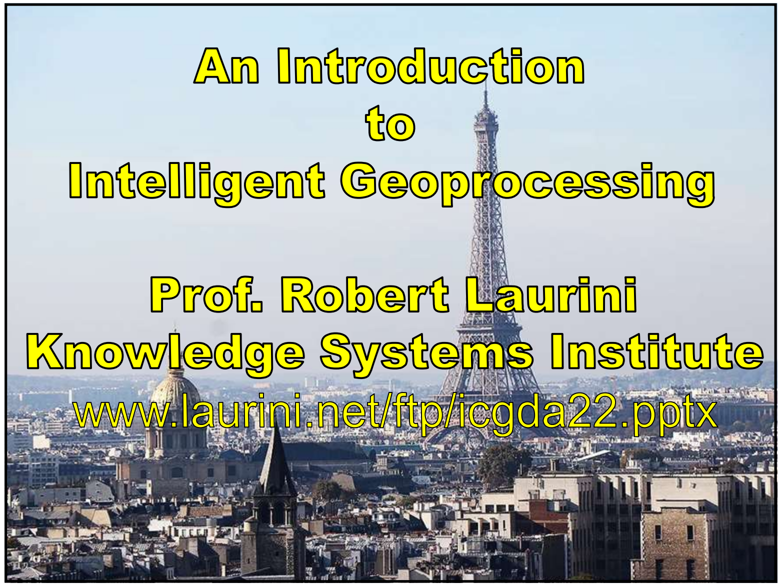

1

An Introduction to Intelligent Geoprocessing

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

2

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

3

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

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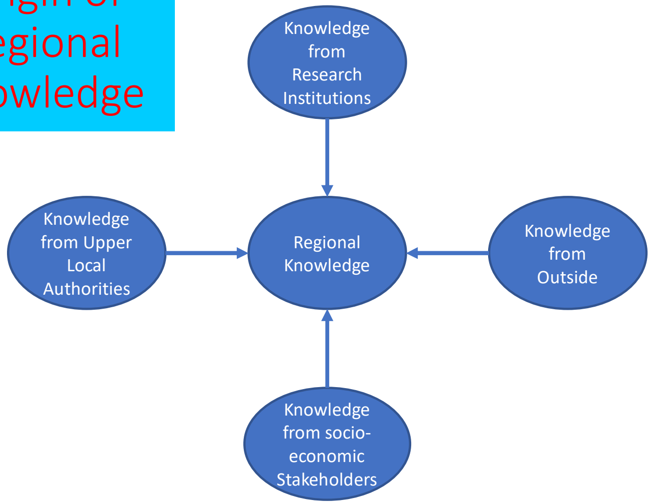
Origin of Regional Knowledge



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2 – Knowledge Management

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

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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

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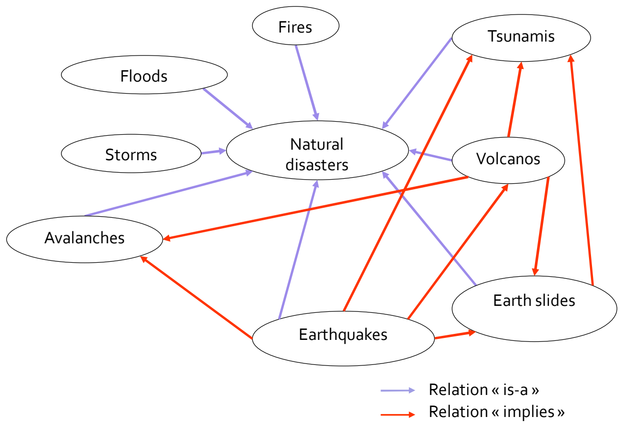
Example of ontology



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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)

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Concepts

- Distinguish between terms and concepts
- At mathematical level :

Ontology = graph between concepts

= semantic network

Sometimes with additional constraints

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Ontology for landcover

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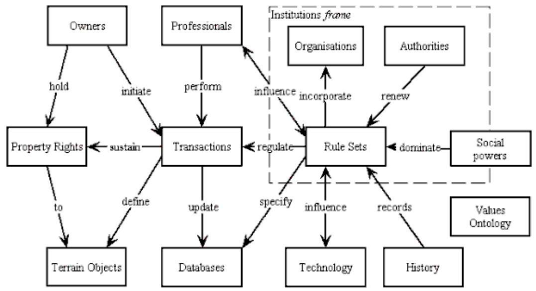
Cadastral



