Semantic integration of thematic geographic information in a multimedia context

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- Our semantic framework
  - Ontology for representing thematic GI
  - Merging methods
    - String-based mapping algorithm
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    - Spatial mapping algorithm
    - Evaluation of mapping algorithm
  - Semantic queries
- A multimedia context
- Conclusions and future research
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Evolution of Geographic Information Systems

1970’s-1980’s

GIS as *islands of information*

- Proprietary and monolithic software tools
- Information produced and maintained locally, not shared

1990-...

*Interoperable GIS*

- Open systems that can integrate software components from different developers (OGC specifications)
- Maps built from different sources. Shared information

Introduction and objectives
Problems of sharing information

- Past: Locally maintained (not-shared) information was unambiguous
- Present: heterogeneous information
  - Syntactic heterogeneity
  - Structural heterogeneity
  - **Semantic heterogeneity**
    - Different needs, different mental models, different concepts
- **Semantic interoperability** (or **semantic integration**):
  - Mechanisms to enable agents to share and to integrate information from different sources overcoming semantic heterogeneity
Two examples of semantic heterogeneity (I)

1. Artificial surfaces
   1.1. Urban fabric
      1.1.1. Continuous urban fabric
      1.1.2. Discontinuous urban fabric
   1.2. Industrial, commercial and transport units
      1.2.1. Industrial or commercial units
      1.2.2. Road and rail networks and associated land
      1.2.3. Port areas
      1.2.4. Airports
   1.3. Mine, dump and construction sites
      1.3.1. Mineral extraction sites
      1.3.2. Dump sites
      1.3.3. Construction sites
   1.4. Artificial non-agricultural vegetated areas
      1.4.1. Green urban areas
      1.4.2. Sport and leisure facilities

2. Agricultural areas
   2.1. Arable land
      2.1.1. Non-irrigated arable land
      2.1.2. Permanently irrigated land
      2.1.3. Rice fields
   2.2. Permanent crops
      2.2.1. Vineyards
      2.2.2. Fruit trees and berry plantations
      2.2.3. Olive groves
   2.3. Pastures
      2.3.1. Pastures
   2.4. Heterogeneous agricultural areas
      2.4.1. Annual crops associated with permanent crops
      2.4.2. Complex cultivation
      2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
      2.4.4. Agro-forestry areas

3. Forests and semi-natural areas
   3.1. Forests
      3.1.1. Broad-leaved forest
      3.1.2. Coniferous forest
      3.1.3. Mixed forest
   3.2. Shrub and/or herbaceous vegetation association
      3.2.1. Natural grassland
      3.2.2. Moors and heathland
      3.2.3. Sclerophyllous vegetation
      3.2.4. Transitional woodland shrub
   3.3. Open spaces with little or no vegetation
      3.3.1. Beaches, dunes, and sand plains
      3.3.2. Bare rock
      3.3.3. Sparsely vegetated areas
      3.3.4. Burnt areas
      3.3.5. Glaciers and perpetual snow

...
Two examples of semantic heterogeneity (II)

- What does “area at risk of forest fires” mean?
  - Pine forest with high temperatures, low rains and very windy
  - Forest close to a road or a picnic area
Two examples of semantic heterogeneity (II)

- What does “area at risk of forest fires” mean?
  - Pine forest with high temperatures, low rains and very windy
  - Forest close to a road or a picnic area
- What does “pine forest” mean?
  - Pine trees covering at least a 60% of the area
  - Forest area where pine trees are predominant
Three levels of semantic heterogeneity

- Syntactic level
- Terminological level
- Conceptual level
  - Metaphysical mismatches
    - Example of land cover maps of Majorca
  - Epistemic mismatches
    - Example of “area at risk of forest fires”

(mainly based on classification of the Knowledge Web Consortium)
On **Thematic** Geographic Information

- 3 components of GI
  - Spatial
  - Temporal
  - **Thematic**

- Thematic variable or attribute
  - Qualitative variables
  - Quantitative variables
    - Classified quantitative variables

- Semantic integration is mainly related to the thematic component
- Semantic Reference Systems: need for an equivalent to Spatial or Temporal Reference Systems
Example of Spatial Reference System

- Hayford ellipsoid
- European Datum (1950)
- Longitude referred to Greenwich meridian
- Altitude referred to the level of the sea in Alicante
- UTM projection system (31)

