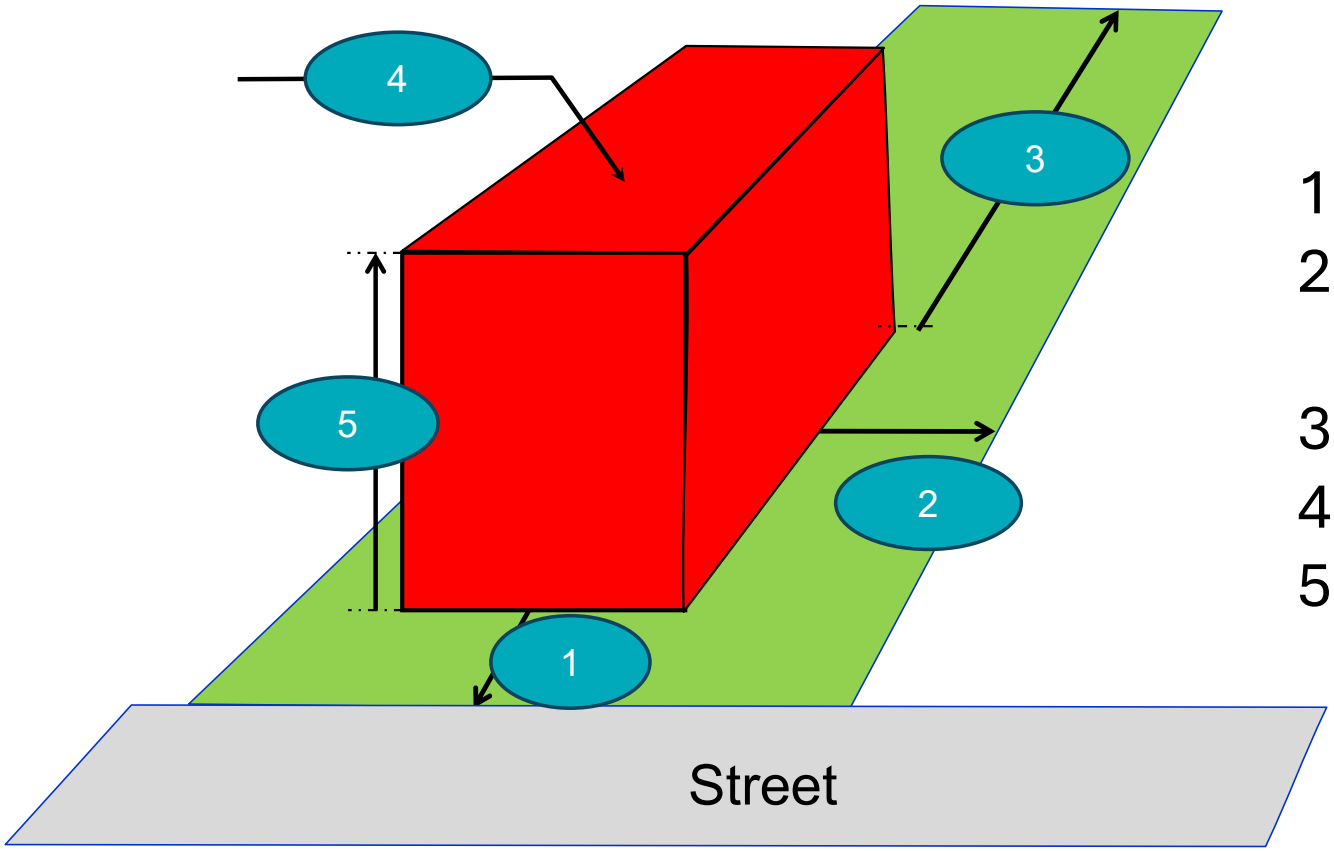
State (B) = “LM_Approved”

