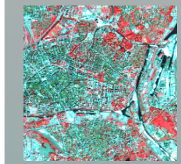
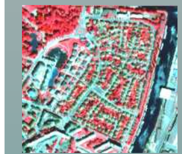
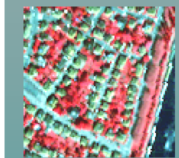
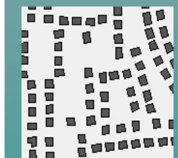
Use of knowledge in a classification process to extract urban objects

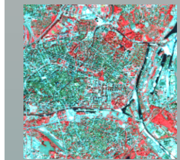





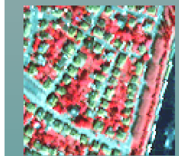
A. Puissant*, G. Forestier**

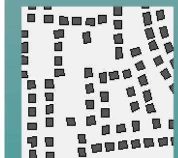
* Image & Ville – CNRS / ULP Strasbourg (FR)

** LSIIT – CNRS / ULP Strasbourg (FR)

Summary



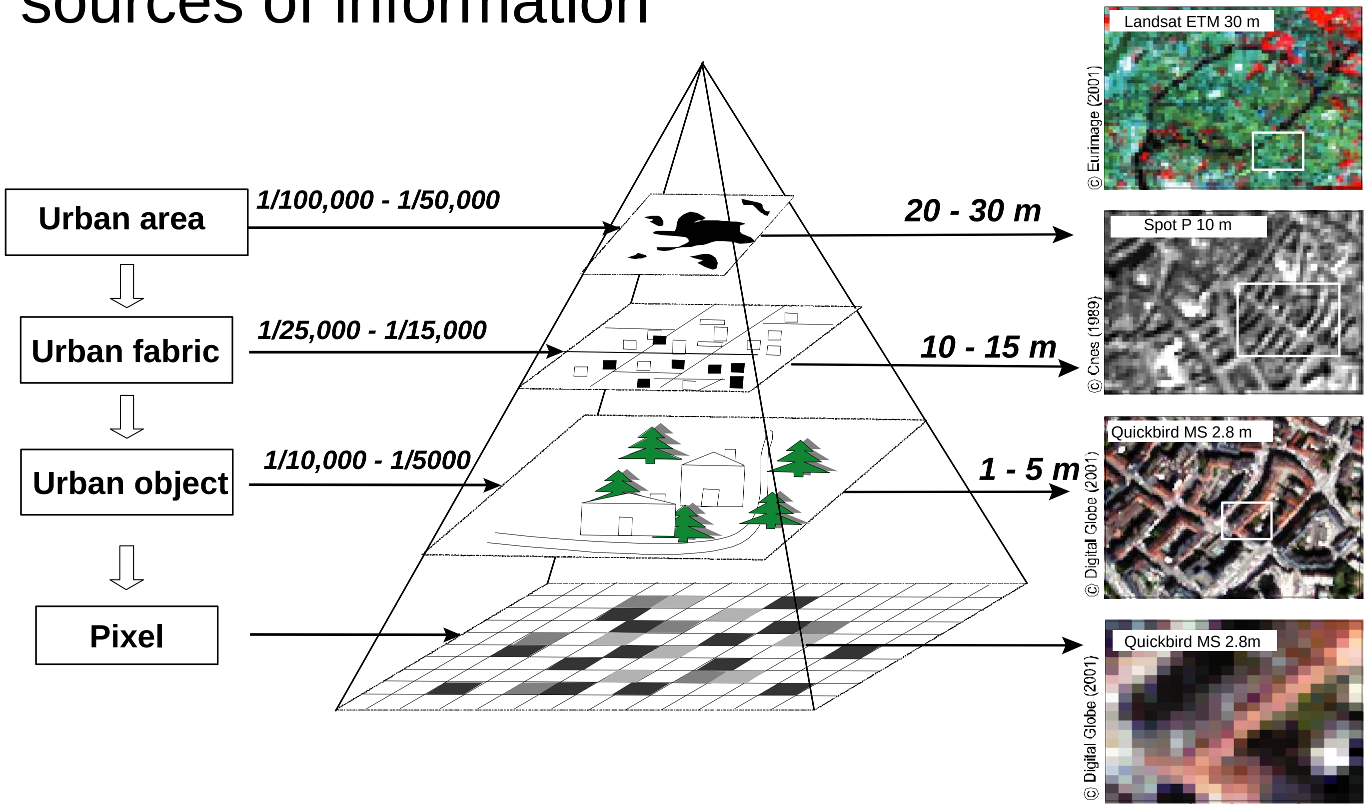




- Context
- Objective
- Ontologies applied to images
- Construction of an urban ontology oriented 'image'
- Use of the ontology in a classification process => matching procedure
- Experiments on VHR imagery
- Conclusions and perspectives

