
Knowledge Systems Institute
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An Introduction
to
Intelligent Geoprocessing
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An Introduction to Intelligent Geoprocessing

- 1 – Promises of AI in geoprocessing
- 2 – Knowledge Management
- 3 – Case-based Reasoning
- 4 – Deep learning
- 5 – Final remarks

1 – Promises of AI in geoprocessing

- **Def:** Artificial Intelligence (AI) is the machine intelligence that simulates human behavior or thinking and can be used and trained to solve specific problems.

- AI Winter
- Companies
- Local authorities ??
- Necessity of taking space into account

Tools mechanisms

- Data – Database engine – Queries – Set of Data
- Documents – Search Engine – Pieces of documents
- Knowledge – Reasoner – Sketch of Solution

Example of a cake

- Data: basic ingredients
- Documents: book of recipes
- Knowledge: how to make a cake

IA Market

- A recent 2020 report from Statista reveals that the global AI software market is expected to grow approximately 54% year-on-year and is expected to reach a forecast size of 22.6 billion U.S. dollars.

And in geoprocessing and alike?

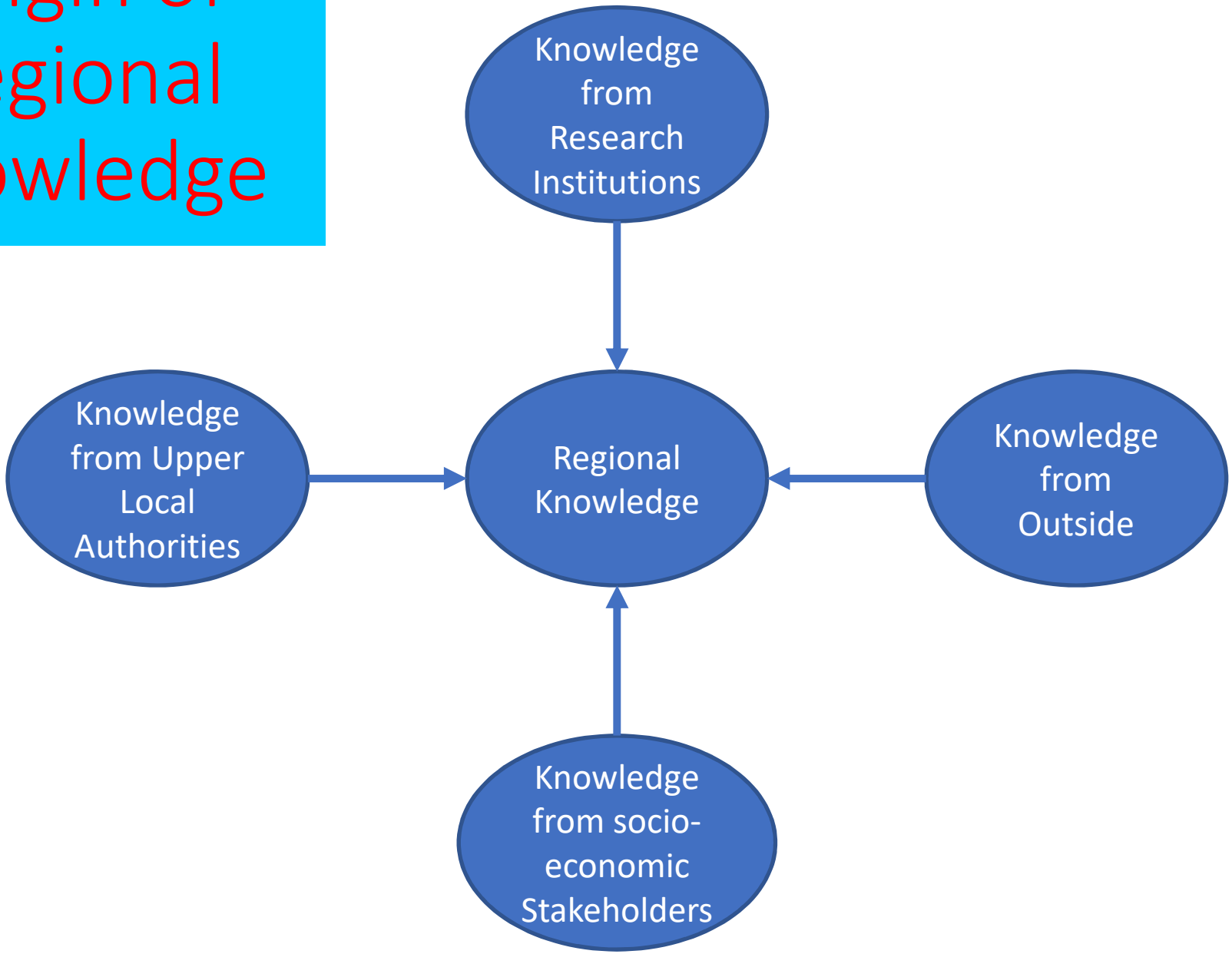
- Wikipedia: Applications of artificial intelligence
- Practically nothing in geoprocessing and alike
- Except
  - Military applications
  - Remote sensing
  - Digital agriculture
- But nothing in
  - Urban planning
  - Environment planning

Why?

- Difficulties for mixing logics with
  - Computational geometry
  - Spatial analysis

- Other characteristics
  - Several stakeholders
  - Different juridical frameworks
  - Combining Human Intelligence and Computer Intelligence
  - → Territorial Intelligence

Origin of Regional Knowledge



2 – Knowledge Management

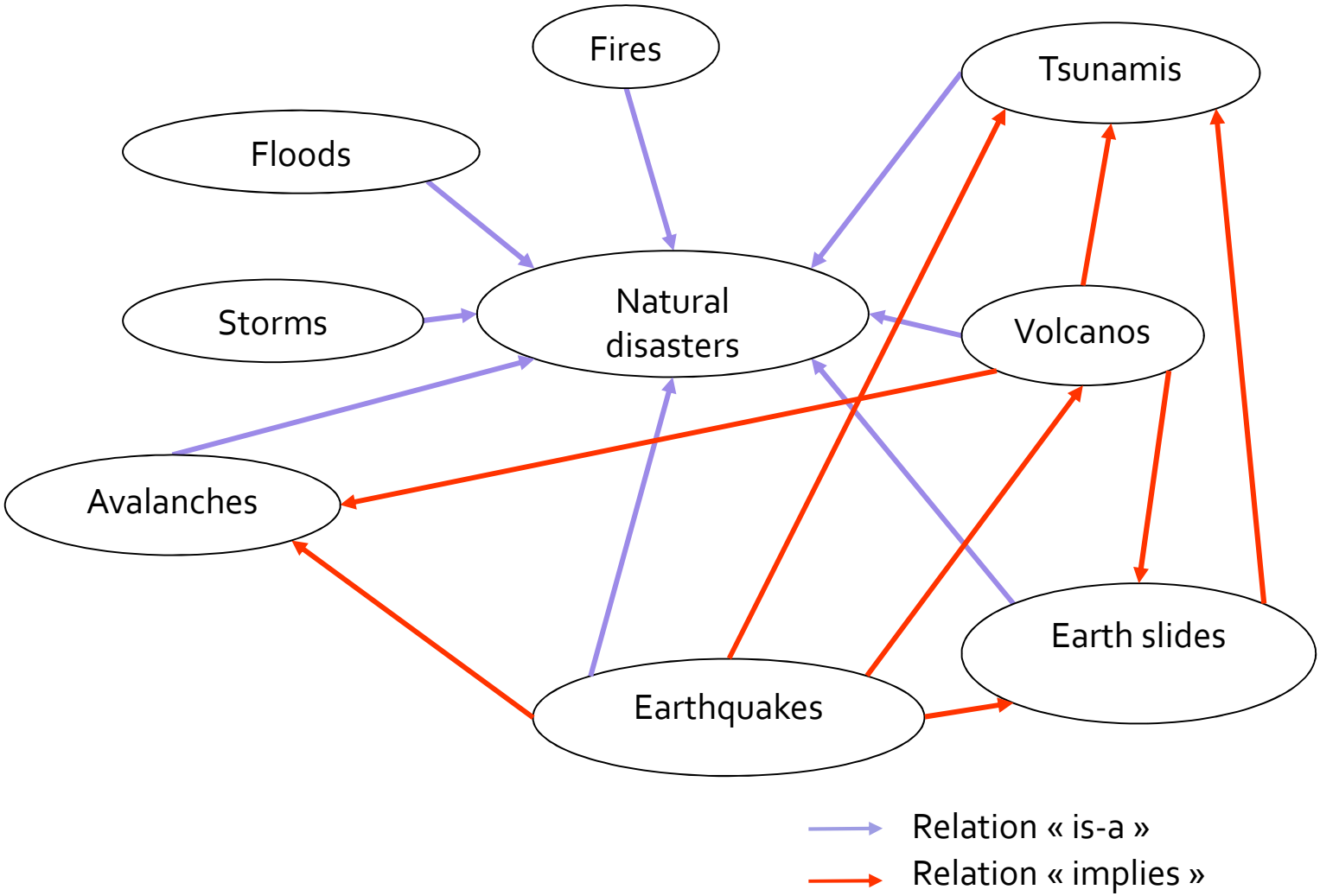
- Data, Information, Knowledge, Wisdom
- Ontologies
- Knowledge networks
- Rule-based systems
  - Geographic rules