Context

Boolean Conditions

Consequence

Urban Planning Rules Concerning New Buildings



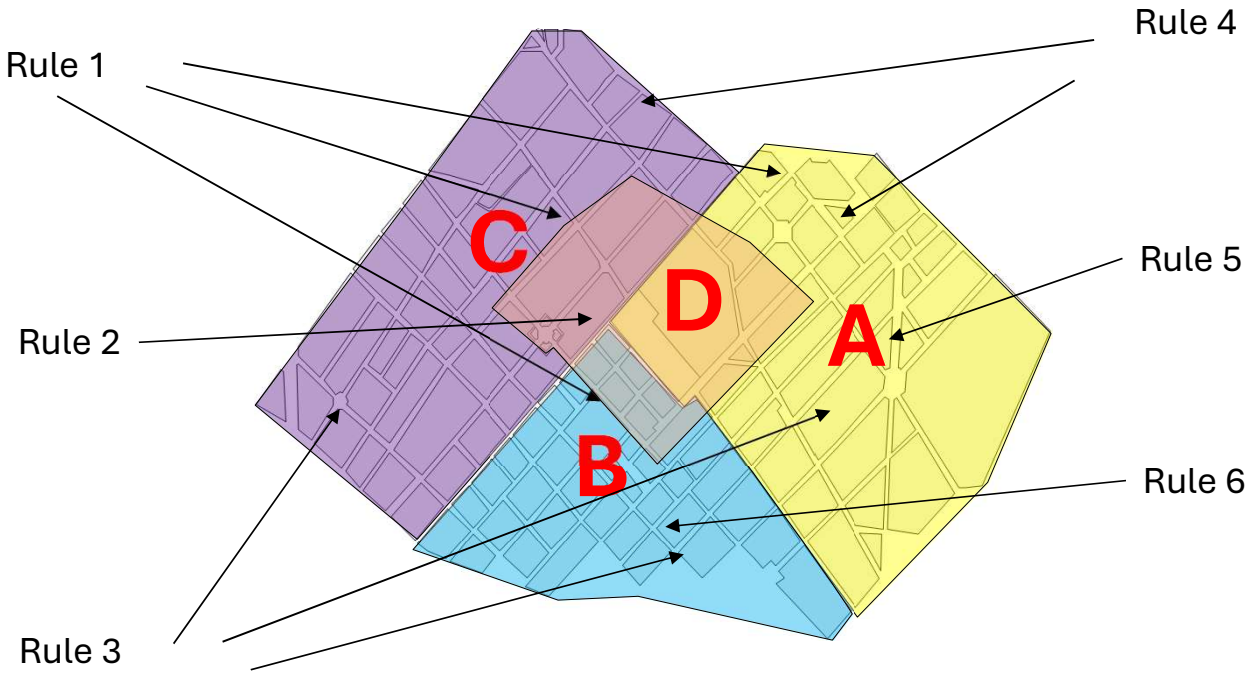
1 – distance from the street
2 – distance to neighboring buildings
3 – distance of the backyard
4 – shape of roof
5 – height of the building

Own elaboration

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

Located rules




```
IF Object Z Belongs to ZoneA
Then Apply Rules 1, 3 and 5
```

Own elaboration

Conclusion about rules

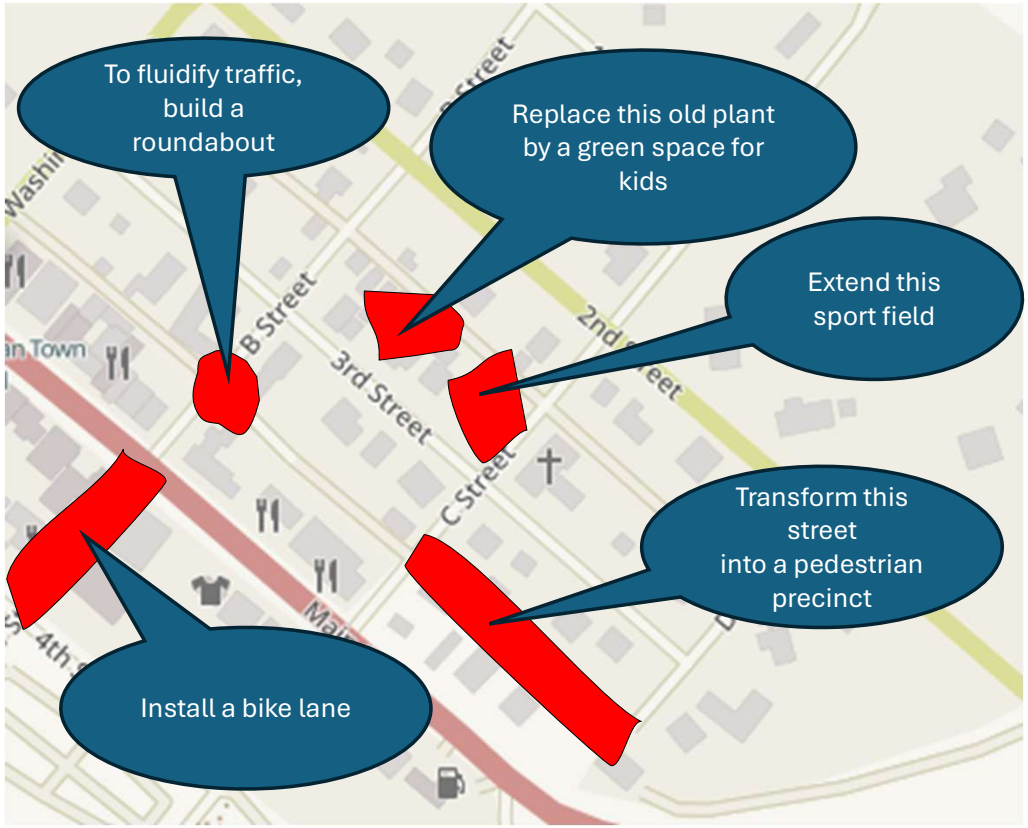
- More than `IF-Then-fact` and `IF-Then-Action`