Context

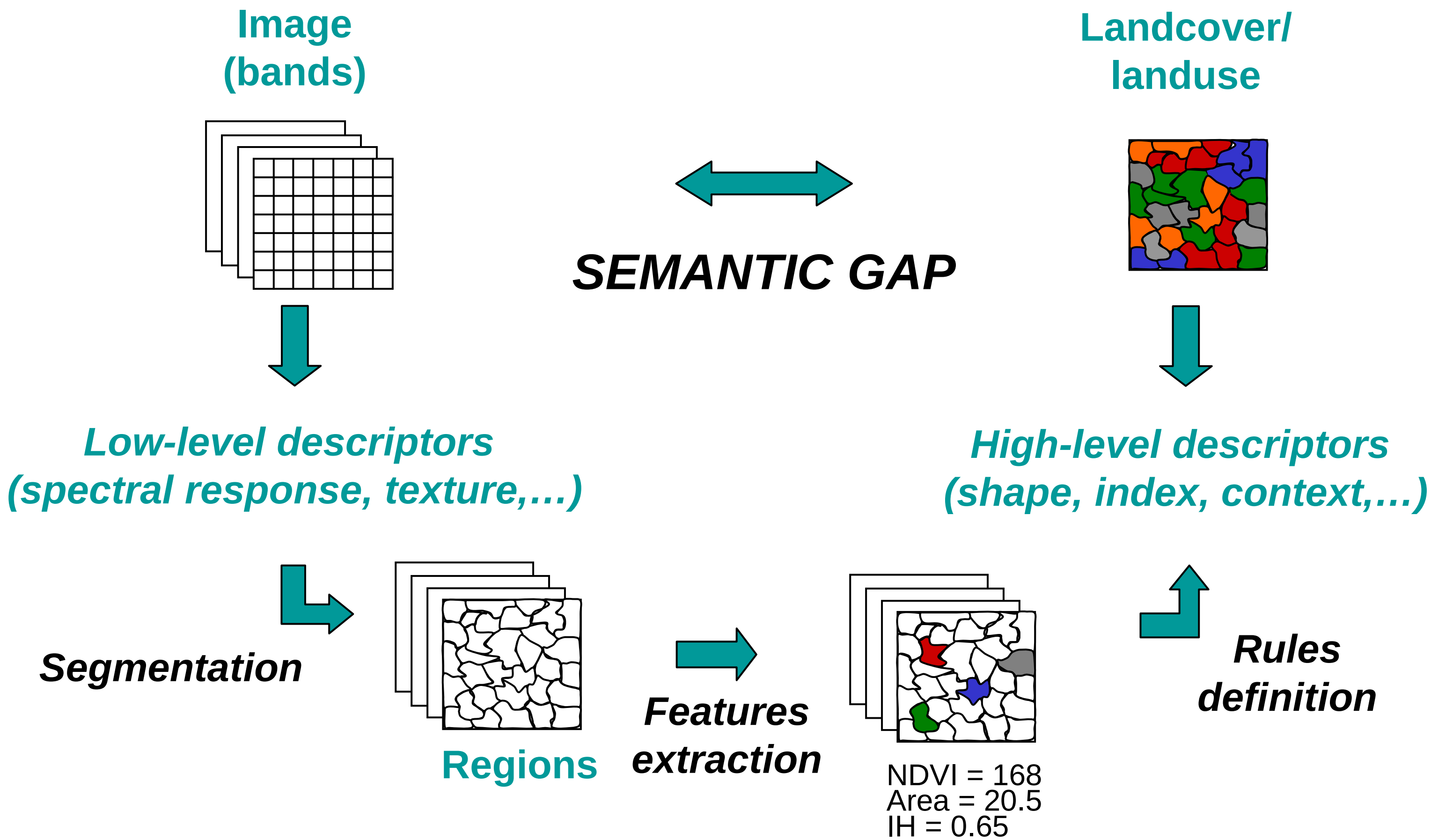
- Needs of up-to-date and multiscale information
- Automatic acquisition is complex, difficult and time-consuming
- High and very high resolution images are potential sources of information



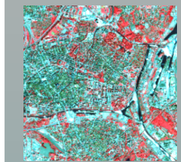
Exemple of Strasbourg (France)

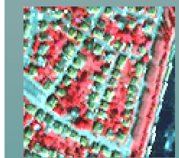
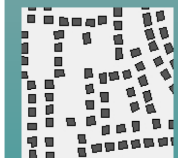
Context

- Image interpretation
- Object-oriented method based on the used of domain-knowledge