2.1 – Ontologies

- Ontology (capital "o") :
  - A philosophic discipline

- An ontology (low case "o") :
  - an artifact invented to describe the meaning of a vocabulary in computing

Example of ontology



Definition

- Οντος = being ; Λογια = discourse
- **Aristotle:** « The study of existing objects »
- **Def1**: theory of objects and their relations
- **Def2**: theory of entities, especially of entities which exist in a language
- **Def3**: explicit specification of conceptualization (Gruber)

Guarino's definition

- **Nicola Guarino** : "*An ontology is generally regarded as a designed artifact consisting of a specific shared vocabulary used to describe entities in some domain of interest, as well as a set of assumptions about the intended meaning of the terms in the vocabulary*"

Concepts

- Distinguish between terms and concepts

- At mathematical level :

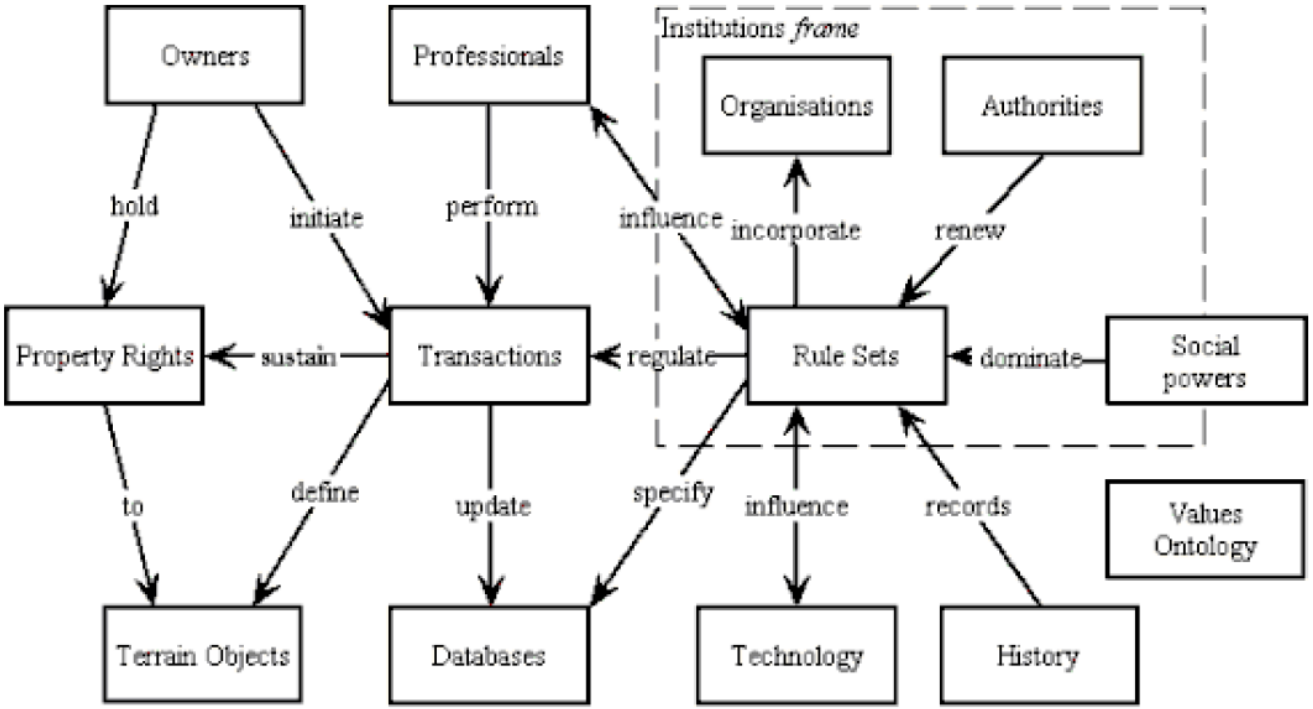