Mapa topogràfic de Catalunya, ICC, 1:25.000 (Parc Nacional d’Aigües Tortes i Estany de Sant Maurici)
Overview of our approach

- Repository of geographic datasets
  - from different providers
  - with different ontologies

- Definition of a formal Semantic framework, with 3 main elements:
  1) An ontology is defined to represent the thematic concepts and their relations in the repository of datasets
  2) Merging methods are defined to easily add new datasets to the repository and to the ontology
  3) Semantic services are defined to enable agents to find and to integrate thematic information
OntoGIS tool

- The three elements of the framework have been implemented in the OntoGIS tool
  - Developed in Java using the HP Jena framework
  - Ontology expressed in OWL
  - Connection to DL reasoners as Racer and FaCT
  - Supports datasets in GeoTIFF format
  - Supports metadata in FGDC CSDGM standard
Our multimedia context

- Application of the semantic framework in other contexts, by external "agents", following the philosophy of the Semantic Web
- Indexing and retrieval of geo-referenced multimedia elements (still images and video sequences) according to their thematic geographic content
Main objectives

- Definition of a formal framework to solve the problem of semantic interoperability in the geographic domain, particularly overcoming terminological, metaphysical and epistemic discrepancies
  - Formal conceptual model (ontology)
  - Merging methods
  - Semantic services

- Application of the framework to the problem of indexing and retrieval of geo-referenced images and videos according to their geothematic content
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Representing the knowledge in the repository (I)

- Datasets and datasets values
  - It comes from datasets metadata
  - Qualitative and quantitative

- Normalized vocabularies
  - Understood by the community
  - None for the whole GI domain
  - Some for specific contexts
    - Example CORINE land cover vocabulary
Representing the knowledge in the repository (II)

- Thematic concepts (themes) and their relations
  - Superclass/subclass (taxonomy)
  - Equivalent classes
  - Disjoint classes
  - Property value restriction (partitions)
- Connections or mappings between dataset values and thematic concepts
- Models: themes defined through DL
Managing the ontology

Ontology for representing thematic GI
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Mapping, alignment and merging (I)

- Mapping: a semantic relation between two or more entities belonging to different ontologies
- Ontology Alignment: a set of mappings between two or more ontologies

(Knowledge Web Consortium)
Mapping, alignment and merging (II)

- Ontology Merging: the creation of a new ontology from two or more source ontologies. It is closely related to integration from the database community (Knowledge Web Consortium)
Our merging process

- Merging of:
  - The application ontology of a dataset (extracted from the metadata file)
  - The ontology of the overall repository

- Each value in the dataset being inserted is mapped to one or more thematic classes in the repository
  - It usually requires the creation of new thematic classes

- The repository ontology is built by merging new datasets and normalized vocabularies

- Particularities:
  - Dataset ontology: few classes, almost flat, little detail
  - Repository ontology: bigger and denser, better defined
Two merging methods

- Merging process conducted according to one of the two merging methods:
  - Manual method:
    The domain expert manually identifies relations between datasets values and thematic classes, one by one
  - Semi-automatic method
Semi-automatic merging method

- It considers the whole dataset structure (not isolated values)
- The system generates a list of suggested mapping actions
- The user may confirm or modify each suggested mapping action (or all at once)

Step 1: Select a dataset (and see its properties and dataset values)
Step 2: Define a hierarchy structure of dataset values (optional)
Step 3: Automatic generation of suggested list of mapping actions
Step 4: Confirm or modify mapping actions
Example of semi-automatic merging method (step 1)
Example of semi-automatic merging method (step 2)
Example of semi-automatic merging method (steps 3 and 4)
Mapping algorithm

- Key point of the semi-automatic method: it automatically generates the list of suggested mapping actions (step 3)
- We have defined and tested three different heuristic *mapping algorithms*
  - Based on names similarities (string-based algo.)
  - Using a terminological base (terminological algo.)
  - Based on the spatial distribution of dataset values (spatial algo.)
- Generic for merging ontologies presenting a hierarchical structure of classes (taxonomy)
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Semantic integration of thematic geographic information in a multimedia context

Toni Navarrete

String-based mapping algorithm

- Main assumptions:
  - Two classes with the same name normally refer to the same concept
  - A class name adding words to another usually specifies its meaning (‘forest’ and ‘coniferous forest’)
  - We need an asymmetric similarity measure that indicates us how a class name is included in the other

