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Contents

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1 – Importance of knowledge

- Knowledge society
- Business intelligence/ Territorial intelligence/smart cities
- Importance of rules
- Examples of rules
- Knowledge encoding
- Big data

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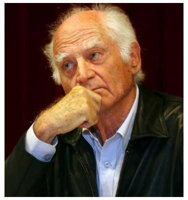
Michel Serres

"Knowledge is now the infrastructure"



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About knowledge and the knowledge society

- What is knowledge?
- How can knowledge be an infrastructure for smart cities and territories?

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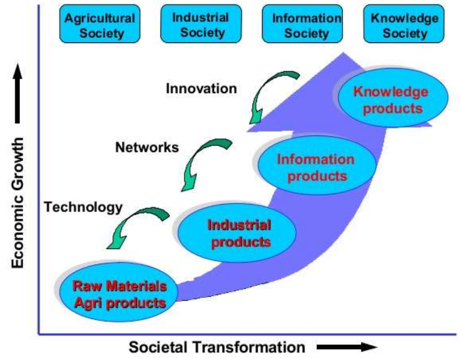
Societal Transformation



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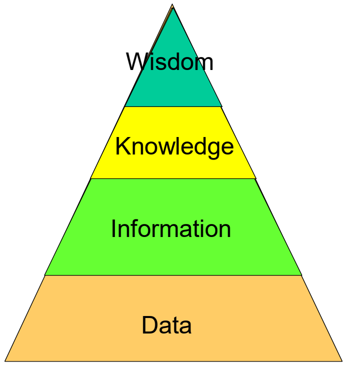
Data, information, knowledge



Applica-tion	I do stop
Context	If the traffic light is red, I do stop
Meaning	Traffic light of George Washington Avenue is red
Raw data	« Red », 234, 10.34, « George Washington »

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Cake metaphor (Gurteen)

Data: molecular components

Information: ingredients

Knowledge: recipe (know-how)

Wisdom: choose to whom to make the cake (know-why)

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Definition of Geographic Knowledge

- Geographic knowledge corresponds to information potentially useful to
  - explain,
  - manage,
  - monitor,
  - plan a territory,
  - and to innovate possibly from another territory

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Knowledge Representation

- Several representation models
  - Based on logic
  - Based on graph/network
  - Based on a computer language
    - Example KRL (Bobrow and Winograd) Airport
    - (Knowledge Representation Language)
    - OWL Web Ontology Language
- Difficulty or impossibility to integrate geographic semantics and geometric issues (topology, computational geometry, etc.)

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OWL

- "Pizza has PizzaBase as its base; Pizza is disjoint with PizzaBase; NonVegetarianPizza is exactly Pizza that is not VegetarianPizza; isIngredientOf is a transitive property; isIngredientOf is inverse of hasIngredient".

```
Namespace(p = <http://example.com/pizzas.owl#>)
      Ontology( <http://example.com/pizzas.owl#>
        Class(p:Pizza partial
          restriction(p:hasBase someValuesFrom(p:PizzaBase)))
        DisjointClasses(p:Pizza p:PizzaBase)
        Class(p:NonVegetarianPizza complete
          intersectionOf(p:Pizza
complementOf(p:VegetarianPizza)))
        ObjectProperty(p:isIngredientOf Transitive
          inverseOf(p:hasIngredient))
      )
```

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KRL

```
[Airport UNIT Basic <SELF> <location (a City)>]
[City UNIT Basic <SELF> <localAirports (SetOf (an Airport
with location = ThisOne)) ; DEFAULTp]
[PaloAlto UNIT Individual <SELF (a City with localAirports
= (Items SJO SFO OAK))>] ...these airports are units too
[SJO UNIT Individual <SELF (an Airport with location =
SanJose )>]
[UniversalCharge UNIT Individual <SELF (a CreditCompany)>]
[Magnitude UNIT Relation <SELF (an ArithmeticRelation)
(TRIGGERS (ToTest ...some LISP code appears here...))>
<greater (a Quantity)> <lesser (a Quantity)>]
[IsGreaterThan PREDICATE Magnitude greater lesser] ...
defines the Predicate IsGreaterThan with focus being the
slot greater in Magnitude. The argument which follows the
predicate is to fill the lesser slot. This predicate is
used in predications having a form like (which IsGreater
Than 2) as an equivalent for (the greater from Magnitude
(a Magnitude with lesser .7- 2))
[IsLessThan PREDICATE Magnitude lesser greater] ... a
second predication based on Magnitude, with its focus on
lesser
```