Ontology = graph between concepts

= semantic network

Sometimes with additional constraints

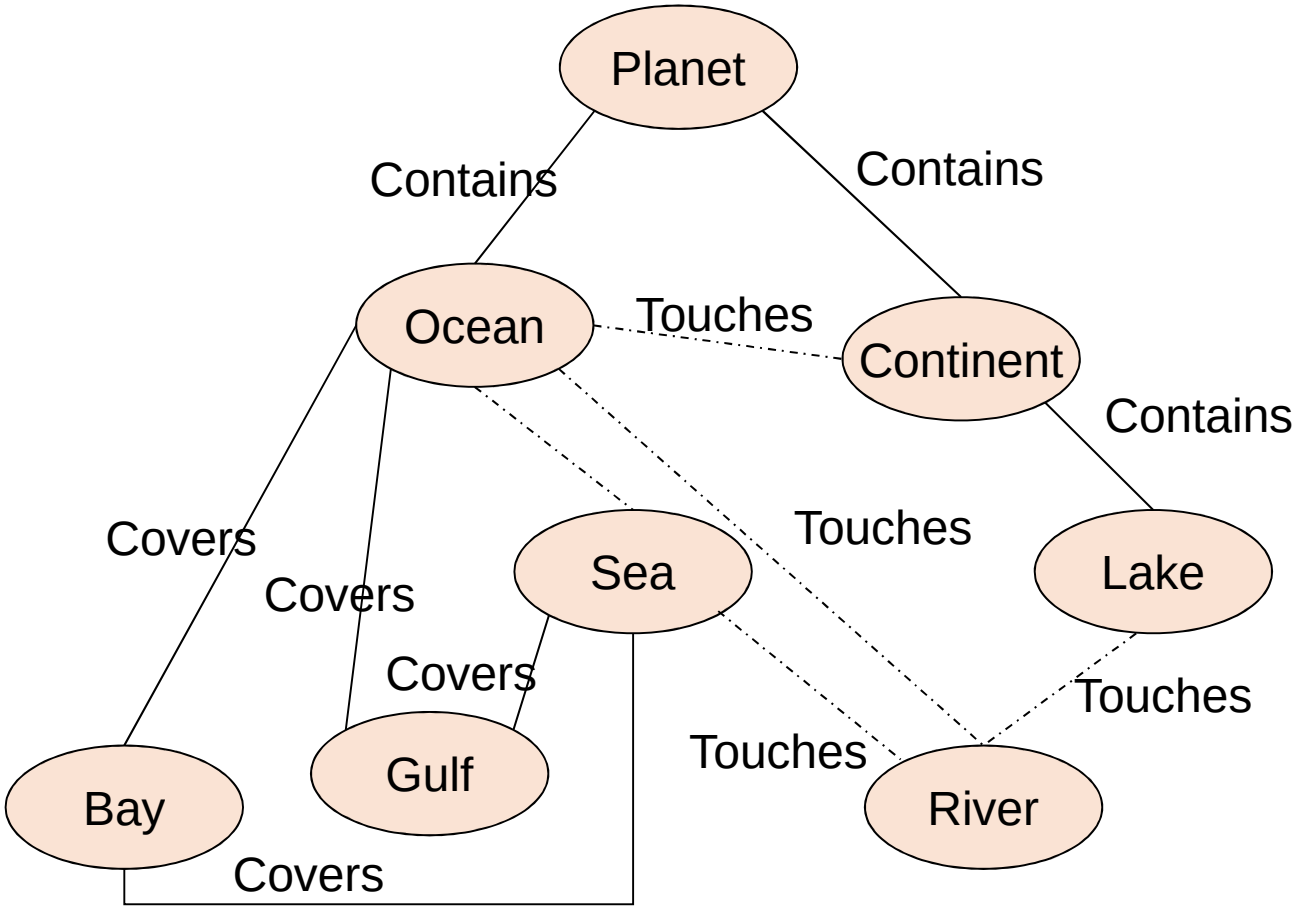
Ontology for landcover

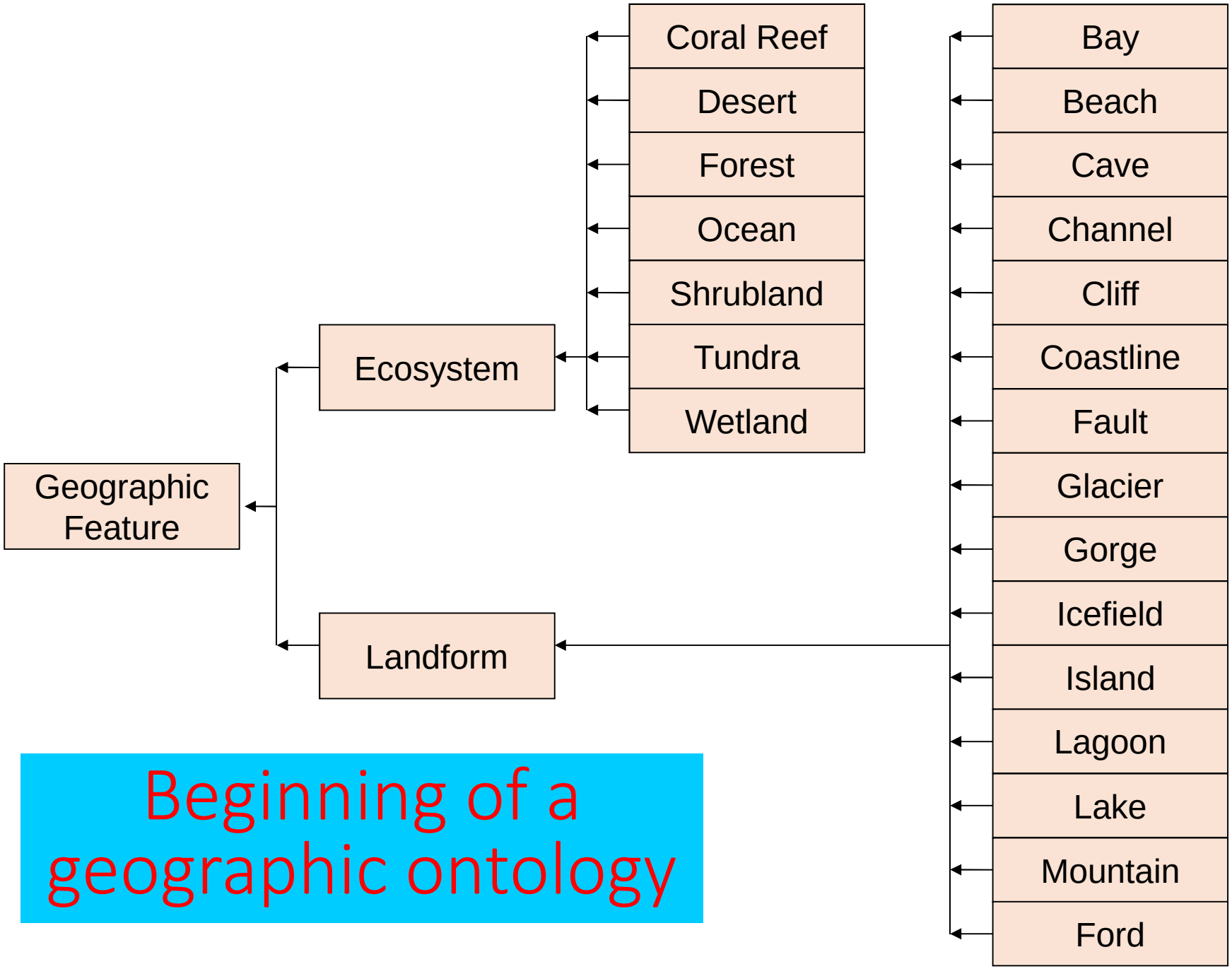
Cadastral



Stubkaer, E., 1999. Cadastral research – issues and approaches. Kart og Plan 59 (3), 267{278.

Examples of geographic relations





Beginning of a geographic ontology

Conclusions about ontologies

- Allow the description of a domain of activities
- Allow reasoning over a domain in general
- Sometimes possible to integrate some cases

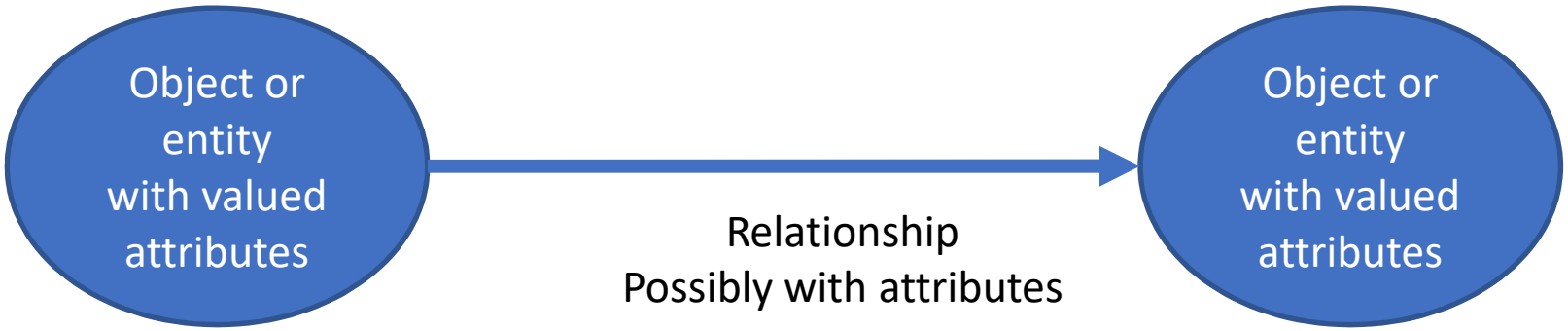
- Tools
  - Protégé

2.2 – Knowledge networks

- Instead of a domain, description of a situation, a practical case

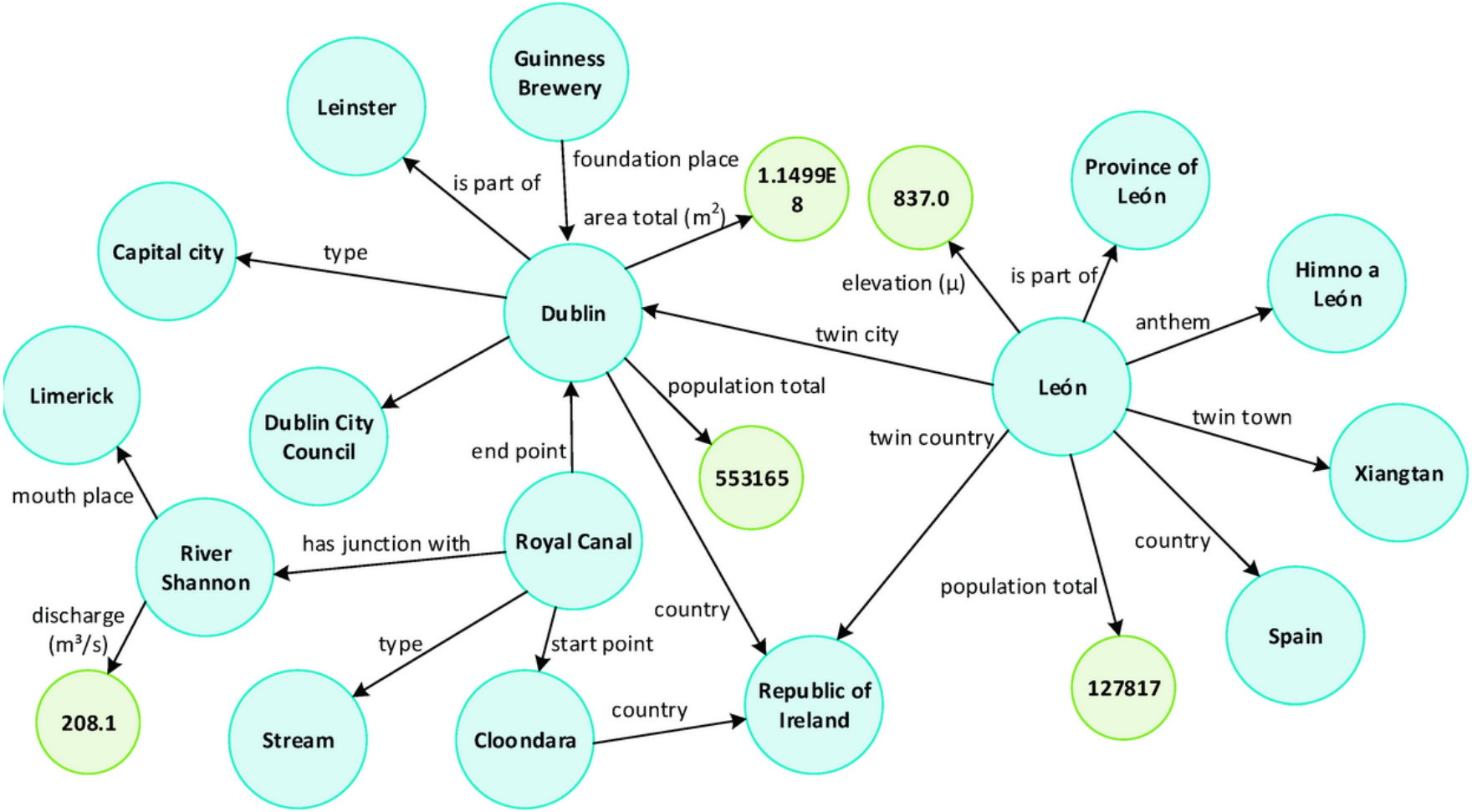
- Sometimes called knowledge graphs
- Issued from Sowa's Frames
- Two concepts
  - Object or entities with valued attributes
  - Relationships between entities