Objective



- **Major issue = domain knowledge formalization and exploitation**
- **Construction of an urban ontology in 3 steps:**

  Step 1: Phase of specification

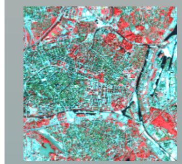
  Step 2: Phase of conceptualisation

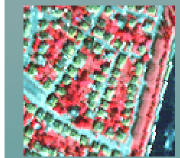
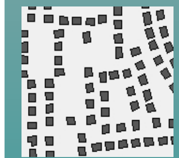
  Step 3: Phase of formalisation

- **Matching process between regions and concepts**
- **Experiments on VHR imagery**

=> multi-scale mapping of urban area (from 1/100,000 to 1/10,000)

Ontologies applied to images



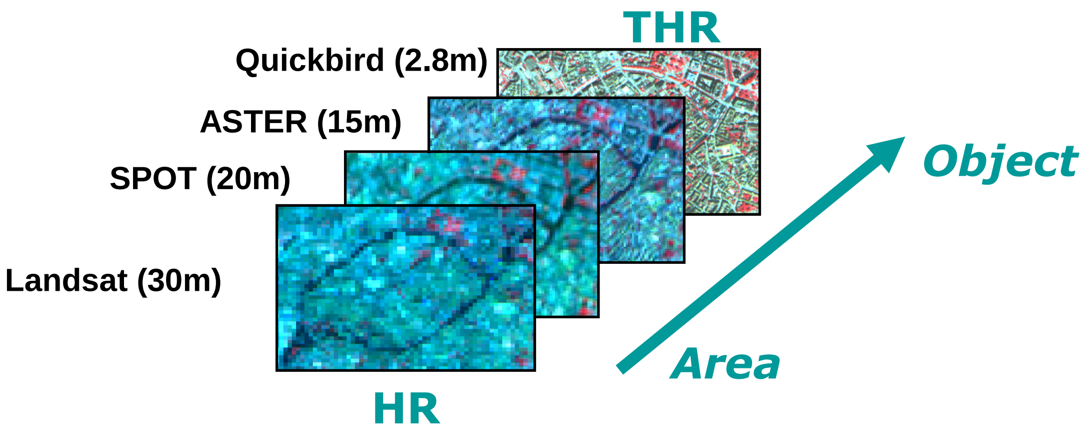
- **Definition (Gruber, 1993)**

  A *'simplified view of the world which is represented for specific purpose*' …. a *'result of a consensus in an user community to clarify the communication*' (Gruber, 1993)

- **Domain-dependent ontology**

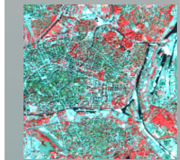
  = landcover/use analysis in urban and peri-urban areas based on aerial or satellite images

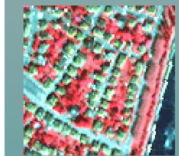
- **From high to very high resolution images**

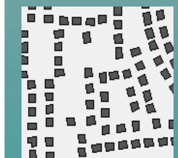


Ontology oriented 'images'

1. Phase of specification



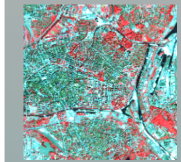


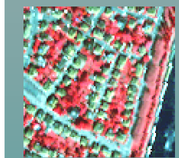


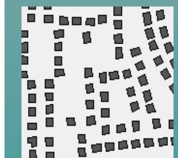
- **Inventory of semantic objects** used by experts in urban management for mapping urban area (from 1/100,000 to 1/10,000)
- **Terminological analysis** of existing typologies and nomenclatures (western cities)
- Range of products to map urban area from 1/100,000 to 1/25,000 but not at 1/10,000
- Utility of VHR images (1m) to **propose a typology** adapted to **map urban area at 1/10,000** ….
- …based on urban objects in **GIS platform** and definition of the **minimal spatial resolution** of urban object identification

Ontology oriented 'images'