- Other types of rules
  - Located rules
  - Bi-location rules

Citizen Contrbutions about Urban Projects

- Any urban planning processes imply a phase for public participation
- Interested people can deliver his/her opinion
  - Approval
  - Deny
  - Modify
  - Other suggestions

Opinion positioning



Feedforward Rules

- Consider two rules:

1 - If it rains, I get wet

- ***Cause-effect chain***

2 - If it rains, I take my umbrella

- ***Result of an anticipation to buy an umbrella***

- This is a Feedforward rule

Definition of Feedforward Rules

- A feedforward rule refers to a control or decision-making process in which outputs are determined based on preset inputs, without relying on feedback from past results.

- They are linked to anticipation processes:
  - ex budget
  - Disaster management

General Model of Feedforward Rules

- General framework in two steps

Pre-rule	Since it frequently rains, Consequently I will buy an umbrella
Post-rule	Whenever it rains, Then I take my umbrella.

Ex1: Monitoring Pollution

Dissemination of sensors

Pre-rule	Since pollution must be monitored, Consequently adequate sensors are distributed throughout the city.
Post-rule	Whenever a threshold is exceeded, Then an alert is triggered.

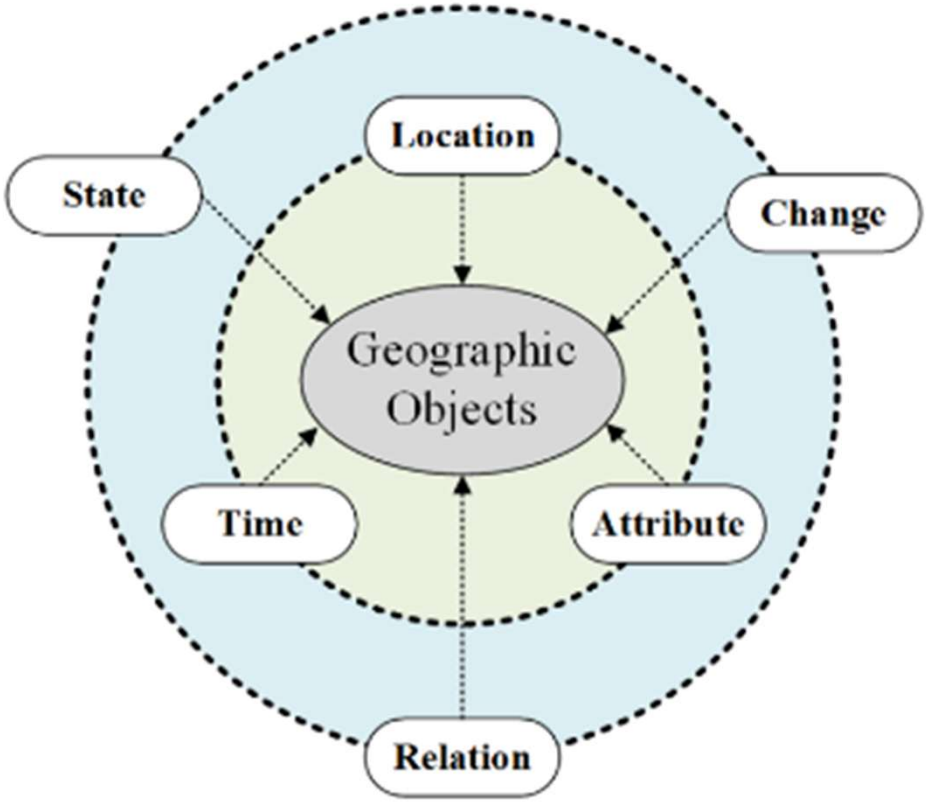
Ex2: Technology Watch

Pre-rule	Since another city puts in place a clever device, and this one is a success Consequently examine it carefully.
Post-rule	Whenever the context is favorable Then this device can be imported into my city.

Ex3: Public Participation

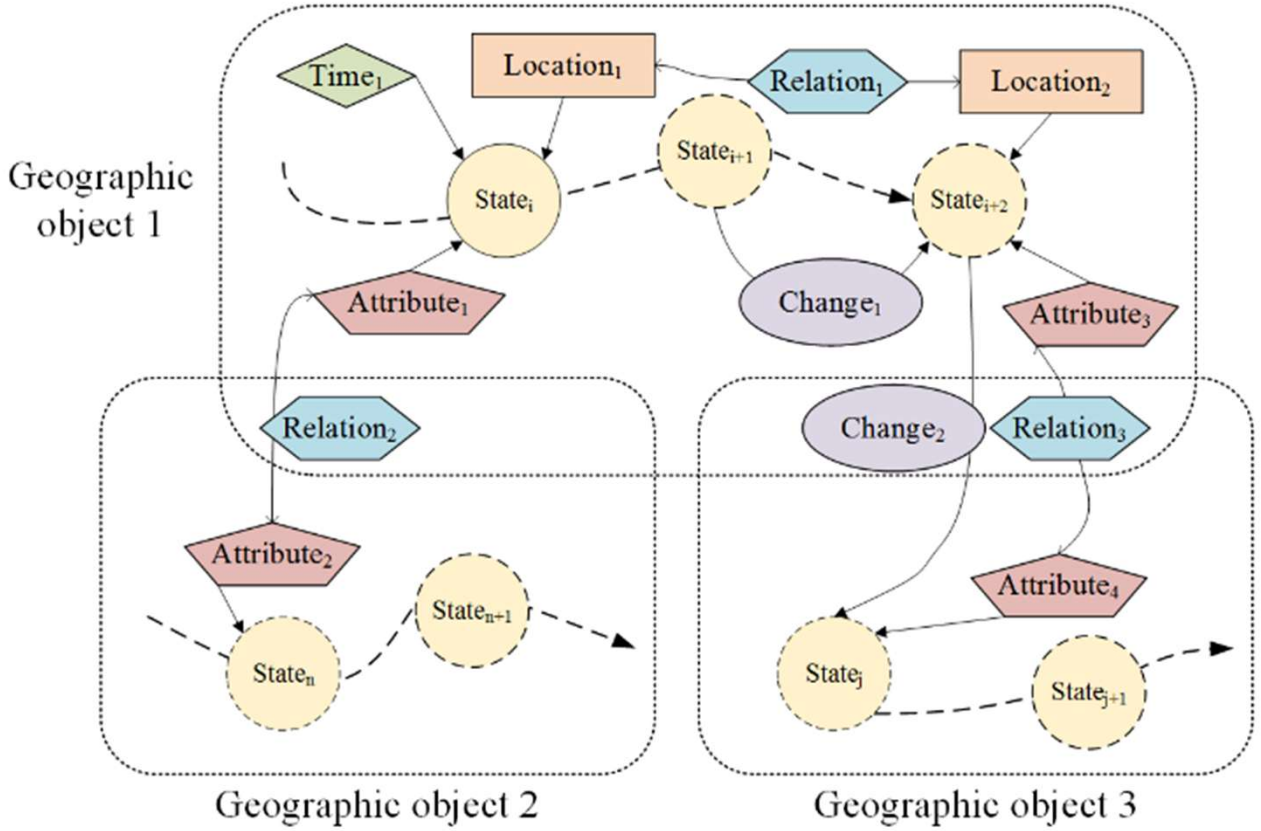
Pre-rule	Since public participation is mandatory for any urban plan or project, Consequently organize it to be efficient.
Post-rule	Whenever a plan or a project is designed, Then collect public opinions and synthesize them.