Elements of knowledge networks



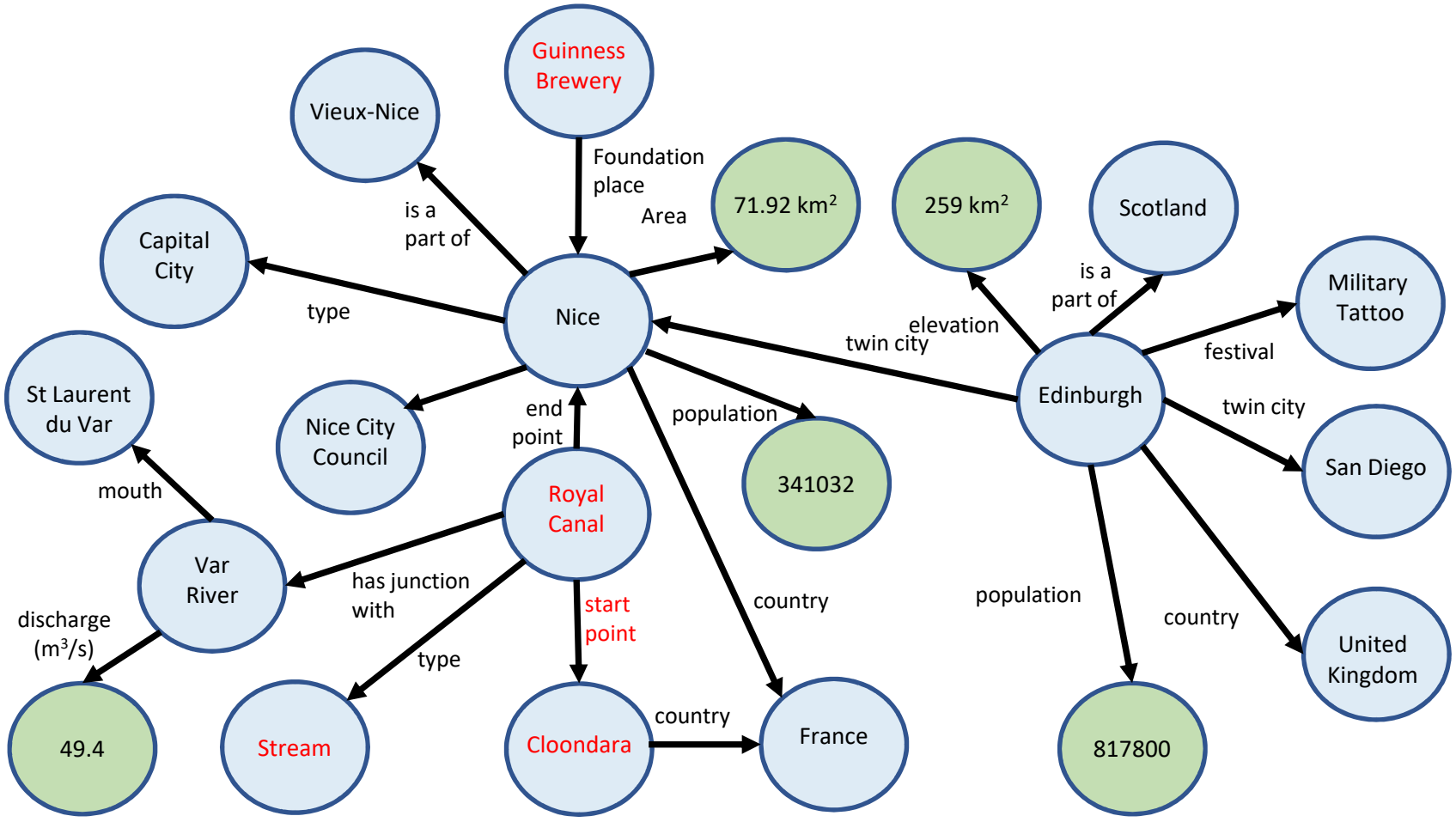
Detective Investigation Board

Knowledge network for Dublin

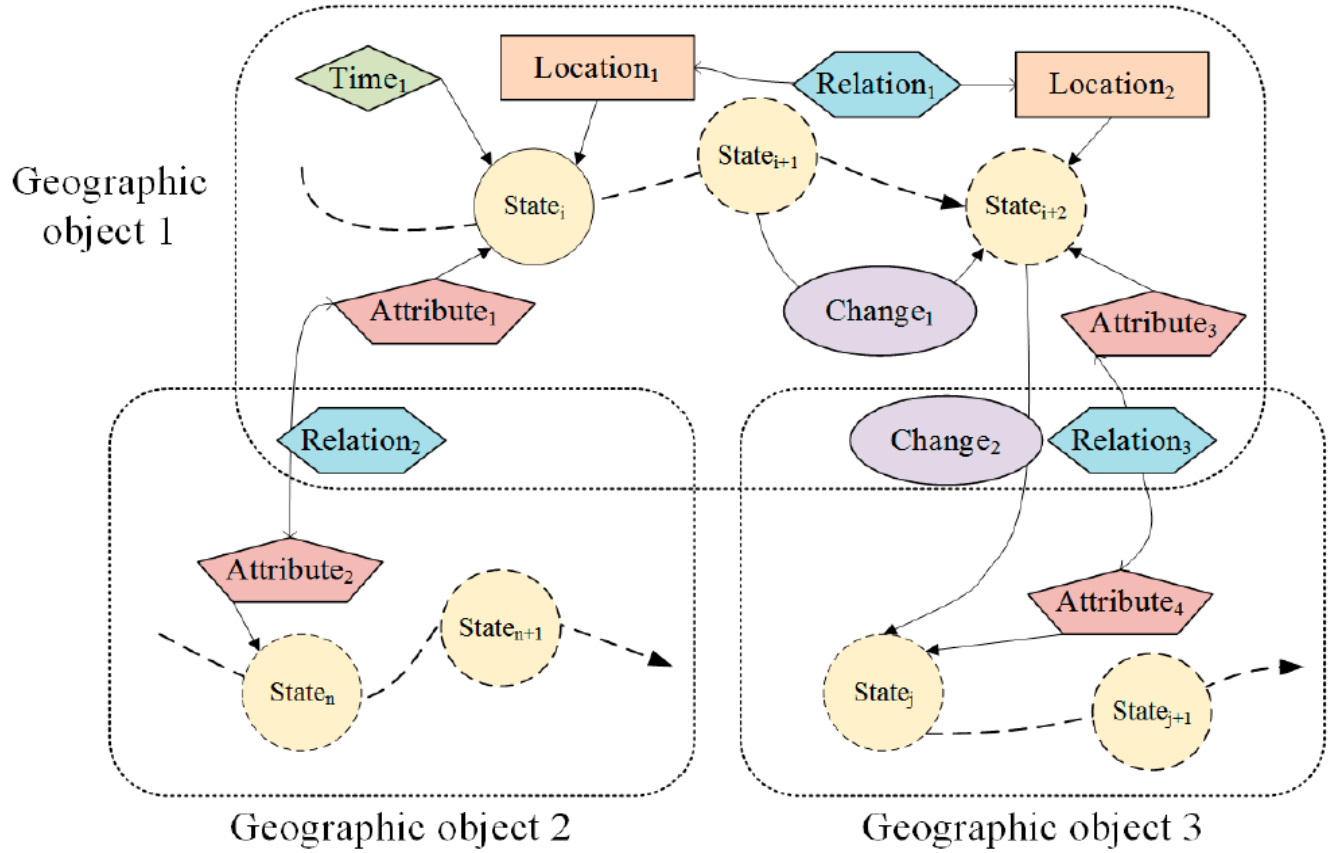


Qiu, P.; Gao, J.; Yu, L.; Lu, F. Knowledge Embedding with Geospatial Distance Restriction for Geographic Knowledge Graph Completion. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 254. https://doi.org/10.3390/ijgi8060254