1. Phase of specification







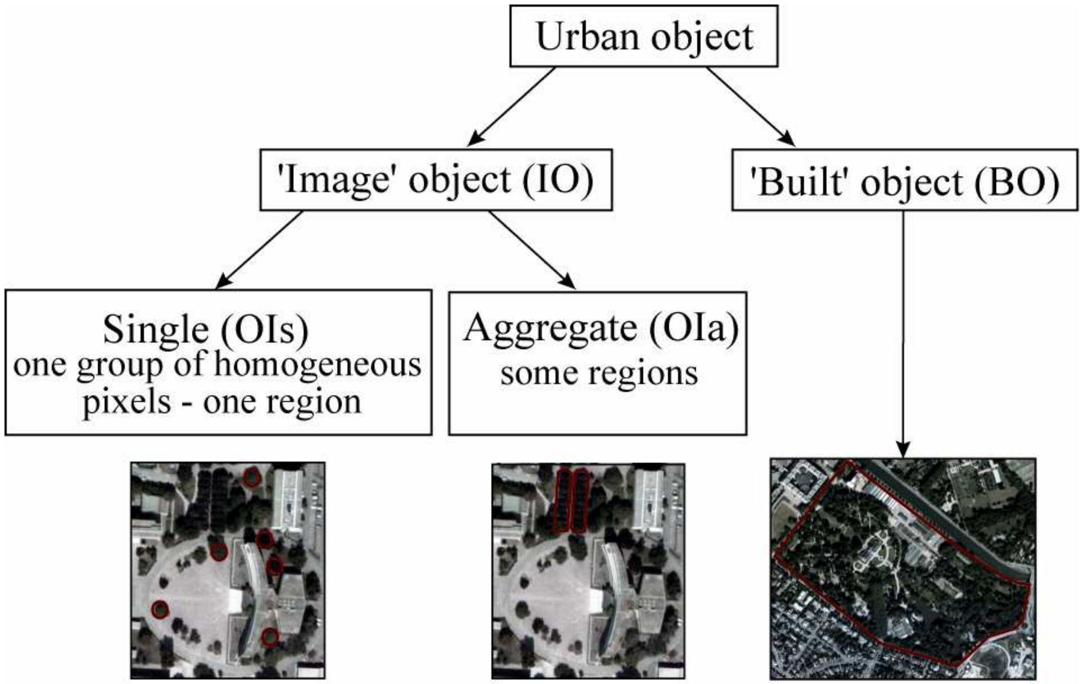
- **Extract of the nomenclature** for mapping urban area (from 1/100,000 to 1/10,000)

Level 1 1/100,000	Level 2 1/100,000 to 1/50,000	Level 3 1/50,000 to 1/25,000	Level 4 1/25,000	Level 5 1/10,000
Artificial/ Mineral surfaces	Housing surfaces	Continuous Urban fabric	High density of continuous Urban fabric	High density ofc continuous Urban fabric
			Low density of continuous Urban fabric	Low density of continuous Urban fabric
		Discontinuous urban fabric	Individual houses	Low density of individual houses
				Medium density of individual houses
				High density of individual houses
			Collective building	Building with less than 4 floors
				Building with more than 4 floors
			Mixed	Mixed (houses and building)
		Specific urban surfaces	Specific urban surfaces	Cemetry
				Surfaces with military buildings
				Surfaces with scholar buildings
				Surfaces with hospital buildings
				Others surfaces

Ontology oriented 'images'

2. Phase of conceptualisation

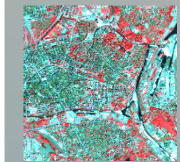
- **From a lexicon of thematic classes to a taxonomy of concepts**
- **Definition of *'Image Objects'* and *'built Objects'***

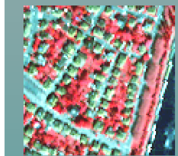


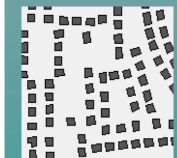
a tree ***a tree line*** ***a park***

Ontology oriented 'images'

2. Phase of conceptualisation







- **'Image object' (IO) stored in a dictionary with:**

  - Name and textual definition
  - Representation in a GIS database
  - Range of spatial resolution at which the object is identifiable
  - Type of IO (single, aggregate)
  - Thematic code
  - Color code

  Satellites images

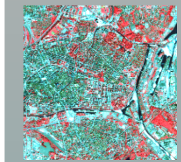
  - Radiometric measures (some objects)
  - Graphic illustration (orthophoto)

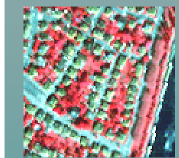
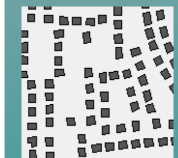
  Real world

  - Low-level descriptors in images

Ontology oriented 'images'

2. Phase of conceptualisation

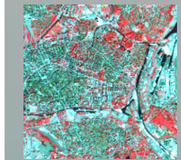


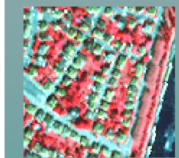
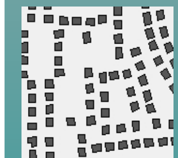