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2 – Specificities of urban knowledge

- Components of Geographic Knowledge Base
  - Geographic objects
  - Ontologies
  - Gazetteer
  - Relations
  - Rules
- Origin of geospatial rules
- Structure of GKS

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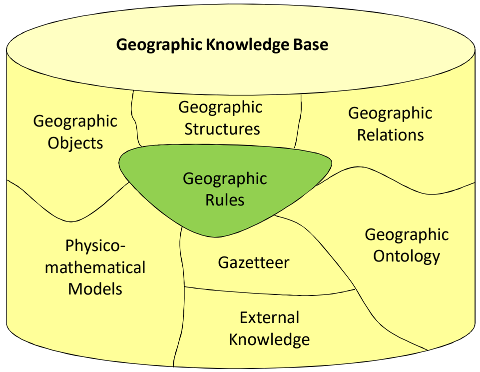
GKB Components



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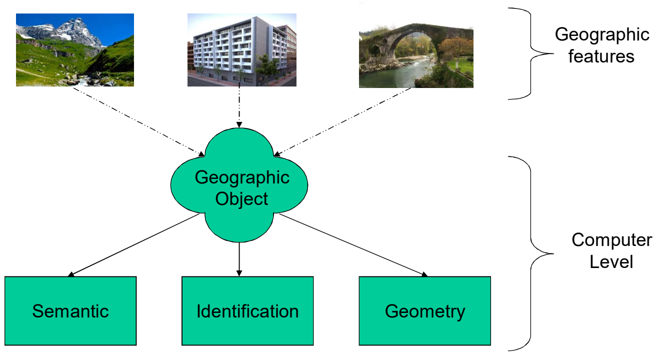
Geographic objects



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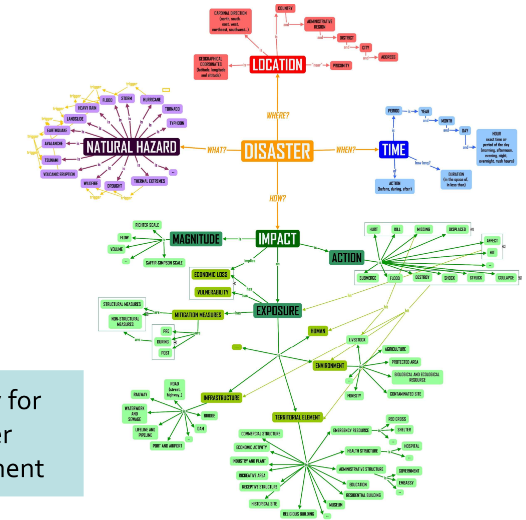

Ontology for disaster management

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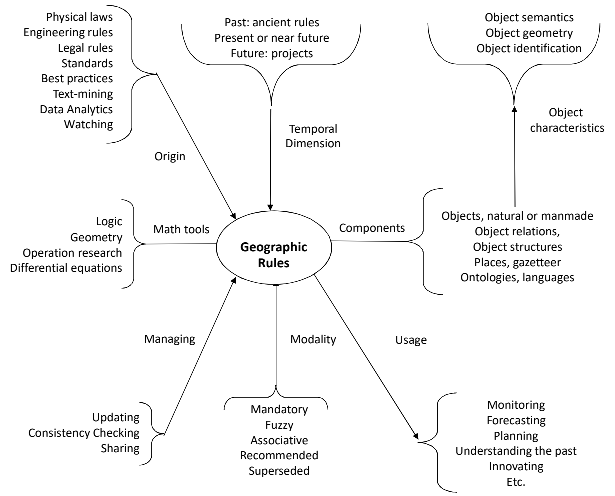

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First typology of geospatial rules

- **IF-THEN-Fact, IF-THEN-Action**
- **Co-location rules:** "*if something here, then another thing nearby*"
- **IF-THEN-Zone**: for the creation of a zone
- **Metarule:** "*IF some conditions hold, THEN apply RuleA*"
- **Located rule:** "*IF in a place B , THEN apply RuleB*";
- **Bi-location rule:** "*IF something holds in place P, then something else in place Q*"

