Geospatial knowledge for territorial intelligence

1 – Territorial Intelligence
- Business intelligence applied to territories
  - Cities (smart cities)
  - Regions, Countries
- Links with urban, regional and environmental
  - Planning
  - Management
- Objective: Sustainable development

Geospatial Knowledge for Territorial Intelligence
- 1 – Territorial Intelligence
- 2 – Generalities about Geographic Knowledge
- 3 – Generic Geographic knowledge
  - 3.1 – Mutation of topological relations
  - 3.2 – Gazetteers and toponyms/placenames
  - 3.3 – About raster
- 4 – Conclusions

Geographic relations
- In addition to spatial relations
  - Tessellations for administrative objects
  - Networks
  - Ribbon relations
  - Geographic ontologies with Geo Relations
  - Gazetteers

Prof. R. Laurini
INSA/University of Lyon
KSI Fellow
UDMS Vice-President
A new family of concepts

- Such as
  - competitive intelligence,
  - strategic economic intelligence,
  - distributed intelligence,
  - social intelligence, or collective,
- emphasizing organized and systematic collection, analysis and dissemination of information for the purpose of development.

Territorial Intelligence

Territorial Intelligence = (Territory + Collective Human Intelligence + Artificial Intelligence) ➔ Sustainable development

2 – Generalities about GK

- Definitions
  - Feature = geographic entity existing in the real word
  - Geographic object = computer representation of a feature
  - Rule = mathematical inference
- Not only logics, but also space/geometry

AI + Computational Geometry

- Necessity to include
  - Computational geometry
  - Topology
  - Spatial analysis
  - Operation research
  - Linguistics
  - Etc.
- Earth rotundity
Geospatial knowledge for territorial intelligence

**Generic and specific knowledge**

- Specific knowledge
  - Devoted to a particular place in the world
  - F.i. Antarctica, near Equator, etc.
  - Mountains, seashore
- Generic knowledge
  - Valid everywhere
  - Links with acquisition devices
  - Links with maths and linguistics

**Application knowledge**

- Knowledge rules valid in one domain
  - Urban planning
  - Environmental planning
  - Transportation, logistics
  - Etc.

**Geographic Ontologies**

- Organizations of geo features
- Relations « is_a », « has_a », « whole_part »
- Necessity of spatial relations

**Conventional ontology of geographic features**
Geospatial knowledge for territorial intelligence

Egenhofer topological relations

A Disjoint B
A Contains B
B Inside A
A Overlaps B
A Touches B
A Equals B
A Covers B
A CoveredBy B

Example of geographic ontology with spatial relations

Planet
Contains

Ocean
Contains

Continent
Contains

Sea
Covers

Lake
Covers

Bay
Covers

Gulf
Covers

River
Covers

Example of geographic ontology with spatial relations

Rapid analysis of toponyms

• “Mississippi” can be the name of a river or of a state,
• The city is “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’θi:na].
• “Istanbul” was known as “Byzantium” and “Constantinople” in the past.
• The modern city of “Rome” is much bigger than in Romulus time.
• The toponym “Milano” can correspond to the city of Milano or the province of Milano.
• Some cities have specific characteristics such as capital of a state; a river can have an estuary in a sea.
Geospatial knowledge for territorial intelligence

**Gazetteers**
- A dictionary of toponyms/placenames
- A database structure for placenames

![Diagram of Gazetteers]

**Example of gazetteer**
- Toponym
  - Feature type
  - Feature shape (geometry)
  - Feature georeferencing
  - Language
  - Pronunciation
  - Date
  - Other names

![Diagram of Gazetteer Example]

**About ribbons**
- Line with some width
- Area
- Rectangular ribbon
- Extended ribbon
- Loose ribbon
- Relations between ribbons

![Diagram of Ribbons]

**Modeling with ribbons**
- Median
- Lanes
- Emergency lane
- Verge/Shoulder

![Diagram of Modeling with Ribbons]
Urban example

Relations between ribbons

<table>
<thead>
<tr>
<th>Side-by-side</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>End-to-end</td>
<td></td>
</tr>
<tr>
<td>Fusion</td>
<td></td>
</tr>
<tr>
<td>Splitting</td>
<td></td>
</tr>
</tbody>
</table>