Merging methods: String-based mapping algorithm
Similarity measures

- Similarity between two terms $u$ and $v$

$$tsim(u, v) = \frac{2 \cdot \text{length}(x)}{\text{length}(u) + \text{length}(v)}$$

(where $x$ is the longest common substring between $u$ and $v$ beginning at the first character of both and containing at least 3 characters)

- Asymmetric similarity between two class names $S = \{s_1, \ldots, s_n\}$ and $T$

$$sim(S, T) = \frac{\sum_{i=1}^{n} \max_{t \in T}(tsim(s_i, t))}{n}$$
Determining the relation between two classes

$C_D$ and $C_R$ two classes with names $S_D$ and $S_R$

- If $\text{sim}(S_D, S_R) \geq \lambda$: $C_R \sqsubseteq C_D \quad C_D \sqsupseteq C_R$
- If $\text{sim}(S_R, S_D) \geq \lambda$: $C_D \sqsubseteq C_R$
- If $\text{sim}(S_D, S_R) \leq \mu$ and $\text{sim}(S_D, S_R) \leq \mu$: no relation

- Otherwise:
  - they have a common superclass $C_X$: $C_D \sqsubseteq C_X$ and $C_R \sqsubseteq C_X$

Merging methods: String-based mapping algorithm
Structure-driven algorithm

- The algorithm considers
  - The structure of both ontologies
  - The previous mappings

through:

- Mapping restrictions
- Structural rules
Mapping restrictions

- The mapping "CD equivalent to CR" influences mappings for CD1, ..., CDn

Merging methods: String-based mapping algorithm
Mapping restrictions

- The mapping “CD equivalent to CR” influences mappings for \( CD_1, \ldots, CD_n \)

Merging methods: String-based mapping algorithm
Structural rules

- New mappings may be inferred from certain structural “patterns”

- In general, applicable when a dataset class has only one candidate repository class
- Used to detect possible spelling errors

Merging methods: String-based mapping algorithm
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Terminological mapping algorithm

- ‘Pine forest’ is related to ‘wood’, but their string-based similarity is 0
- Terminological bases used to obtain for each term:
  - Synonyms
  - Hypernyms (more general terms)
  - Hyponyms (more specific terms)
  - In some cases:
    - Meronyms (part of)
    - Holonyms (whole of)
    - Lexical category
Terminological bases considered

- **GEMET thesaurus of environmental terms**
  - Widest in the GI domain: 6,500 terms (UMLS in the medical domain has 5 million entries)
  - Synonymy (USE/UF), hypernymy/hyponymy (BT/NT)

- **WordNet lexical base**
  - Terms organized in *synsets* (sets of terms with a common meaning)
  - 117,000 nouns in 81,000 synsets
  - Lexical category, hypernymy/hyponymy, meronymy/holonymy, antonymy

Merging methods: Terminological mapping algorithm
Score measures and term mapping restrictions

- Score between two terms $t_1$ and $t_2$:

$$t_{score}(t_1, t_2) = \begin{cases} 
1 & \text{if } \text{sim}(t_1, t_2) \geq \lambda \text{ and } \text{sim}(t_2, t_1) \geq \lambda \\
\max_{i,j} \left( \frac{\text{threlated}(th_{i_1}, th_{j_2})}{1 + \text{distance}(th_{i_1}, th_{j_2})} \right) & \text{otherwise}
\end{cases}$$

- Asymmetric score between two classes $C=\{t_1, \ldots, t_n\}$ and $E$:

$$\text{score}(C, E) = \frac{\sum_{i=1}^{n} \max_{t \in E} (t_{score}(t_i, t))}{n}$$

Merging methods: Terminological mapping algorithm
Structure-driven algorithm

- Similar to the string-based algorithm:
  - Based on mapping restrictions
  - Uses structural rules to infer new relations
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Spatial mapping algorithm

- Based on the spatial distribution of dataset values
- Main assumption:
  - If the spatial extent of two values in different datasets have a high overlapping, they probably refer to equivalent themes
Spatial mapping algorithm

- Based on the spatial distribution of dataset values
- Main assumption:
  - If the spatial extent of two values in different datasets have a high overlapping, they probably refer to equivalent themes
Related work

- Not applicable to real datasets
- Only consider relations if overlapping is 100%
- Only 1-to-1 relations
  - Not valid for different classifications for a common theme:
    - union of 'dense forest' and 'sparse forest' equivalent to 'forest'
    - union of 'dense forest' and 'sparse forest' equivalent to union of 'evergreen forest' and 'deciduous forest'