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Mathematical language

- Analysis of geographic semantics
- Language based on set theory
- Integrating topology and computational geometry
- Preliminary step for a dedicated computer language
- First version
- Present limitations
  - Only 2D
  - not yet included
    - Graph theory
    - Continuous fields

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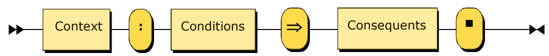
Simplified Grammar

- Main concepts
  - *Geographic Objects* (GO)
  - *Earth* and *Terr* (any territory belonging to *Earth*)
  - *Projects*
- Formal grammar



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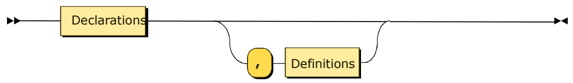
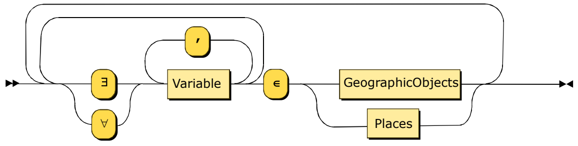
Context and declarations

Context:



Declaration:



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3 – A few simple examples

- Creation of a relationship

$\forall p_1, p_2 \in Earth,\ GeomType\ (p_1) \equiv Point,\ GeomType\ (p_2) \equiv Point$: $Latitude\ (p_1) > Latitude\ (p_2)$ $\Rightarrow$ $\models North\ (p_1, p_2)$ ■	Rule 1
$\forall p_1, p_2 \in Earth,$ $GeomType\ (p_1) \equiv Point,\ GeomType\ (p_2) \equiv Point$: $(Longitude\ (p_1) > Longitude\ (p_2))$ $\wedge\ (Longitude\ (p_1) - Longitude\ (p_2) < 180°)$ $\Rightarrow$ $\models West\ (p_1, p_2)$ ■	Rule 2

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Other examples

Definition of a floodplain by a buffer along a river

$\exists\ T \in Town,\ \forall\ R \in River,\ Topo\ (T) \equiv$ "Smart Town" : $Overlap\ (R, T) \vee Covers\ (T, R)$ $\Rightarrow$ {CreateGO (F); Type (F) := "Floodplain"; Geom (F) := Intersection (Geom (T), Buffer (R, 100))} ■	Rule 4

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In Planning

$\forall\ P \in Parcel,\ L \in\ Plants,\ B \in Project.Building,$ $\models contains\ (P, L),\ \models contains\ (P, B)$: $L.Erased\ \wedge P.Depolluted$ $\Rightarrow$ $\models B.Authorized$ ■	Rule 5
$\exists C \in County,\ M \in Marsh,\ \forall\ B \in Project,$ $\models Contains\ (C, M)$: $Contains\ (M, B)$ $\Rightarrow$ $Prohibit\ (B)$ ■	Rule 6

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Best practice

To each lamppost, assign a sensor

∃T, ∈ *Town*, ∃ R ∈ *Road*, ∀ L ∈ *Lamppost*, ∀ S ∈*Pollution.Sensor*, *Topo* (T) ≡ "Smart Town", *Topo* (R) ≡ "Churchill Road" : *Contains* (*Geom*(T), *Geom*(R)) ∧ *Contains* (*Geom* (R), *Geom* (L)) ⇒ [BP] *Assign* (S, L) ■	Rule 11

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- When studying road incidents in the city of Helsinki, Finland, Karasova et al. have shown by spatial data mining that many incidents occur near bars and restaurants. More exactly, around each incident they have designed a 50 m buffer and see whether there were incidents in those zones (Support 1.7% and confidence 40.0%).

∃C ∈ *City*, ∀ B ∈ *Bar*, ∀ R ∈*Restaurant*, ∀ I ∈ *Incident*, ∃ *RiskyZone* ∈ *Terr*, *Topo* (C) ≡ "Helsinki", ⊧ *Contains* (*Geom* (C), *Geom* (B)), ⊧ *Contains* (*Geom* (C), *Geom* (R)), ⊧ *Contains* (*Geom* (C), *Geom* (I)), *Geom* (*RiskyZone*) ≡ *Union* (*Buffer* (*Centroid* (*Geom*(B), 50), *Buffer* (*Centroid* (*Geom*(R), 50)) ⇒ [1.7%, 40.0%] ⊧ *Contains* (*Geom* (*RiskyZone*), *Geom* (I)) ■	Rule 12

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- In their study in the city of Antwerp, Belgium, Zhou et al. have a lot of co-location association rules within 600 m buffers.