➢ **Low-level descriptors**

Descriptors	**Comments**
Spectral reflectance	Range of observed values in 4 spectral bands: Blue (B) – Green (G) – Red (R) – near-infrared (NIR)
Normalized Difference Vegetation Index (NDVI)	Range of observed values of NDVI
Soil Brightness Index (BI)	Range of observed values of BI
Shape properties	Range of observed values of area, perimeter, elongation, diameter, compactness (Miller index), and solidity
Texture	Range of observed values of the homogeneity index and of the variance derived from the co-occurrence grey-level matrix (Haralick, 1973)
Context (or relationships)	Adjacency, inclusion, composition, neighbourhood

Example



Fiche 1 : Pavillon

A. Identification de l'objet

Type	Nom de l'objet :	Type d'objet élémentaire	T
Polygone	*Pavillon*	*Bâtiment*	C

B. Description de l'objet dans le monde réel

B.1 Définition textuelle

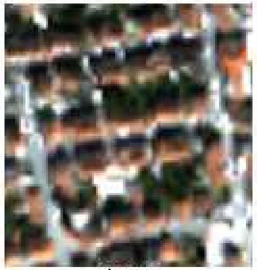
L'objet « pavillon » ou « maison individuelle » appartient à la catégor
Il désigne une construction durable destinée à abriter l'activité humaine

La portée de cette définition est restreinte par les critères suivants. En
- est situé dans un îlot physique (domaine privé) ;
- a une emprise au sol d'au moins 12 m² ;

Ces critères visent à exclure notamment les abribus, les aubettes, les
de la définition de l'objet « pavillon ».

Le pavillon ou maison individuelle est le plus souvent organisée en lotis

B.2 Illustration graphique : THR

	THR1 – QB MS (	
- Pavillon	 dense	 moyen de

Emprise d'un bâtiment sur une image s

C. Description de l'objet dans l'image

C.1 Nature de l'objet

Objet physique – objet image simple identifiable à THR1

C.2. Définition textuelle

L'objet « pavillon » ou « maison individuelle » est représenté graphiquement par un polygone dont la surfac
correspond à l'emprise au sol du bâtiment.

C.3. Principales relations

Adjacence	Objets de type « végétation » Objets de type « autre route »
Alignement	oui
Distance entre barycentre = relation de voisinage	Faible = appartenance à une cité ouvrière Moyenne Elevée
inclusion	TU pavillonnaire HR1 et HR2

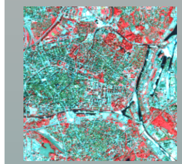
C.4. Attributs

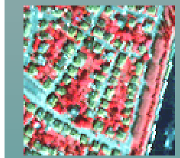
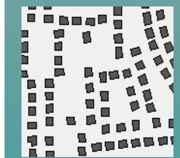
	Mineral – types possibles		
Signature spectrale	Blanc B1 : [56,6 – 255] avec histogramme de 0 à 255 B2 : [58,6 – 255] B3 : [36,6 – 255] B4 : [20,5 – 254,8] IBS : [55 – 255] NDVI : [16 – 65,25]	Gris B1 : [19,3 – 60] avec histogramme de 0 à 255 B2 : [14,3 – 60] B3 : [17,6 – 67] B4 : [14 – 67,3] IBS : [11,6 – 56,3] NDVI : [28 – 99]	Orange B1 : [21,7 – 62,35] avec histogramme de 0 à 255 B2 : [19,4 – 80,15] B3 : [29,7 – 135,1] B4 : [34,8 – 139] IBS : [14,6 – 60,1] NDVI : [50,2 – 108,3]
Longueur ou diamètre (m)	13 à 61		
Largeur (m)	7		
Périmètre	36 à 92		
Surface (m²)	82 à 437		
Indice de Miller	0,55 à 0,78		
Surface Poly Convex (Sc)	82 à 485		
Surface/Sc	0,85 à 1		

Indice de Morton	0.51 à 0.63
Texture (variance)	homogène

Ontology oriented 'images'