Geo-KG (Shu Wang 2019)



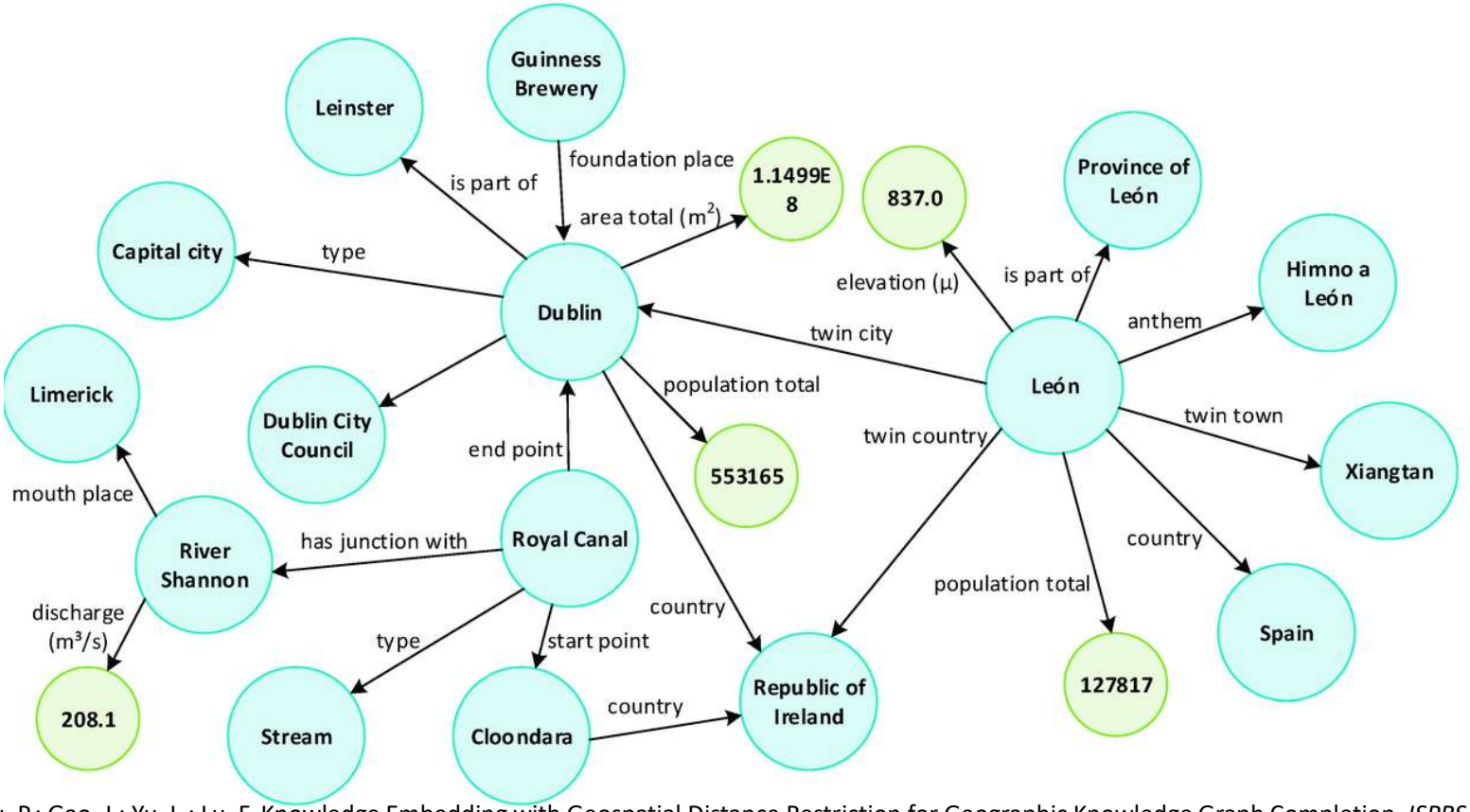
https://www.mdpi.com/2220-9964/8/4/184

Large interactions between urban objects with Geo-KG (Shu Wang 2019)



https://www.mdpi.com/2220-9964/8/4/184

Knowledge Graph for Dublin



Qiu, P.; Gao, J.; Yu, L.; Lu, F. Knowledge Embedding with Geospatial Distance Restriction for Geographic Knowledge Graph Completion. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 254. https://doi.org/10.3390/ijgi8060254