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

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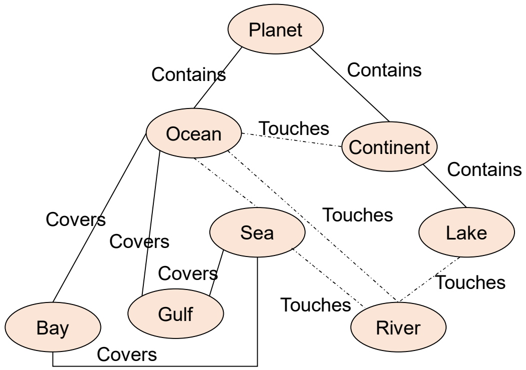
Examples of geographic relations



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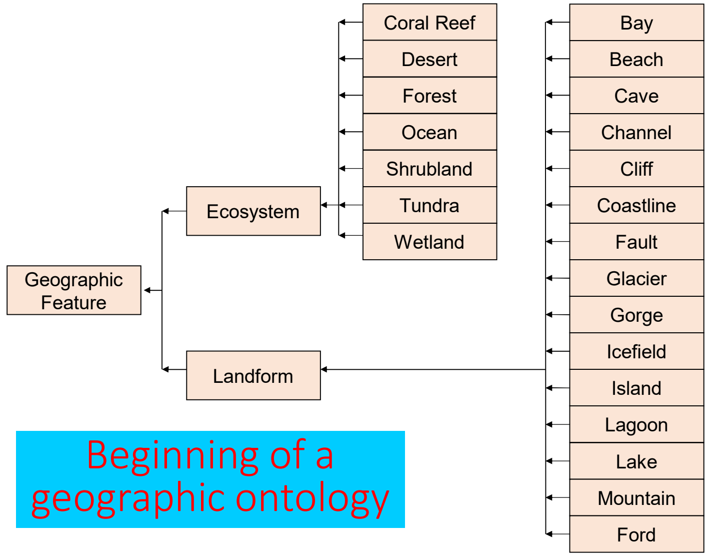

Beginning of a geographic ontology

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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

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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

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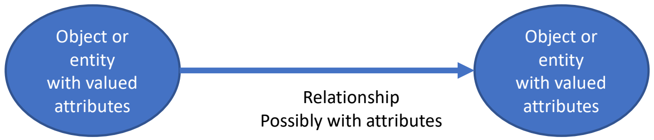
Elements of knowledge networks



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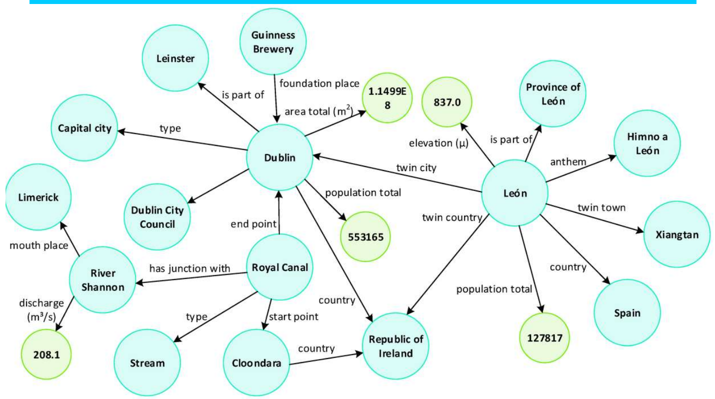
Knowledge network for Dublin



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

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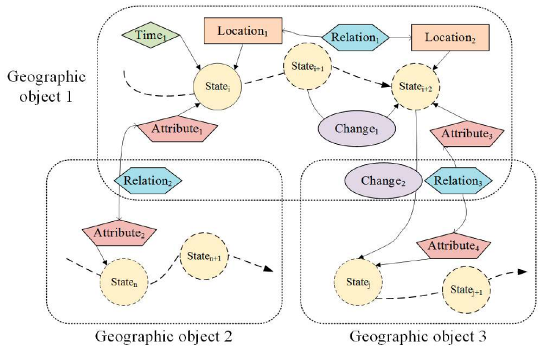
GeoKG model



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

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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.

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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;
-

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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.