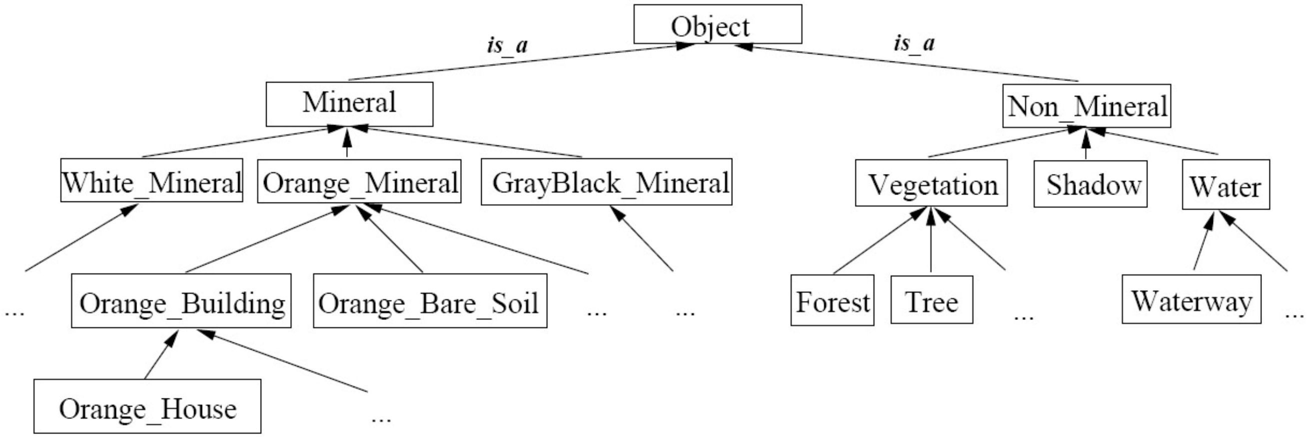
3. Phase of formalisation



- **Modelling and implementing the knowledge in a computer-usable form**

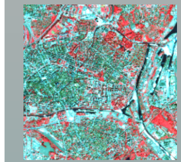
- **Extract of the ontology:**

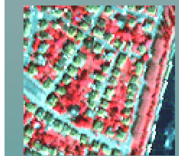
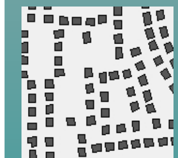


- **91 concepts, 20 attributes, depth (6)**

- **For each concept = a label**

'Orange_house' = individual houses with orange roof tiles



Ontology oriented 'images'

3. Phase of formalisation

- **Example of the concept 'Orange_House' :**

Class	Attribute name	Values
spectral	spectral_signature_Blue	[21.7-62.3]
	spectral_signature_Green	[19.4-80.1]
	spectral_signature_Red	[29.7-135.1]
	spectral_signature_NearInfaRed	[34.8-139]
	spectral_signature_SBI	[14.6-60.1]
	spectral_signature_NDVI	[50.2-108]
spatial	diameter(m)	[13-61]
	area (m^2)	[10-600]
	perimeter (m)	[28-116]
	elongation (m)	[1-3.1]
	Miller index	[0.5-0.8]
	Solidity index	[0.85-1]

Matching process

Step 1: Matching score

- **based on a similarity measure between the features of a region and the characteristics of a the concepts**

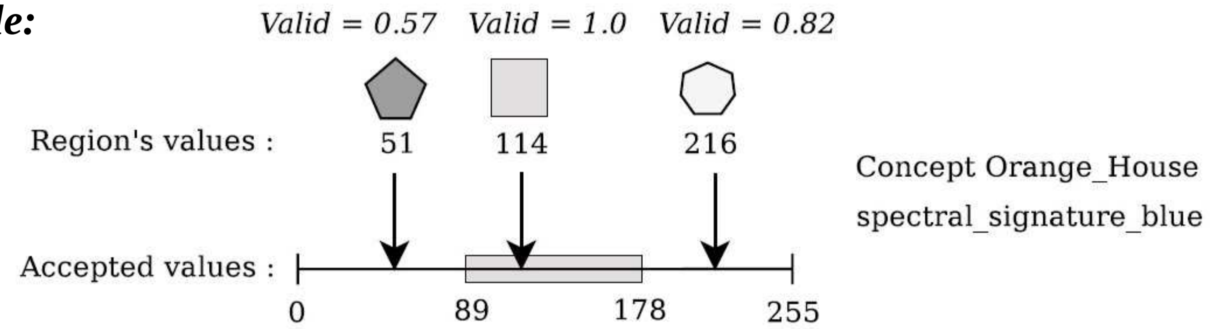
- **with a local component representing the inner properties of the concept and a global component evaluating the pertinence in the hierarchy of concepts**

Degree of validity:

Let Valid(a,C,R) be the validity degree of an attribute 'a' between a region R and a concept C

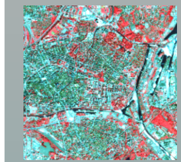
$$Valid(a,C,R)=\begin{cases}1 & \text{if } V'_R(a)\in[\min(V_C(a));\max(V_C(a))]\\ \dfrac{V'_R(a)}{\min(V_C(a))} & \text{if } V'_R(a)<\min(V_C(a))\\ \dfrac{\max(V_C(a))}{V'_R(a)} & \text{if } V'_R(a)>\max(V_C(a))\end{cases}$$