Knowledge network for Nice

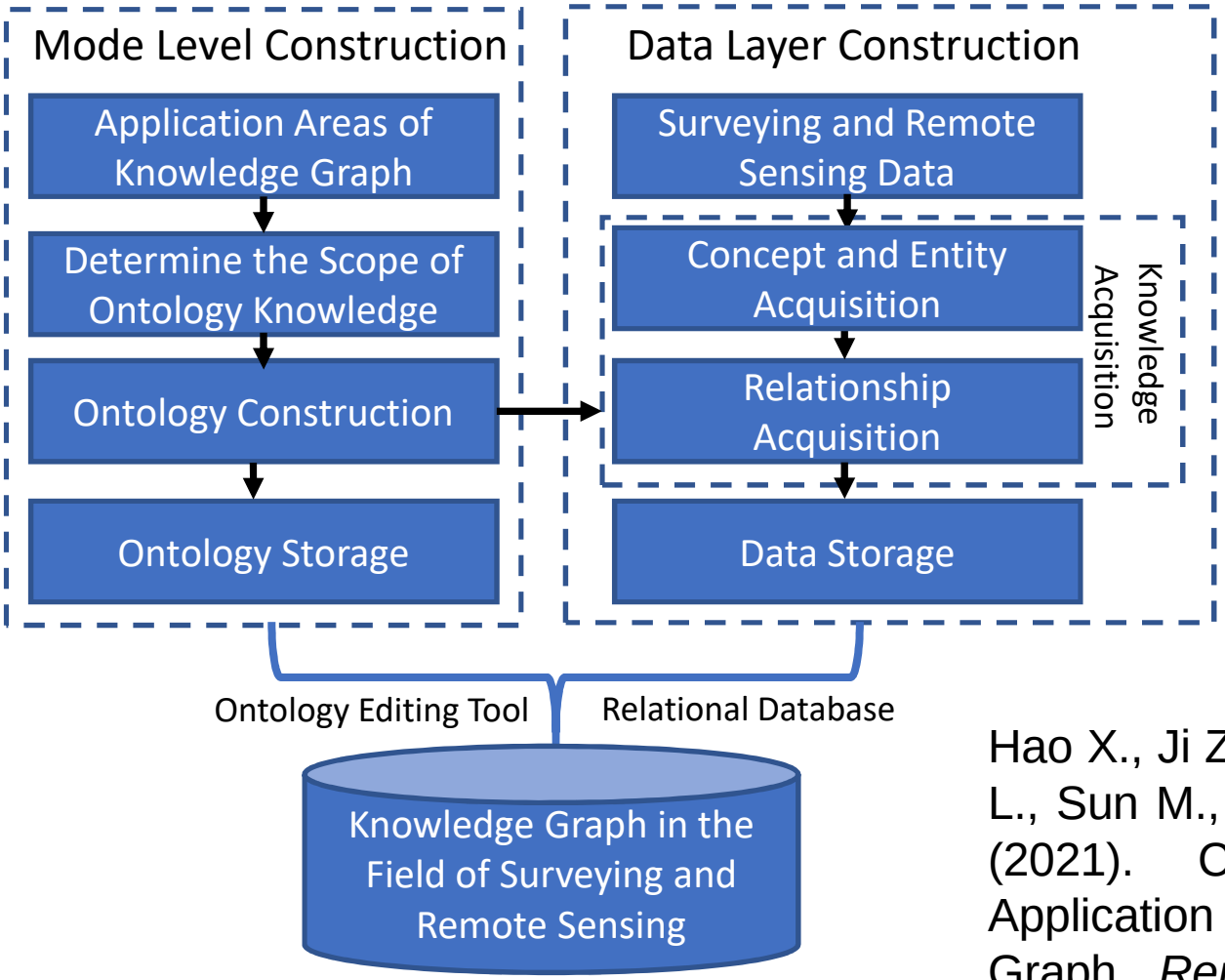


GeoKG model



Wang, S, Zhang, X., Ye, P., Dun M., Lu Y. & Xue H. (2019). Geographic Knowledge Graph (GeoKG): A Formalized Geographic Knowledge Representation. *ISPRS Int. J. Geo-Inf.* 2019, 8, 184

Design of a knowledge graph



Hao X., Ji Z., Li X., Yin L., Liu L., Sun M., Liu Q. & Yang R. (2021). Construction and Application of a Knowledge Graph. *Remote Sensing*. In Press.

Marketed software products

- HubSpot Knowledge Base Software
- Guru
- Helpjuice
- ProProfs Knowledge Base
- Bitrix 24
- Sabio
- Quip
- ServiceNow
- Bloomfire
- Tettra
- IntelligenceBank
- OpenKM

Not yet dedicated software products for geographic applications

2.3 – Rule-based systems

- Rules must be considered as first-class citizens in IT (Graham, Morgan, Ross, etc.)
- Generally, in business intelligence:
  - IF-THEN-Fact
  - IF-THEN-Action
- Encoded by means of logic

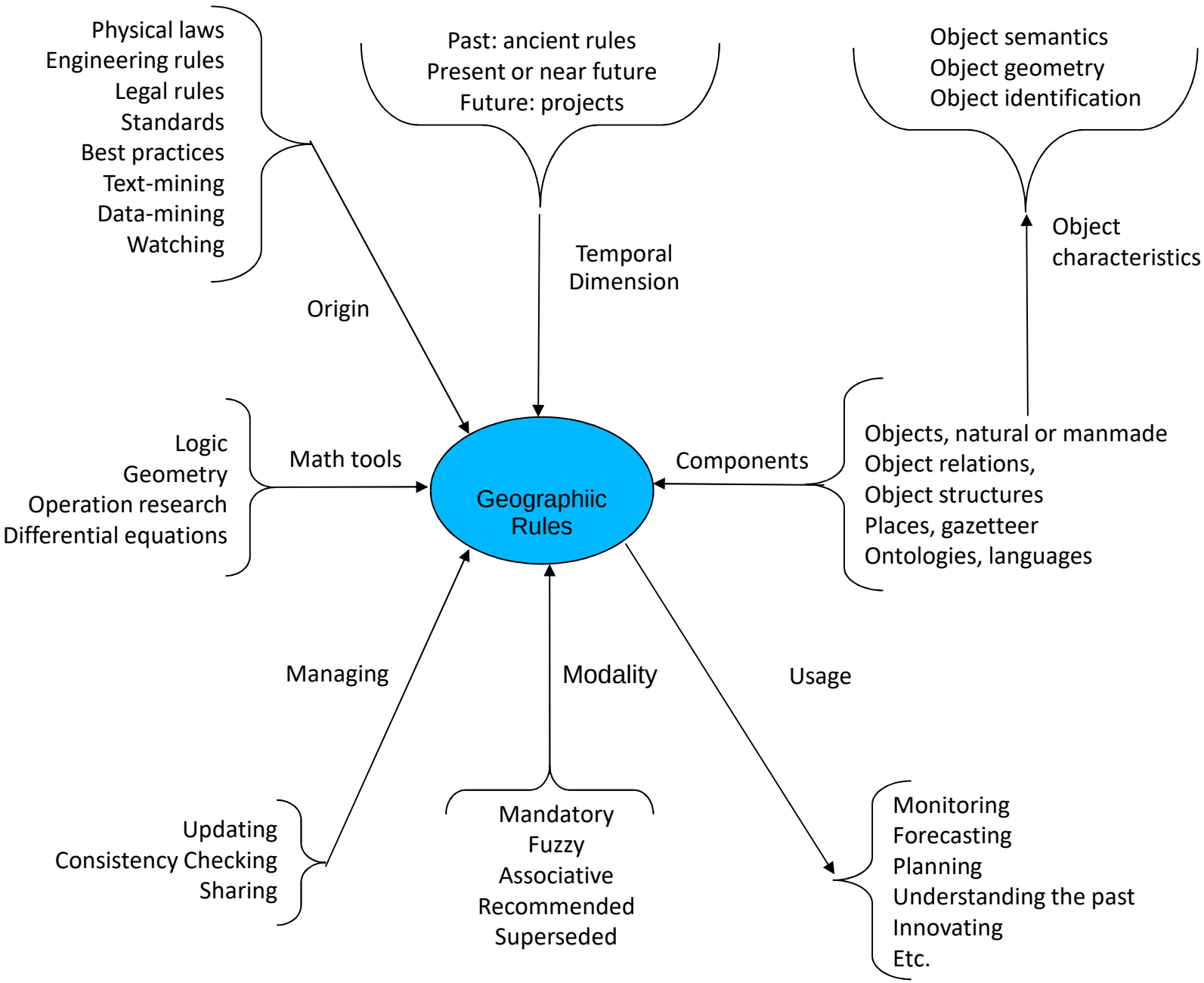
- But for geospatial rules: geometry, topology, etc.