∃C ∈ *City*, ∀ K ∈ *Kindergarten*, ∃ P ∈*Playground*, *Topo* (C) ≡ "Antwerp" : *Contains* (*Geom* (C), *Geom* (K)), *Contains* (*Geom* (C), *Geom* (P)) ⇒ [α, β] ⊧ *Contains* (*Geom* (*Centroid* (*Geom*(K), 600), *Geom* (*Centroid* (P)) ■	Rule 13

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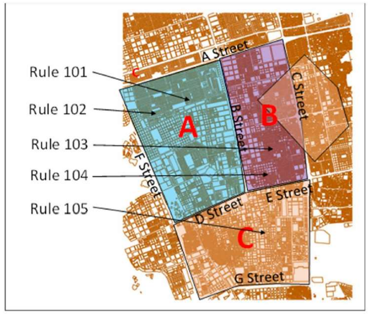
Located Rules



∃ C ∈ *City*, ∀B ∈ *Project*, ∃ *ZoneA* ∈ *Terr*, *Geom* (*ZoneA*) ≡ *SurroundedByStreet* (*A_Street*, *B_Street*, *D_Street*, *F_Street*) : *Contains* (*Geom* (*ZoneA*), *Geom* (B)) ⇒ {*AppliedRule* (101); *AppliedRule* (102) } ■	Rule 17

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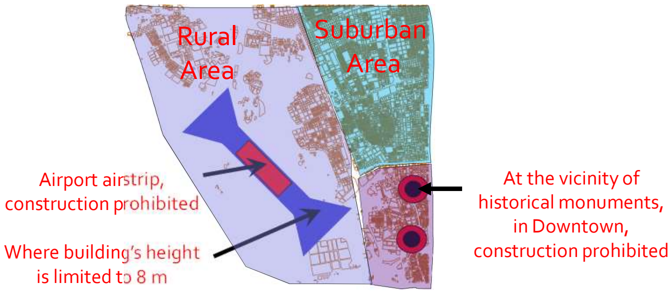
4 – Examples in Urban Planning



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Parameters

TABLE I. PLANNING ZONES AND THEIR PARAMETERS

Zone ID	Max Height (in m)	Max Floorspace ratio	Max Footprint
Downtown	12	3	80 %
Suburban area	15	4	70 %
Rural area	12	0.5	30 %
Near airport (Bowtie)	8	2	50 %
Airstrip	0	0	0

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Creation of Urban Planning Zone

∃ *C* ∈ *City*, ∃ *PZoneA* ∈ *Project.Terr*, *Topo* (*C*) ≡ "Smart Town" *Geom* (*PZoneA*) ≡ *Polyg* (731, 128; 903, 133; 905, 341; 839, 346; 814, 349) : *Approved* (*PZone*) ⇒ *AffectName* (*PZoneA*, "Downtown") ■	Rule 18

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For Suburban Zone

∃ *C* ∈ *City*, ∃ *ZoneB* ∈ *Terr*, ∀ *B* ∈*Project.Building*, ∀ *P* ∈ *Parcel*, *Topo* (*C*) ≡ "Smart Town", *Topo* (*ZoneB*) ≡ "Suburban Area" ⊧ *Contains* (*Geom* (*C*), *Geom* (*ZoneB*)), ⊧ *Contains* (*Geom* (*ZoneB*), *Geom* (*P*)), ⊧ *Contains* (*Geom* (*P*), *Geom* (*B*)) : *B.Height* ≤ *15* ∧ *Area* (*Union* (*Geom* (*Floors*)))/*Area* (*Geom* (*P*)) ≤ 4 ∧ *Area* (*B*)/ *Area*(*Geom* (*P*)) ≤ 0.70 ⇒ ⊧ *B.ZoneB_Approved* ■	Rule 22