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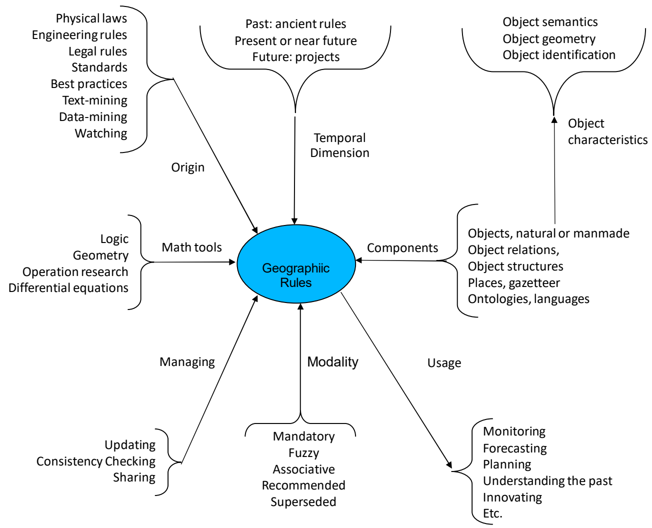

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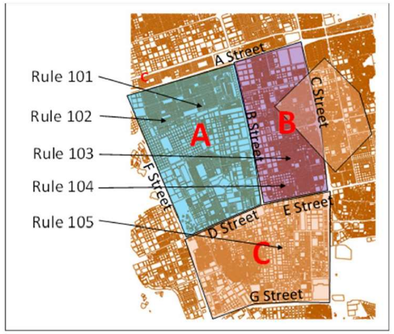
Located Rules



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

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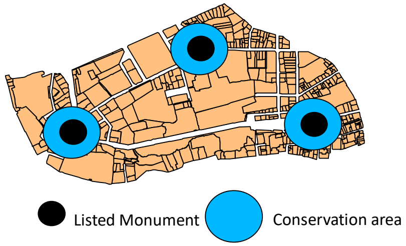
Listed historic monuments



∀ T ∈ Earth, ∀ B ∈ PROJECT, ∃ M ∈ 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)))
⇒
State (B) = "LM_Approuved"

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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):
- $K\,(\underbrace{k_{\#}, k_1, k_2, k_3, \ldots, k_i}_{\text{Description of the case}},\ \underbrace{k_{i+1}, k_{i+2}, \ldots k_{i+n}}_{\text{Outcomes}})$

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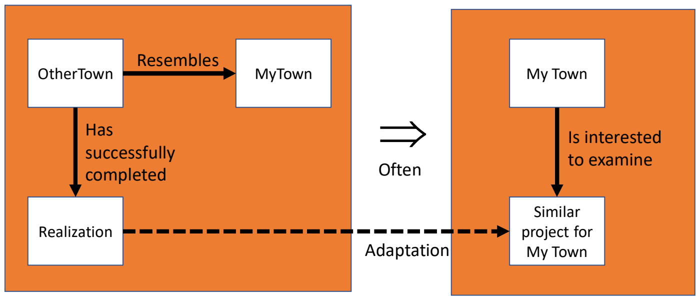
Case-based reasoning



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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".

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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

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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?

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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?

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Applications

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

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4 – Deep Learning

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

- Importance of a training set

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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.

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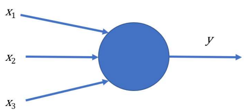
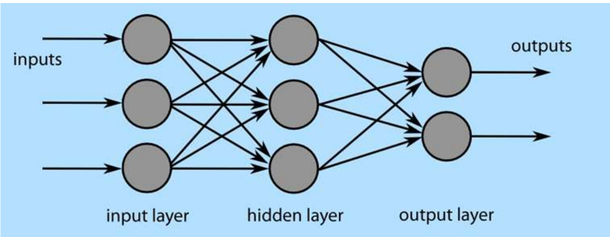
Deep Learning principle



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



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Applications of Deep Learning

- Classification
- Clustering
- Predictions
- Domains: sat image processing, etc.

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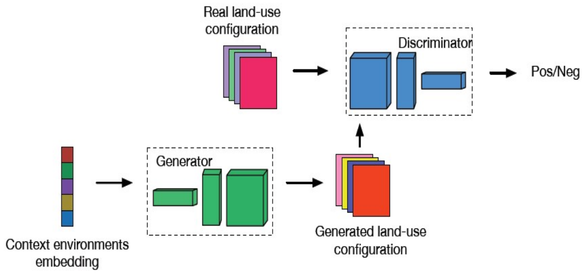
Automatic land-use configuration planner



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.

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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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Recent publications

- See www.laurini.net/Robert/
- Laurini R. (2020) "A primer of knowledge management for smart city governance". Land Use Policy, 2020, 104832, ISSN 0264-8377.
- Laurini R. (2019) "A Mathematical Language for the Modeling of Geospatial Static Rules". Journal of Visual Language and Computing, Volume 2019 (1). pp. 1-13.
- Laurini R. (2017) "Geographic Knowledge Infrastructure: Applications for Territorial Intelligence and Smart Cities". Elsevier and ISTE, 312 pages.
- Laurini R. (2022) "Promises of Artificial Intelligence for Urban and Regional Planning and Policymaking" To be published by Springer

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