Examples of geographic rules (1/2)

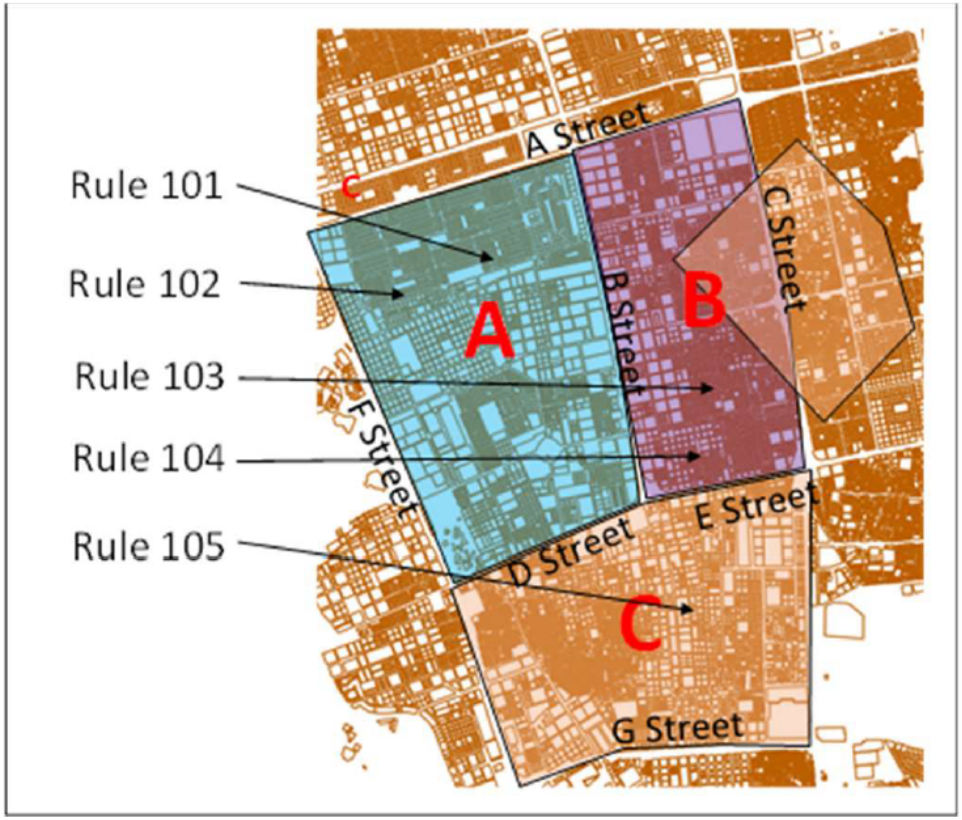
- If a lane is narrow, make it one-way, except if it is a cul-de-sac (dead end);
- When planning a metro, move underground networks;
- No parking, no business;
- Each building must be connected to utility networks (water, electricity, gas, sewerage, telephone, internet, etc.);
- Council flats must be connected to urban heating systems;
- If a cross-road is dangerous, install traffic lights;
- In city centers, transform streets into pedestrian precincts;
- When a commercial mall is planned in the neighborhood of a city, shops located in the city center will be in jeopardy;
- If the number of car parking lots is insufficient, encourage using buses or bikes;
-

Examples of geographic rules (2/2)

- When a big plant is closing, unemployment will increase;
- At the vicinity of an historic building, no modifications of building are allowed
- Every lamppost can be considered as holder of sensors (temperature, pollution, noise, etc.);
- When defining a new industrial area, unemployment will diminish;
- When a road is wide and buses are running, provide a bus lane;
- If a recreational park is inside a city, provide bike lanes coming to this park;
- In France, it is forbidden to open a new tobacconist shop within 500 meters from an existing one;
- If there is one or several rivers crossing a city, design systems to mitigate floods;
- In a city with many hills, consider cable-cars linking them.

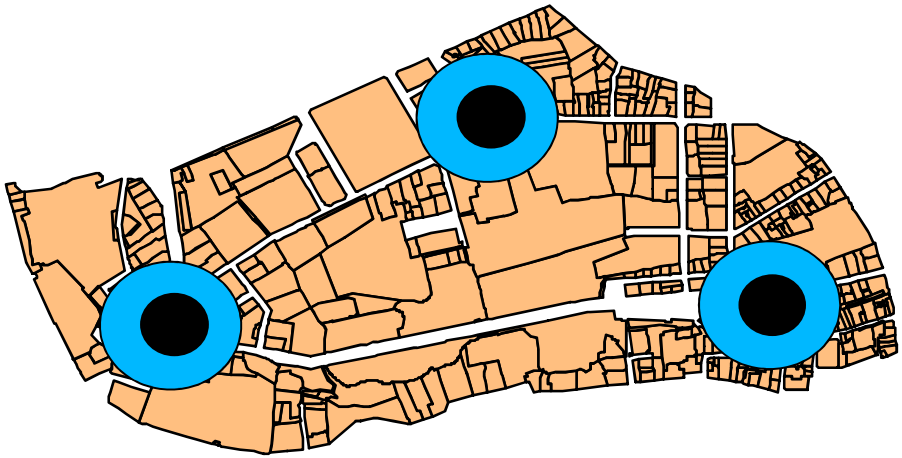

Physical laws
Engineering rules
Legal rules
Standards
Best practices
Text-mining
Data-mining
Watching
Origin
Past: ancient rules
Present or near future
Future: projects
Temporal
Dimension
Object semantics
Object geometry
Object identification
Object
characteristics
Logic
Geometry
Operation research
Differential equations
Math tools
Geographiic
Rules
Components
Objects, natural or manmade
Object relations,
Object structures
Places, gazetteer
Ontologies, languages
Managing
Modality
Usage
Updating
Consistency Checking
Sharing
Mandatory
Fuzzy
Associative
Recommended
Superseded
Monitoring
Forecasting
Planning
Understanding the past
Innovating
Etc.