Organization of Geographic Knowledge

3 – Generic Geographic knowledge

- Geographic knowledge valid everywhere
- Linked to
  - Maths
  - Linguistics
  - Acquisition devices
- Only three types
  - Mutation of topological relations
  - Gazetteers and toponyms
  - About raster reasoning
3.1 – Mutation of topological relations

- Granularity of interest
- Independence from scale
- Ex. Road along a coast
  - Touches
  - Disjoint
- According to scales, topological relations can vary

Visual acuity

- According to scale, objects are present or not.
- Cities: area, then point, then nothing
- River: ribbon, then line, then nothing
- Threshold for visual acuity
  - 0.1 mm (object no more visible)
  - 1 mm (ribbon is transformed into a line)

Features and mutation of their corresponding geographic objects

<table>
<thead>
<tr>
<th>Feature</th>
<th>Logarithmic Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 km wide city</td>
<td>10^10</td>
</tr>
<tr>
<td>1 ha wide hamlet</td>
<td>10^8</td>
</tr>
<tr>
<td>100 m wide motorway</td>
<td>10^6</td>
</tr>
<tr>
<td>1 m wide path</td>
<td>10^4</td>
</tr>
</tbody>
</table>

Vicinity of topological relations

- DISJOINT
- TOUCHES
- OVERLAPS
- COVERED BY
- CONTAINS
- INSIDE
- EQUALS
Example: Overlap-to-Touches

Ex. From OVERLAPS to TOUCHES

∀ O₁, O₂ ∈ GeObject, (∀ σ ∈ Scale)
∧ (O₁σ = 2Dmap(O₁, σ)) ∧ (O₂σ = 2Dmap(O₂, σ))
∧ (Overlaps(O₁, O₂)) ∧ (Area(O₁ ∩ O₂) < Area(¬(O₁ ∩ O₂)))
⇒ Touches(O₁σ, O₂σ).

In which 2Dmap is a cartographic function

Other possible mutations

- Disjoint-to-Touches
- Overlaps-to-Covers
- Contains-to-Touches

3.2 – Gazetteers and toponyms

- Geographic information retrieval
- Multilingualism
- Concepts in different languages are different
Geospatial knowledge for territorial intelligence

Pr. Robert Laurini

**Geometric homology**
- Taking measurement errors or uncertainties into account
- The same feature can have different geometric representations
- Geometry: polygons with point coordinates

**Linguistic homology**
- Equivalence class (Objects linked by ≡)
  - United States of America - United States - USA - U.S.A.
- Homology class (Objects linked by ₪)
  - Etats Unis d’Amérique - Estados Unidos de América - Stati Uniti d’America - Vereinigte Staaten von Amerika - Соединённые Штаты Америки - etc

**Non-linguistic transitivity**
- Principauté de Monaco, Munique, Monaco di Baviera

**Type homology**
- Consider two geographic ontologies in different languages
- Equivalence or homology
- Example: French « quai », three meanings
  - Wharf ₪ muelle
  - Riverside ₪ avenida a lo largo de un río
  - Platform ₪ andén
Formalization

- Set of languages: $\lambda \in \Lambda$
- Ontology of types: $\Omega = \text{set of Types with relations between them}$
- Gazetteer: $\Gamma = \text{set of Toponyms}$
- Set of spatial relations
- Geometric Earth: Geoid

Definition of GK System

- $GKS = \{T, \lambda, \Omega, \Gamma, Og, R\}$
  - $T$ inside Geoid
  - $\lambda \in \Lambda$
  - $Og = \{Og_1, \ldots, Og_n : n \in \mathbb{N}\}$
- $Og_i = (\text{id}_i, \text{geom}_i, \text{Type}_i, \text{Toponym}_i)$
  - $\text{Type}_i \in \Omega$
  - $\text{Toponym}_i \in \Gamma$
- $R$ set of relationships $\{Og_i R Og_j : (i, j \leq n) \land (i, j \in \mathbb{N})\}$
- $R$ relation