Knowledge from geovisualization

- Geovisualization: much more than cartography
- Idea:

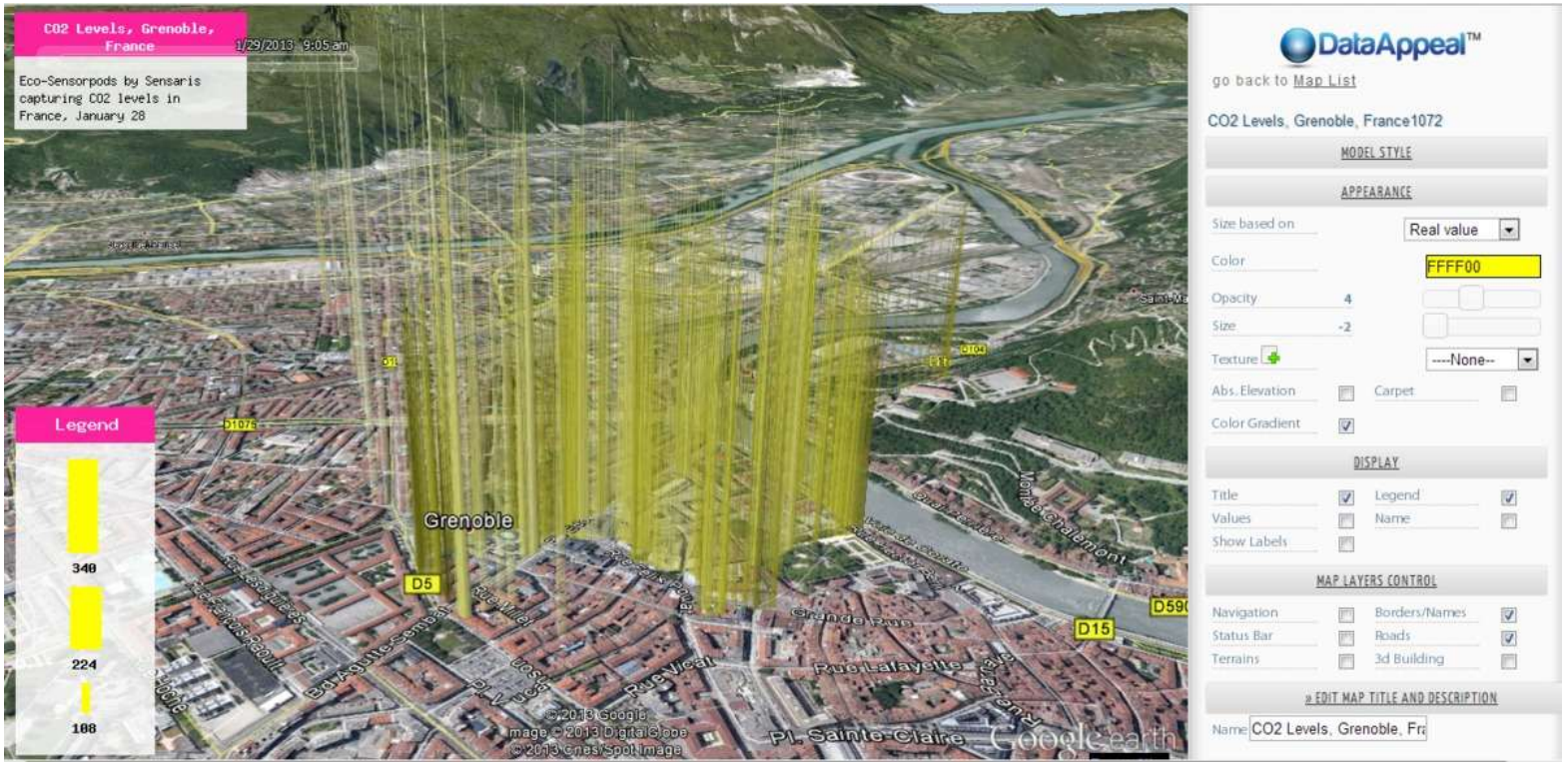
- Trying to extract knowledge from novel visual layouts