Merging methods: Spatial mapping algorithm
Remarks

- With some optimizations, the spatial mapping algorithm is faster than the terminological one.
- If datasets contain enough spatial units for each value: reliable results.
- If not, or if merging a vocabulary (no dataset): terminological (or string-based) approach.
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Evaluation of mapping algorithms

- Ontology merging/alignment new discipline
- 2 problems related to evaluation:
  - No benchmarks for evaluation (as TREC for text IR)
  - Precision and recall consider a mapping either valid or not, but not how close it is to the expected one. Example:
    - Reference mapping: “A equivalent to X”
    - Obtained mapping: “A equivalent to Y”
    - If X is subclass of Y the mapping is better than if X and Y are not related
Problem 2: precision and recall (I)

Solution: we have defined a relaxed precision and recall for ontology merging/alignment

- Let $M' = <A', B', rel'>$ be a mapping from the reference alignment and $M = <A, B, rel>$ a mapping from the obtained alignment.

- $X(M)$ is the set of inferred axioms from $M$.

- Partial relaxed precision and recall for a mapping:

\[
p(M, M') = \frac{|X(M) \cap X(M')|}{|X(M)|} \quad \quad r(M, M') = \frac{|X(M) \cap X(M')|}{|X(M')|}
\]
Problem 2: precision and recall (II)

Solution (cont.):

- Global relaxed precision and recall for an alignment $\mu$ (with respect to the reference alignment $\mu'$):

\[
P(\mu, \mu') = \frac{\bigcup_{i=1}^{k} (X(M_i) \cap X(M'_i))}{\bigcup_{i=1}^{k} (X(M_i))} \quad \text{and} \quad R(\mu, \mu') = \frac{\bigcup_{i=1}^{k} (X(M_i) \cap X(M'_i))}{\bigcup_{i=1}^{k'} (X(M'_i))}
\]
Problem 1: no benchmarks for evaluation

- Different strategies to obtain a reference merging/alignment:
  1. Merging a copy of the ontology (and a copy with modifications)
  2. Merging different levels of a hierarchical land cover vocabulary
  3. Merging Eurasia land cover datasets
Merging a copy of the ontology

- The 3 algorithms obtain the right equivalence mappings
- CORINE and CORINE with modifications:
  - No problem with the spatial algorithm
  - Structural rules infer the right mappings if only one modification between “brothers”
  - Structural rules provide a good way to overcome possible spelling mistakes and to deal with synonyms not appearing in the terminological base
Merging different levels of a hierarchical land cover vocabulary

- Anderson level 2 merged with Anderson level 1

<table>
<thead>
<tr>
<th></th>
<th>string-based (α=0.75)</th>
<th>WordNet without meronyms</th>
<th>WordNet with meronyms</th>
<th>GEMET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct mappings</td>
<td>18</td>
<td>26</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>Wrong mappings</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No relation mappings</td>
<td>19</td>
<td>11</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Total mappings</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Precision</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Recall</td>
<td>0.49</td>
<td>0.70</td>
<td>0.70</td>
<td>0.68</td>
</tr>
</tbody>
</table>

- CORINE level 3 merged with CORINE levels 1+2

<table>
<thead>
<tr>
<th></th>
<th>string-based (α=0.75)</th>
<th>WordNet without meronyms</th>
<th>WordNet with meronyms</th>
<th>GEMET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtained mapping equal to reference mapping</td>
<td>12</td>
<td>15</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Obtained mapping intersects reference mapping</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Wrong mappings</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>No relation mappings</td>
<td>24</td>
<td>14</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Total mappings</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Relaxed precision</td>
<td>0.92</td>
<td>0.82</td>
<td>0.79</td>
<td>0.89</td>
</tr>
<tr>
<td>Relaxed recall</td>
<td>0.37</td>
<td>0.47</td>
<td>0.47</td>
<td>0.47</td>
</tr>
</tbody>
</table>
Merging Eurasia land cover datasets (I)

- Global Land Cover project of USGS
  - Eurasia map: $169 \cdot 10^6$ cells with a big number of cells for any value

- Each proposed mapping is validated through the datasets
  - Spatial precision
  - Spatial recall cannot be computed in this way. Instead: ratio of mapped classes
Merging Eurasia land cover datasets (II)