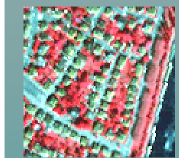
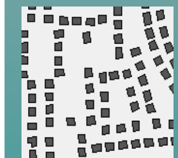
Example:



Matching process

Step 1: Matching score



- **The local similarity measure compares the features of a region with the attributes of a concept**

Local similarity:

Let be Simα(R,C) the local similarity between a region R and a concept C using the attributes of each class in α.

$$Sim_{\alpha}(R,C) = \frac{\sum_{a \in F_{\alpha}(C)} \omega(a,C) Valid(a,C,R)}{\sum_{a \in F_{\alpha}(C)} \omega(a,C)}$$

- **The global score measure evaluates the pertinence of the matching in the hierarchy of concepts**

Matching score:

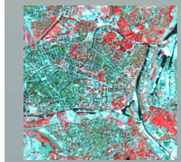
Let Score$_{\alpha}$(R,C) be the matching score between a region R and a concept C, and P(C) be the path starting from the root of the ontology and ending at the concept C.

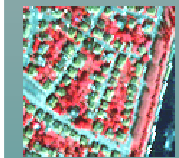
$$Score_{\alpha}(R,C) = \frac{\sum_{C_j \in P(C)} \rho(C_j) Sim_{\alpha}(R,C_j)}{\sum_{C_j \in P(C)} \rho(C_j)}$$

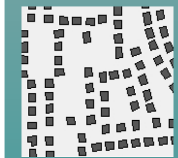
ρ is the depth of the concepts

Matching process

Step 2: Navigation in the ontology







- **Objective = navigate in the ontology to find the best concept(s) according to the score for a region**

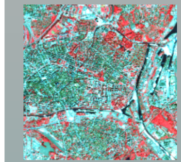
- **Level-wise algorithm developed to navigate in the ontology using heuristics to reduce the search space**

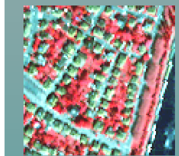
- **With two thresholds :**

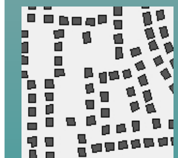
  - *maxDepth* is the exploration maximal depth (e.g. the degree of detail)
  - *minScore* is the minimal value of the matching score between a region and a concept to allocate the corresponding label to the region

Matching process

Step 2: Navigation algorithm







Algorithm 1 Navigation algorithm of the ontology.

Input: a region R, an ontology $(\Theta, \Phi, \mathcal{V}_C(a), \ldots)$, a set of attribute classes (α), $maxDepth$ and $minScore$.

Output: the best label(s) and the matching score value.

$depth = 1;\quad scoreMax = minScore;$
$\mathcal{L}_\alpha(R) = \emptyset;$
$\mathcal{RC} = \{root\};\quad scoreDepth = 0;\quad bestsDepth = \emptyset;$
while $(\mathcal{RC} \neq \emptyset$ and $depth \leq maxDepth)$ **do**
  $scoreDepth = 0;\quad Best = \emptyset;$
  for all $C \in \mathcal{RC}$ **do**
    $s = Score_\alpha(R, C);$
    if $(s == scoreMax)$ **then**
      $\mathcal{L}_\alpha(R) += \{C\};$
    end if
    if $(s > scoreMax)$ **then**
      $\mathcal{L}_\alpha(R) = \{C\};\quad scoreMax = s;$
    end if
    if $(s == scoreDepth)$ **then**
      $bestsDepth += \{C\};$
    end if
    if $(s > scoreDepth)$ **then**
      $bestsDepth = \{C\};\quad scoreDepth = s;$
    end if
  end for
  $\mathcal{RC} = \emptyset;$
  for all $C_j \in bestsDepth$ **do**
    $\mathcal{RC} = \mathcal{RC} \cup \{C_i | C_i \preceq_\Theta C_j\};$
  end for
  $depth++;$
end while
return $\{\mathcal{L}_\alpha(R),\ score\};$

Experiments on VHR images

- **Area of Strasbourg (France) – urban fabric with individual houses**
- **Quickbird image (pan-sharpened image with 0.7m spatial resolution) with four spectral bands**
- **Test only with some concepts** (*vegetation, water, orange house, road*)
- **Validation with a manually labeled map**

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Experiments on VHR images

Step 1: Segmentation

- Importance of the algorithm of segmentation (research in progress by Sebastien Derivaux)

Step 2: Matching and results

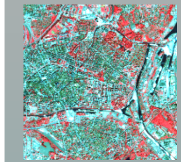
Quickbird image

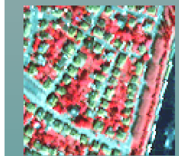
Segmented image

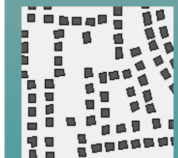
Recognized objects
In white = unknown object