- Visual reasoning

3D Example

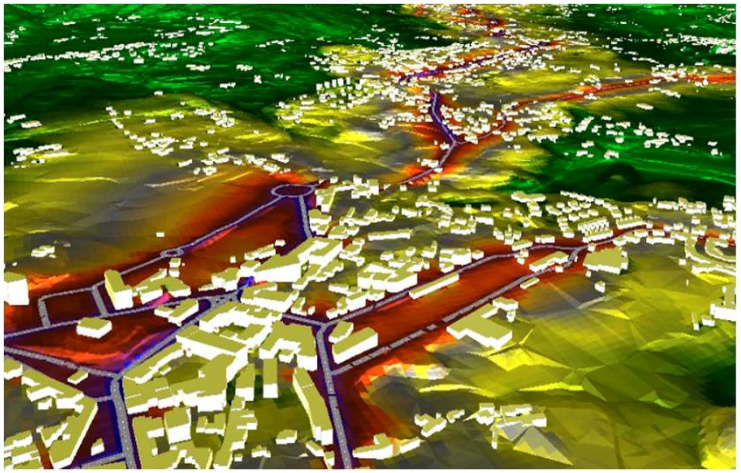
https://www.artstation.com/artwork/JeQAr0

Air pollution in Grenoble

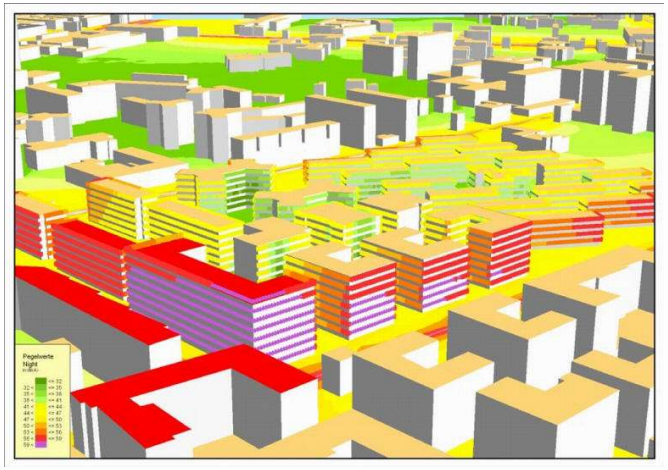


https://www.nadiaamoroso.com/creative-cartography

Noise visualization



https://apambiente.pt/sites/default/files/_Ar_Ruido/Ruido/SituacaoNacional/MapasRuidoMunicipais/Lousada_RNT.pdf



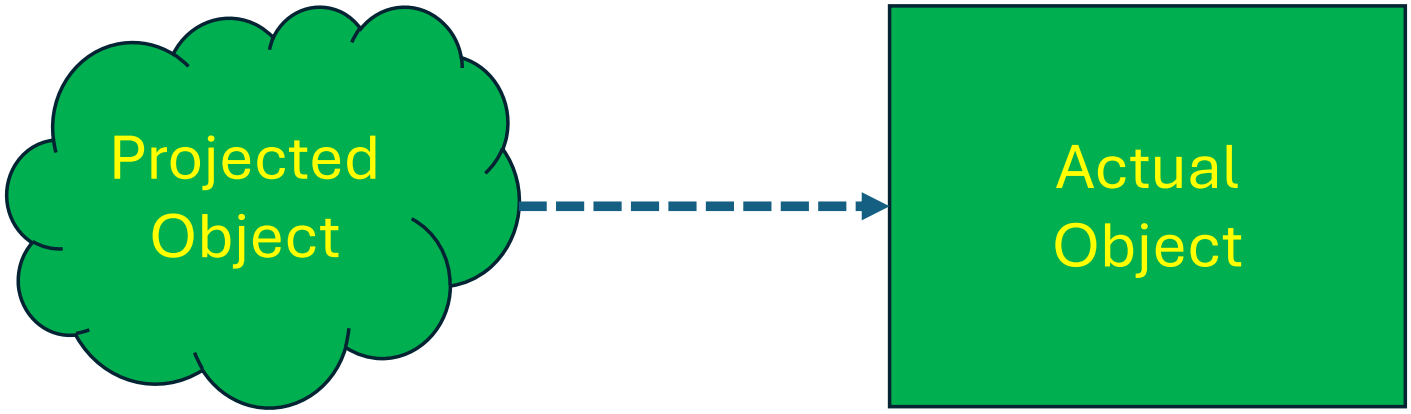
https://www.adamsengg.com/expansion-modules/