<table>
<thead>
<tr>
<th>Datasets being merged</th>
<th>Global Spatial Precision</th>
<th>Ratio of mapped classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGBP and USGS *</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>IGBP and USGS datasets **</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>BAT and USGS datasets *</td>
<td>0.82</td>
<td>0.89</td>
</tr>
<tr>
<td>BAT and USGS datasets **</td>
<td>0.85</td>
<td>0.89</td>
</tr>
<tr>
<td>SBM2 and USGS datasets *</td>
<td>0.70</td>
<td>0.91</td>
</tr>
<tr>
<td>SBM1 and USGS datasets *</td>
<td>0.84</td>
<td>0.67</td>
</tr>
<tr>
<td>SBM2 and SBM1 datasets *</td>
<td>0.82</td>
<td>0.91</td>
</tr>
</tbody>
</table>

* (only physical values)  
** (physical and abstract values)

- **Average:** 83% of spatial precision and 85% of classes mapped
- **PROMPT**
  - The best ratio of mapped classes is 0.59, but usually 0 or almost 0
  - In the best case for PROMPT, the ratio of mapped classes is 0.36 lower than ours
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First type of semantic query
Finding

- Objective: to find where (dataset and values) we can get information about a particular theme
Examples

**Query 1**

*Without inference*

*With inference*

**Reciprocal of query 1**
Remark on the first type of query

- Although its simplicity, it is a significant improvement with respect to current catalogues which only provide a keyword-based search.
Second type of semantic query
Translation

- Objective: to convert a dataset schema to an understandable vocabulary (for instance CORINE)
Third type of semantic query

Integration

- Objective: to generate a new dataset that integrates information about one theme from several datasets from different sources with different application ontologies

```
Objective: to generate a new dataset that integrates information about one theme from several datasets from different sources with different application ontologies
```

```
Objective: to generate a new dataset that integrates information about one theme from several datasets from different sources with different application ontologies
```
Related work on dataset integration

- Based on lattices
- Significant restrictions
  - Usually only applicable to small datasets
  - Assumption of complete knowledge
  - Only disjoint classifications
  - No support for many-to-many relations
  - No support for complex semantic relations
  - No support for modelled themes
- Our approach is based on DL and on the open-world assumption
Examples of datasets integration (I)

- Integration of two land cover maps, with different classifications of forests

Raster datasets
Cell size: 10 m²
Area of interest: \( \sim 5 \cdot 10^6 \) cells
Examples of datasets integration (II)

Integration involving modelled themes

- High risk of forest fires: forests closer than 1 km to roads, with a slope higher than 25° and annual rains below 800 mm
- Moderate risk of forest fires: forests closer than 1 km to roads with either a slope smaller than 25° or annual rains above 800 mm

Raster datasets
Cell size: 10 m²
Area of interest: \( \sim 5 \cdot 10^6 \) cells
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Geo-referenced video

- Recorded through a digital video camera synchronized with a GPS and other devices (camera location, orientation and tilt)
- Commercial systems exist to record geo-referenced videos and to visualize them in a GIS environment
- Wide use in maintenance of linear infrastructures

Screenshot of Red Hen GeoVideo
Our approach

- Geo-referenced videos as the basis for a digital video library

- A Digital Elevation Model can be used for a more precise area of vision

- Thematic geographic information is used to index the video

- External agents can access the video collection to retrieve sequences according to thematic criteria
Still image and video indexing

- Indexing is done according to a set of themes $T_1, \ldots, T_n$ (*indexing themes*)
  - For instance: vegetation, agriculture, protected land and monuments
- Indexing themes are previously selected by the user responsible of the process
- In principle all the videos in the collection are indexed according to the same set of indexing themes
Indexing algorithm for a still image