Considering 2 GKS

- $GKS_1 = \{T_1, \lambda_1, \Omega_1, \Gamma_1, Og_1, R_1\}$
- $GKS_2 = \{T_2, \lambda_2, \Omega_2, \Gamma_2, Og_2, R_2\}$
  - With
    - $T_1 \cap T_2 \neq \emptyset$
    - $\lambda_1 \neq \lambda_2$
    - $\Omega_1 \neq \Omega_2$
    - $\Gamma_1 \neq \Gamma_2$

Inferring geometry: Rule #1

**Rule 1bis: with MBR**
Inferring types and toponyms

Rule #2

IF
Homologous geometry
THEN
Homologous toponyms

Eng.City or FRE.Venise

⇒
Gazetteer

Antecedent

ENG.Venice.City.Geom1

FRE.Venise.Ville.Geom2

Consequents

Ontology

Output

Rule #3

IF
Two pair of homologous geographic objets are linked thru 2 different relations
THEN
Those relations are homologous

Antecedent

Covers

Consequent

3.3 – From raster representation

• Aerial photos / Satellite images
• Analysis
  – Pattern recognition
• Usage
  – Feature recognition
  – Updating

Visual Ontology

• In addition to feature type, several samples taken at different scales
• Samples = pictures from sky
  – Hyperspectral
  – Different channels
  – Different focus
  – Etc.
• Pictures only at lower level
Excerpt of a visual ontology

Feature recognition

Definitive result

Comparing aerial photo and cadaster
3.4 General characteristics

- Geographic knowledge reasoning
  - Independence from scale
  - Independence from data acquisition techniques
  - Independence from languages
  - Easy integration of
    - Spatial analysis
    - Network analysis

4 – Visual representations

- Four types:
  - Natural Language (classic geography)
  - Mathematics (description logic, etc.)
  - XML dialects
  - Visual

Elementary knowledge (1/2)

- Facts
  - Italy.population = 60 000 000
  - Touches (Italy, Switzerland)

- Flow
  - Bi-directional flow
    - Flow (Dublin, Limerick) = 4000
    - Flow (Limerick, Dublin) = 3500
  - Converging flows
  - Diverging flows
Elementary knowledge (2/2)

- Clusters
  - UK = Union (England, Scotland, Wales, Northern Ireland, etc)

- Co-location relation
  - Co-location (City Hall, Church)

Example

- If
  - Lake
  - Road going to the lake
- Then
  - Restaurant

Logic

\[ \forall l \in \text{Lake} \land \forall s \in \text{Road} \land (\text{touches}(l, s)) \Rightarrow \exists r \in \text{Restaurant} \land (\text{distance}(r, l) < 100 \land (\text{distance}(r, s) < 100)

Vocabulary (generic objects)
Visual Gazetteer

Contexts of interpretation

- **Cartographic Space**
  - North
  - \( A \) is west of \( B \)

- **Topological Space**
  - \( A \) and \( B \) are disjoint

- **Time Line**
  - \( A \) is before \( B \)

Fact statement and query

Topological query

1 cm 10 Km
Co-location rule

5 – Conclusion (1/2)

- Importance of geographic knowledge
- Several layers
  - Generic layers
  - Specific layers
  - Application layers
- First steps to geographic reasoning
Conclusions (2/2)

• Other minor contributions
  – Ribbon
  – Ribbon topology
  – Homology relations
  – Generalization of topological relations
  – Visual knowledge representation

Main recent references

• LAURINI R. (2014c) "Geographic Ontologies, Gazetteers and Multilingualism" submitted to the journal Future Internet
• LEJDEL B., LAURINI R (2014) "Ribbons and Generalizing Topological Relations" submitted to the "Inter'l Journal of Geographic Information Sciences"

To download this talk:
http://liris.insa-lyon.fr/robert.laurini/ftp/GKS.zip

For any contact:
Robert.Laurini@insa-lyon.fr

Thanks for your attention!