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∃ C ∈ City, ∃ ZoneA, ConservA ∈ Terr, ∀ B ∈Project.Building,
∀ P ∈ Parcel, ∀ M ∈ Monuments,
Topo (C) ≡ "Smart Town",
Topo (ZoneA) ≡ "Downtown",
Geom (ConservA) ≡ Union (Buffer (Centroid (Geom(M), 200))),
⊧ Contains (Geom (C), Geom (ZoneB)),
⊧ Contains (Minus (Geom (ZoneA), Geom (ConservA)), Geom (P)),
⊧ Contains (Geom (P), Geom (B))
:
B.Height ≤ 12
∧ Area (Union (Geom (Floors)))/Area (Geom (P)) ≤ 3
∧ Area (B)/ Area(Geom (P)) ≤ 0.80
⇒
⊧ B.ZoneA_Approved ■

Rule 23

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∃ C ∈ City, ∃ ZoneC, Bowtie, Airstrip ∈ Terr,
∀ B ∈Project.Building,
∀ P ∈ Parcel,
Topo (C) ≡ "Smart Town",
Topo (ZoneA) ≡ "Rural Area",
Geom (Bowtie) = Polyg (640, 243; 657, 290; 748, 387; 796, 405; 743, 459; 729, 406; 636, 316; 580, 297),
Geom (Airstrip) = Polyg (670, 311; 724, 365; 707, 386; 650, 330),
⊧ Contains (Geom (C), Geom (ZoneC)),
⊧ Contains (Geom (P), Geom (B))
:
(Contains (Minus (Geom (ZoneC), Geom (Bowtie)), Geom (B)),
∧ B.Height ≤ 12 ∧ Area (Union (Geom (Floors)))/Area (Geom (P)) ≤ 0.5
∧ Area (B)/ Area (Geom (P)) ≤ 0.30)
⊕ Disjoint (Geom (Airstrip), Geom (B))
⊕ (Contains (Geom (Bowtie)), Geom (B))
∧ B.Height ≤ 8 ∧ Area (Union (Geom (B.Floor)))/Area (Geom (P)) ≤ 0.5
∧ Area (B)/ Area (Geom (P)) ≤ 0.30)
⇒
⊧ B.ZoneC_Approved ■

Rule 24

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Final Approbation

∃ C ∈ City, ∀ B ∈Project.Building,
Topo (C) ≡ "Smart Town",
⊧ Contains (Geom (C), Geom (B)
:
(Contains (Geom (ZoneA), Geom (B)) ∧ B.ZoneA_Approved)
⊕ (Contains (Geom (ZoneB), Geom (B)) ∧ B.ZoneB_Approved)
⊕ (Contains (Geom (ZoneC), Geom (B)) ∧ B.ZoneC_Approved)
⇒
⊧ B.FullyApproved ■

Rule 25

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5 - Conclusions

- Several ways of storing geographic knowledge
- Networks, ontologies, formal languages, etc.
- Mathematical language for geographic static rules
- Other types of knowledge categories
- In total 500+ geographic rules encoded

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Perspectives (1/2)

- Integration of 3D, especially for terrain modeling and engineering networks;
- Integration of temporal issues; this will lead to dynamic geospatial rules;
- Integration of rules deriving from continuous fields, especially for dealing with meteorology, pollution, etc. and other aspects in physical geography;
- Integration of additional clauses to extend its expressive power, overall to deal with networks whatsoever, electricity, sewerage, bus lines, etc.;

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Perspectives (2/2)

- Looking for more issues in order to enrich semantics, especially for the automatic adaptation to special contexts; for instance, how to adapt a rule such as "when planning a metro, move underground engineering networks" to various street configurations;
- Transformation of this mathematical language into a computer language;
- Study of metadata relative to geographic rules (origin, etc.);
- Design of an inference engine to reason with those rules;
- Defining the organization of rules together for their access mechanisms taking temporal and spatial superseding mechanisms.

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- LAURINI R. (2019) "A Mathematical Language for the Modeling of Geospatial Static Rules". Journal of Visual Language and Computing, Volume 2019,, pp. 1.13.

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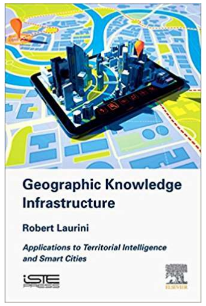
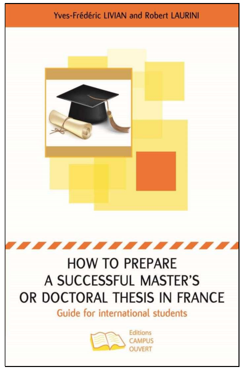
Thanks for your attention!





- Roberto.Laurini@gmail.com
- http://www.laurini.net/robert/

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