Knowledge for/from Projects

- Knowledge is the base for the design of new urban projects

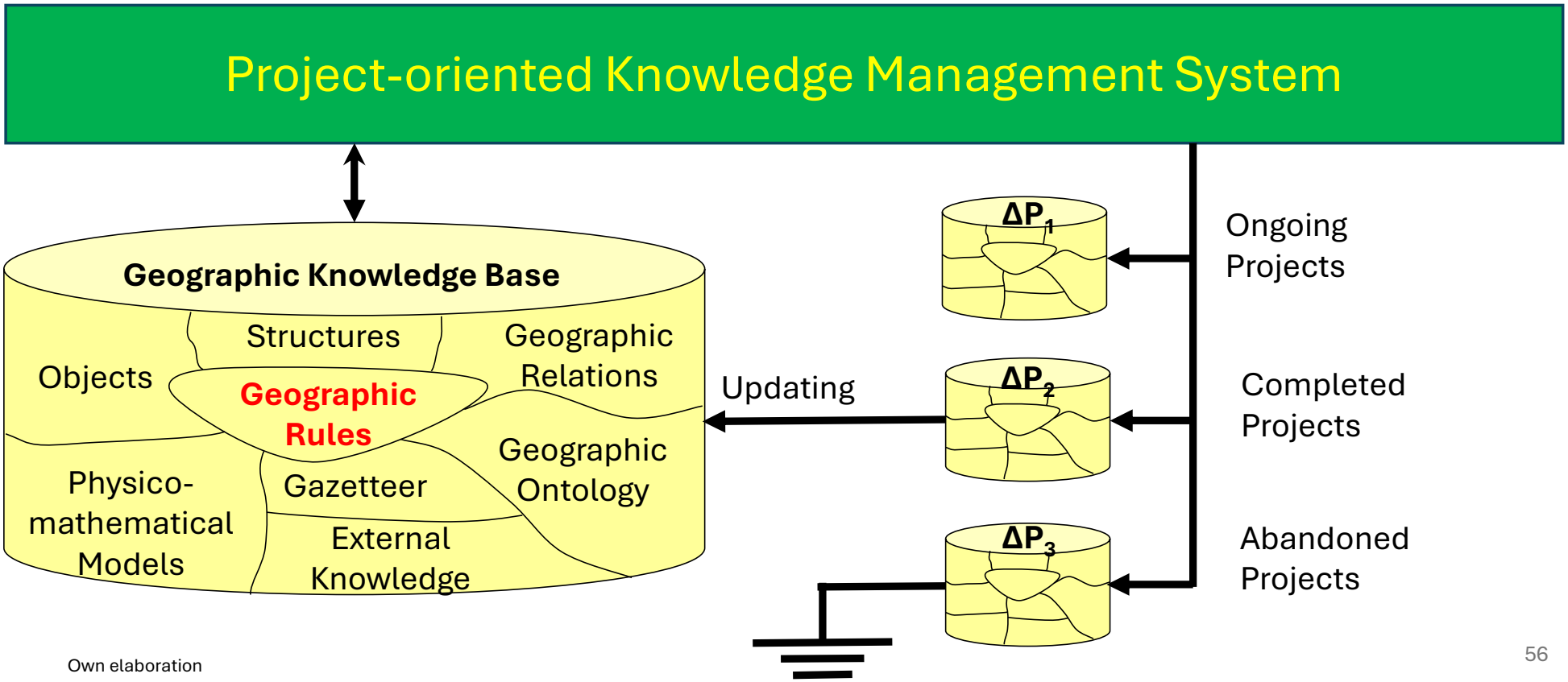
- Lessons learnt from projects
  - Completed projects
  - On-going projects
  - Abandoned projects

From planned objects to actual objects



The term "projected object" refers to an object that is planned for the future or calculated based on information already known.

Architecture for Project Management



Own elaboration

Conclusion

- Urban planning is a complex activity involving several specialties
  - In the past, based on data
  - Now on, based on knowledge
- Only a rapid presentation of geographic knowledge in urban planning
- Importance of feedforward rules
- Territorial intelligence more complex than business intelligence
- Many additional aspects must be developed to get operational systems
- Planning back Pompeii!

Special issue of the “AI Journal”
RL Guest Editor

Special Issue

AI-Powered Smart Cities: Towards Sustainable Urban Environments

https://www.mdpi.com/journal/ai/special_issues/40JO81A46V

Tanks for your attention!

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