Located Rules



$\exists\, C \in City, \forall B \in Project, \exists\, ZoneA \in Terr,$ $Geom\,(ZoneA) \equiv SurroundedByStreet\,(A\_Street,$ $B\_Street, D\_Street, F\_Street)$: $Contains\,(Geom\,(ZoneA), Geom\,(B))$ $\Rightarrow$ $\{AppliedRule\,(101); AppliedRule\,(102)\}$ ■	Rule 17

Listed historic monuments



Listed Monument Conservation area

$\forall$ *T* $\in$ Earth, $\forall$ *B* $\in$ PROJECT, $\exists$ *M* $\in$ Geo-Objects,
Ω-Type (*B*) = "Building",
Ω-Type (*M*) = "Listed_Monument",
Inside (Geom (*B*), *T*), Inside (Geom (*M*), *T*):
Disjoint (Geom(*B*), Union (Buffer (Geom (*M*), 100)))
$\Rightarrow$
State (B) = "LM_Approuved"

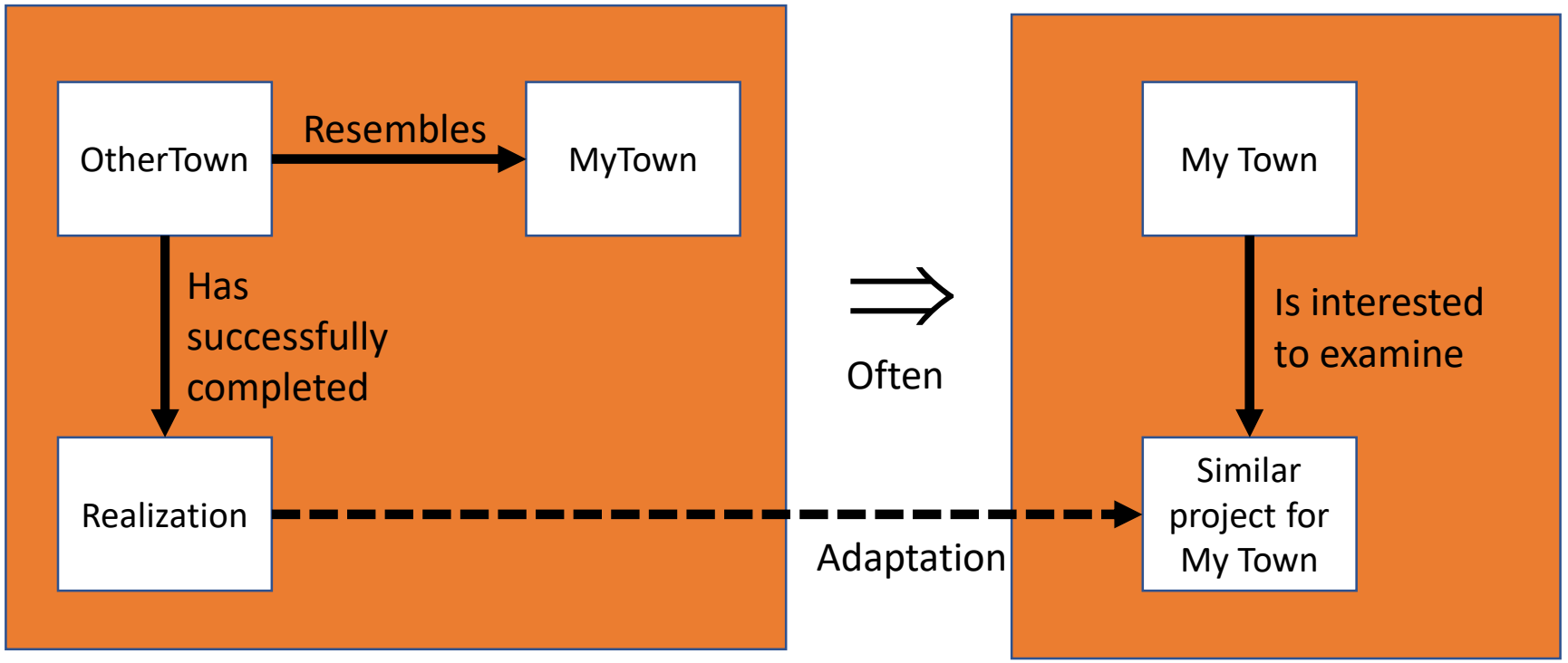
3 – Case-based reasoning (CBR)

- Idea: infer from stored cases
- Solving new problems by retrieving stored ‘cases’ describing similar prior problem-solving episodes and by adapting their solutions or outcomes to fit new needs
- Stored cases (simplified):
- $K\,(k_{\#}, k_1, k_2, k_3, \ldots\ldots, k_i, k_{i+1}, k_{i+2}, \ldots k_{i+n})$

Description of the case

Outcomes

Case-based reasoning



Case-based reasoning (CBR)

- General reasoning mechanism

$$(Description\ (A) \Rightarrow Outcome\ (A)) \wedge Resemble\ (Description\ (B), Description\ (A))$$

$$\Rightarrow$$

$$Resemble\ (Outcome\ (B), Outcome\ (A))$$

- Transcription in geography:

"If a region R_1 resembles to region R_2 and R_1 has successfully completed something, then R_2 may create a project to adapt this realization".

Details of Case Structure

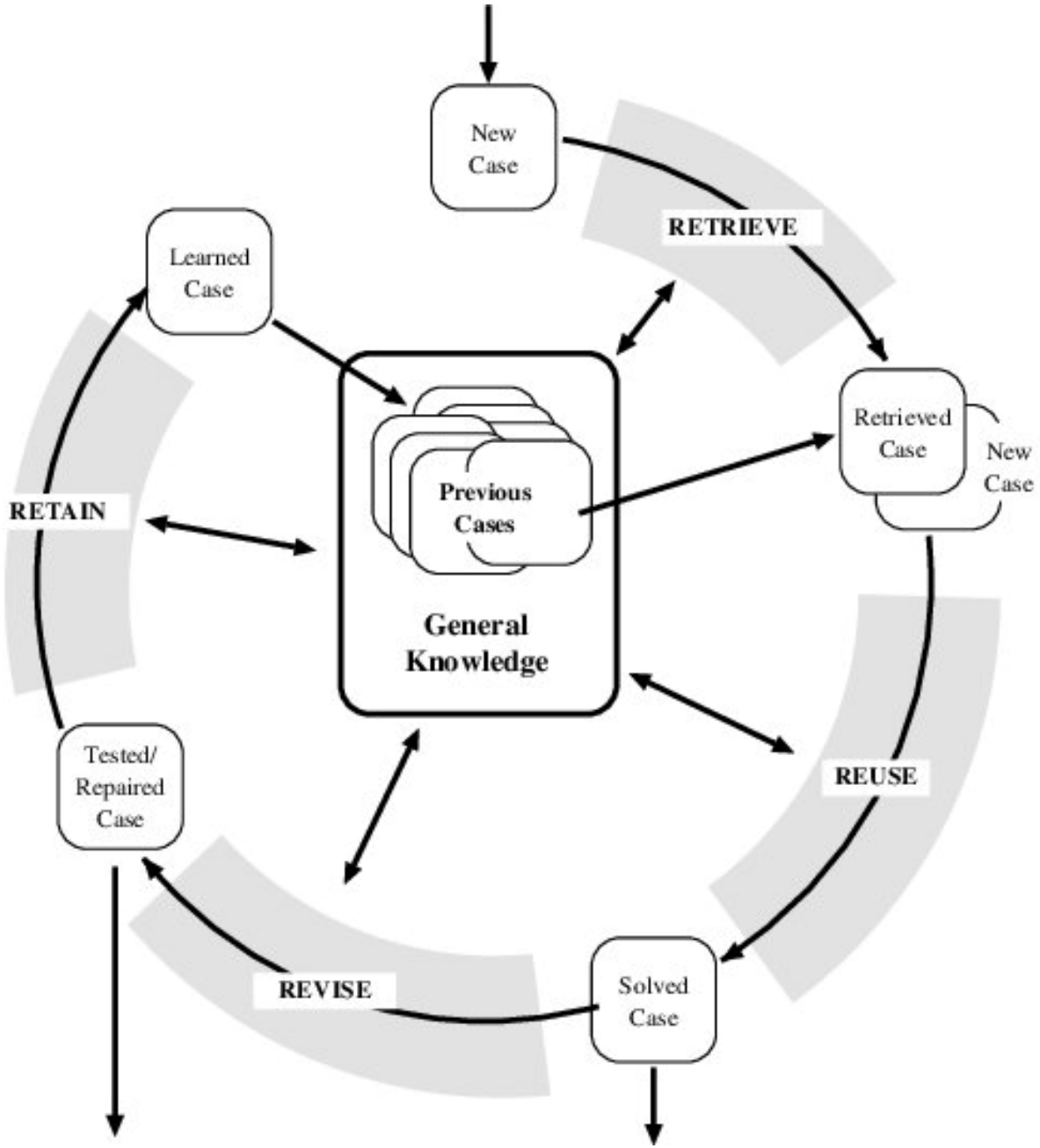
- identifier of the case
- description of the case
- diagnostic of the case
- solution of the case
- derivation of the case, i.e. from where the case has been derived/adapted
- solution result, information indicating whether the proposed case solution has been a
- successful one or not
- utility measure of the case in solving past cases when it was used
- other relevant information about the case

Similarity between cases

- Among cases, find the stored cases the most resembling to our new case
- Define an *n*-dimensional distance between cases

- Sometimes *k*-nearest neighbors to get several resembling cases
- If many cases, how to index them?