Experiments on VHR images

Step 3: Results assessment







Values of Precision, Recall and F-measure (on/in overall, all classes) for several minScore values

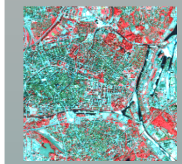
minScore	Precision	Recall	F-Measure
0.85	0.878	**0.861**	0.870
0.9	0.893	0.854	0.873
0.98	0.954	0.823	**0.884**
1	**0.967**	0.771	0.858

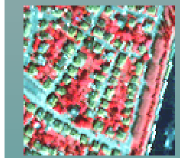
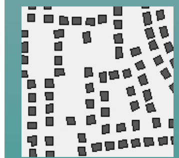
Compared results between minScore = 1 and minScore = 0.98.

classes	Precision		Recall	
	1	0.98	1	0.98
Orange_House	0.895	0.875	0.435	0.585
Vegetation	0.995	0.994	0.950	0.953
Road	0.980	0.947	0.712	0.762
Water	0.999	0.999	0.988	0.995

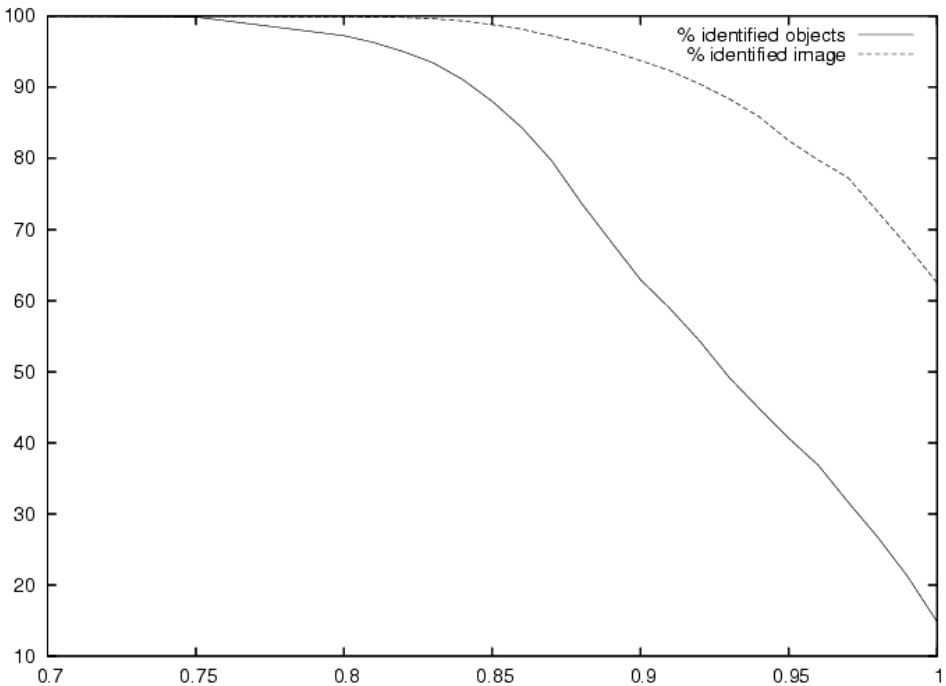
Experiments on VHR images

Step 3: Results assessment



Percentage of recognized objects according to the *minScore* value, and the percentage of the corresponding image (pixels of the recognized objects) according to the *minScore* value



Conclusion and perspectives

- Experiment results have shown effectiveness of the method, despite the fact that the results could be improved with more attention on the segmentation algorithms
- Automatic extraction of knowledge could be done by machine learning system to enrich the ontology
- Topological relations based on the RCC-8 (Region Connection Calculus) theory will also be integrated
- Incorporation in a multi-strategy classification approach in order to guide the process, to label the clusters, and to improve the final classification results

ACI MD 'FoDoMusT' (2004-2007)

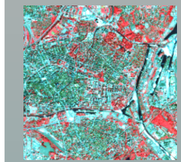
"FOuille de DOnnées MUlti-STratégie pour extraire et qualifier la végétation urbaine à partir d'une banque de données images"

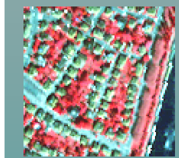
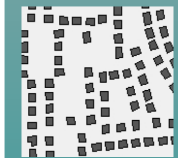
http://lsiit.u-strasbg.fr/afd/sites/fodomust/fr-accueil.php

image et ville

LSiiT Apprentissage et fouille de données

ERIC LABO ÉQUIPE DE RECHERCHE EN INGÉNIERIE DES CONNAISSANCES



Thanks for your attention !