\[
\text{for each } T_i \in \{T_1, \ldots, T_n\} \text{ do} \\
\quad \text{DsSet}_i = \text{query1InferenceDs}(T_i) \\
\quad \text{// where DsSet}_i \text{ is a set of } m \text{ datasets } \{d_{i1}, \ldots, d_{im}\} \\
\quad \text{for each } d_{i k} \in \text{DsSet}_i \text{ do} \\
\quad \quad d_{Aik} = \text{region of dataset } d_{ik} \text{ contained in } A \\
\quad \quad \text{// } A \text{ is the area of vision} \\
\quad \end{for} \\
\quad d_{i} = \text{query3Filtered}(d_{A1i}, \ldots, d_{Aim}, T_i) \\
\quad \text{// where } d_{i} \text{ is a virtual dataset with } p \text{ values } \{C_{i1}, \ldots, C_{ip}\} \\
\quad \text{for each } C_{ij} \in \{C_{i1}, \ldots, C_{ijp}\} \text{ do} \\
\quad \quad \text{add index entry } < I, T_i, C_{ij}, |e(C_{ij}, d_{i})| > \\
\quad \quad \text{// where } |e(C_{ij}, d_{i})| \text{ is the area of} \\
\quad \quad \text{// the spatial extent of } C_{ij} \text{ in } d_{i} \\
\quad \end{for} \\
\end{for} \\
\text{Note: it may be convenient to convert each } C_{ij} \text{ to a normalized vocabulary through } \text{query2}
Typical query

- Retrieve the images depicting a given theme $T$

\[<..., ..., C, ...>\]

$C \subseteq T$
Video segmentation

- Stratification-based (or feature-based) model of video:
  - There are $n$ layers of segmentation
  - At a given layer, a segment defined as a sequence of frames containing the same set of visible classes

<table>
<thead>
<tr>
<th>Layer 1 ($T_1$)</th>
<th>$v_{s11}$</th>
<th>$v_{s12}$</th>
<th>$v_{s13}$</th>
<th>$v_{s14}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 2 ($T_2$)</td>
<td>$v_{s21}$</td>
<td></td>
<td>$v_{s22}$</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer $n$ ($T_n$)</td>
<td>$v_{sn1}$</td>
<td>$v_{sn2}$</td>
<td></td>
<td>$v_{sn3}$</td>
</tr>
</tbody>
</table>

- Each video segment indexed (and retrieved) in a similar way as for still images
Contents

- Introduction and objectives
- Our semantic framework
  - Ontology for representing thematic GI
  - Merging methods
    - String-based mapping algorithm
    - Terminological mapping algorithm
    - Spatial mapping algorithm
    - Evaluation of mapping algorithm
  - Semantic queries
- A multimedia context
- Conclusions and future research
Summary of contributions (I)

- Definition of an ontology to represent geothematic content, including modelled themes
- Definition of a merging solution valid for the case of poorly defined ontologies with a hierarchical structure
  - Key point: mapping algorithms
Summary of contributions (II)

- String-based mapping algorithm:
  - Asymmetric similarity measure between two class names
  - Mapping restrictions
  - Structural rules

- Terminological mapping algorithm:
  - Asymmetric score measure (based on synonyms, hyponyms and hypernyms)
  - Term mapping restrictions (how the relation between two classes is determined)

- Spatial mapping algorithm
  - Asymmetric similarity measure (based on the overlapping of spatial extents)
  - Compared to other approaches:
    - More flexible
    - Supports 1-to-many and many-to-many relations
    - Can be computed in real time, even for big real datasets

Conclusions and future research
Summary of contributions (III)

- Evaluation of merging/alignment:
  - Definition of relaxed precision and recall specific for ontology merging/alignment
- Definition of three semantic services (with some variants) in terms of DL:
  - Improves current catalogues services
  - Compared to other approaches:
    - Removes restrictions of lattices
    - Supports richer definition of concepts, in particular modelled themes
Summary of contributions (IV)

- Semantic framework used in the process of indexing and retrieving georeferenced multimedia elements:
  - Definition of a semantic model for describing still image and video in terms of geothematic information
  - Representation of this model by means of MPEG-7
  - Algorithm for segmenting and indexing georeferenced video based on the thematic content
Future work (I)

- **Representation and reasoning:**
  - Better support for reasoning with quantitative themes
    - Other logics (fuzzy logic)
  - More complex models
    - With weighted and arithmetical expressions
    - Specifying algorithms
- **Space and time**
  - Inclusion of gazetteers and calendars in the framework: queries of type “concepts in a space at a certain time”
  - Spatial relations in the definition of concepts
  - Fuzzy boundaries in merging (spatial mapping algorithm) and integration
Future work (II)

- Technical aspects:
  - Relation with SDIs (Spatial Data Infrastructures)
  - Network of repositories
- Indexing of video based on geographic content:
  - Composition of “intelligent” sequences as response to a thematic query
    - Narrative thread
  - Navigation between sequences (based on thematic and spatial axes)
Thanks for your attention