CBR Cycle according to Aamodt and Plaza



Problems with CBR

- Can be seen as an example of automatic technology watching
- Storing geography cases
- Definition of similarity
- Organizational issues for a city or a region:
  - How to detect potential cases of interest?
  - Who will be in charge of such activity?
  - How to convince decision-makers?

Applications

- Terrain analysis (drainage networks)
- Logistics
- Soil mapping
- Architecture
- Urban planning
- Etc..

4 – Deep Learning

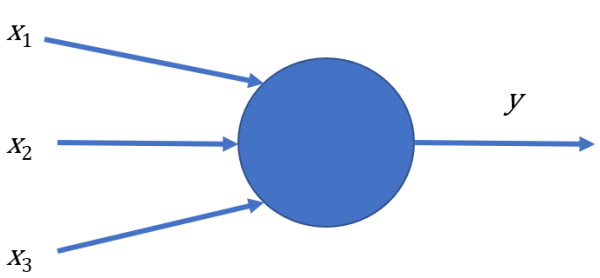
- A subset of machine learning
- Based on neuron networks
- Multiple layers

- Importance of a training set

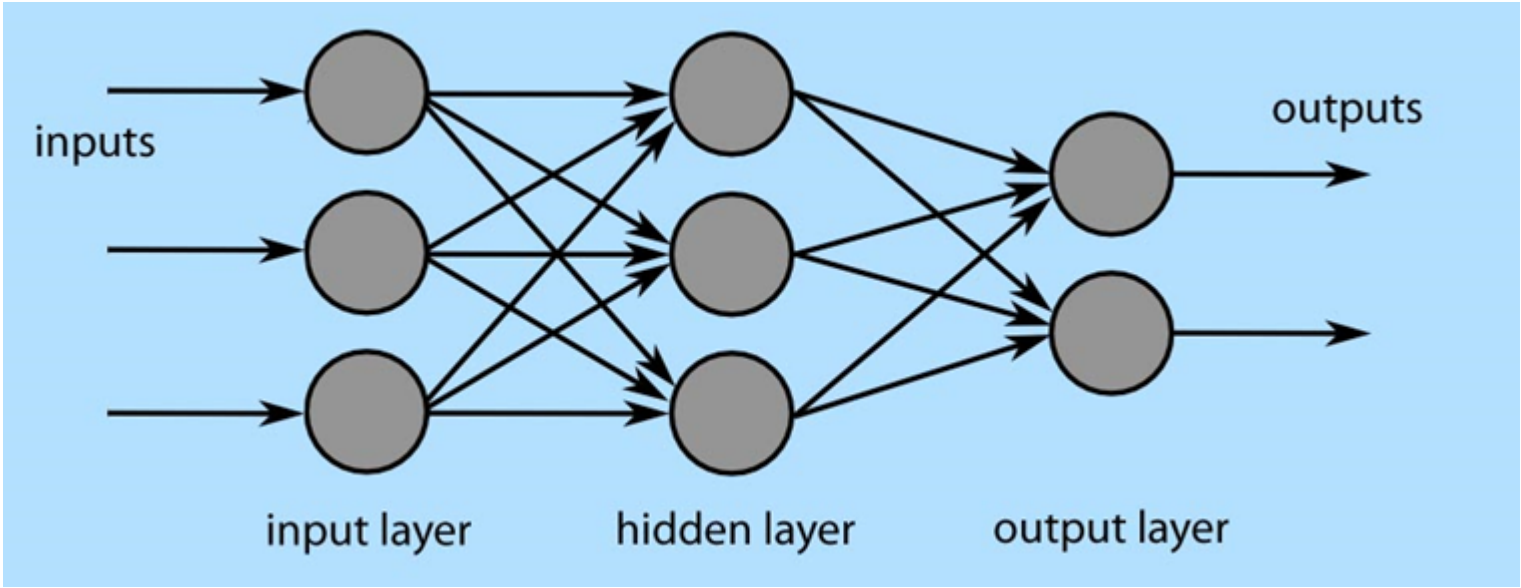
Machine Learning Algorithms

- **Supervised learning**: It involves supervising the entire computation procedure, providing the machine set results and inputs and “teaching” it to produce accurate results.
- **Unsupervised learning**: It involves letting the computer find patterns by itself and produce results without explicit supervision.
- **Reinforcement learning**: It involves a reward-based system where you teach a machine to perform certain behaviors in order to maximize its rewards.

Deep Learning principle



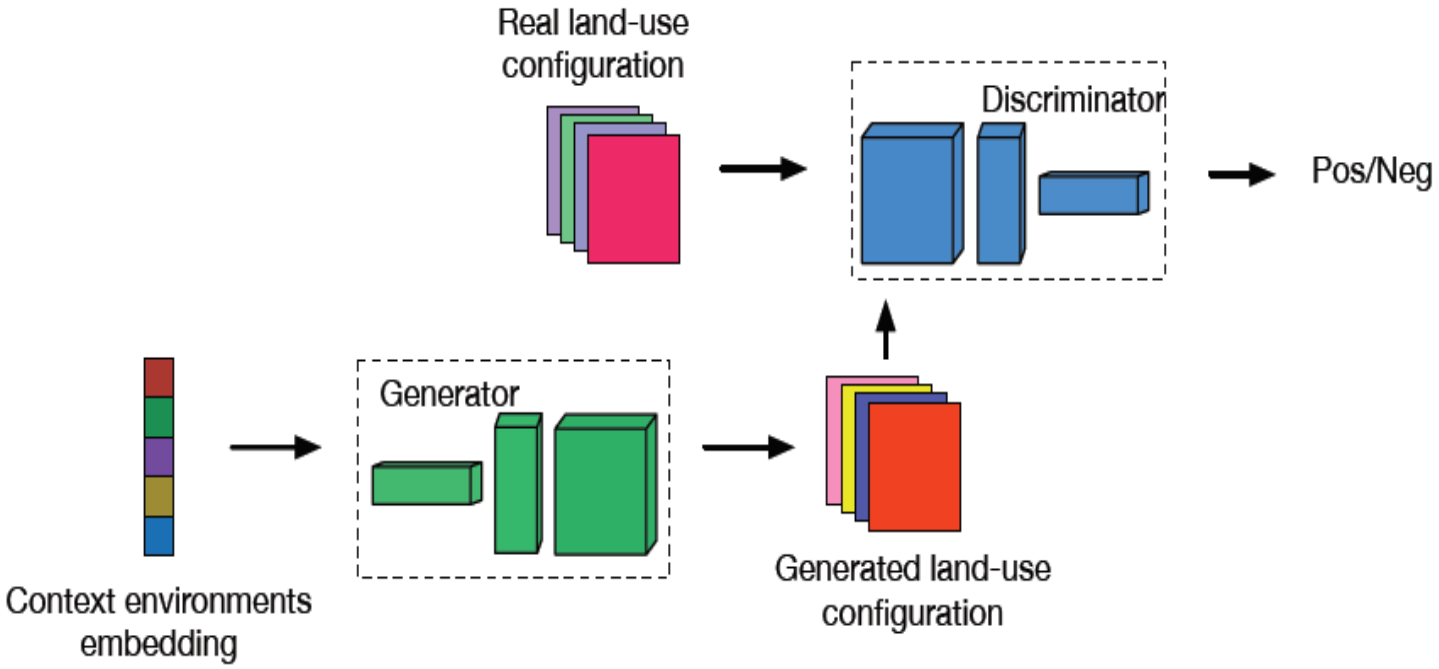
$$y = \begin{cases} 1 \; if \sum_{i=1}^{i=n} w_i x_i \geq 0 \\ 0 \; if \sum_{i=1}^{i=n} w_i x_i < 0 \end{cases}$$



Applications of Deep Learning

- Classification
- Clustering
- Predictions

Automatic land-use configuration planner



Wang D., Fu Y., Wang P., Huang B., & Lu C.T. (2020). Reimagining City Configuration: Automated Urban Planning via Adversarial Learning. In 28th *International Conference on Advances in Geographic Information Systems* (SIGSPATIAL '20), November 3–6, 2020, Seattle, WA, USA. ACM, New York, NY, USA, 10 pages.

5 – Final Remarks

- Many experiences are done especially in business management
  - Few practical experience for geographic applications except for satellite image processing
- Existence of technological barriers
- Difficulties of representing space
  - Remember geo database history
- Dedicated tools must be designed
- **Promises especially for smart cities and regions**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Tanks for your Attention!
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