Modelling Tools for Environmental Data

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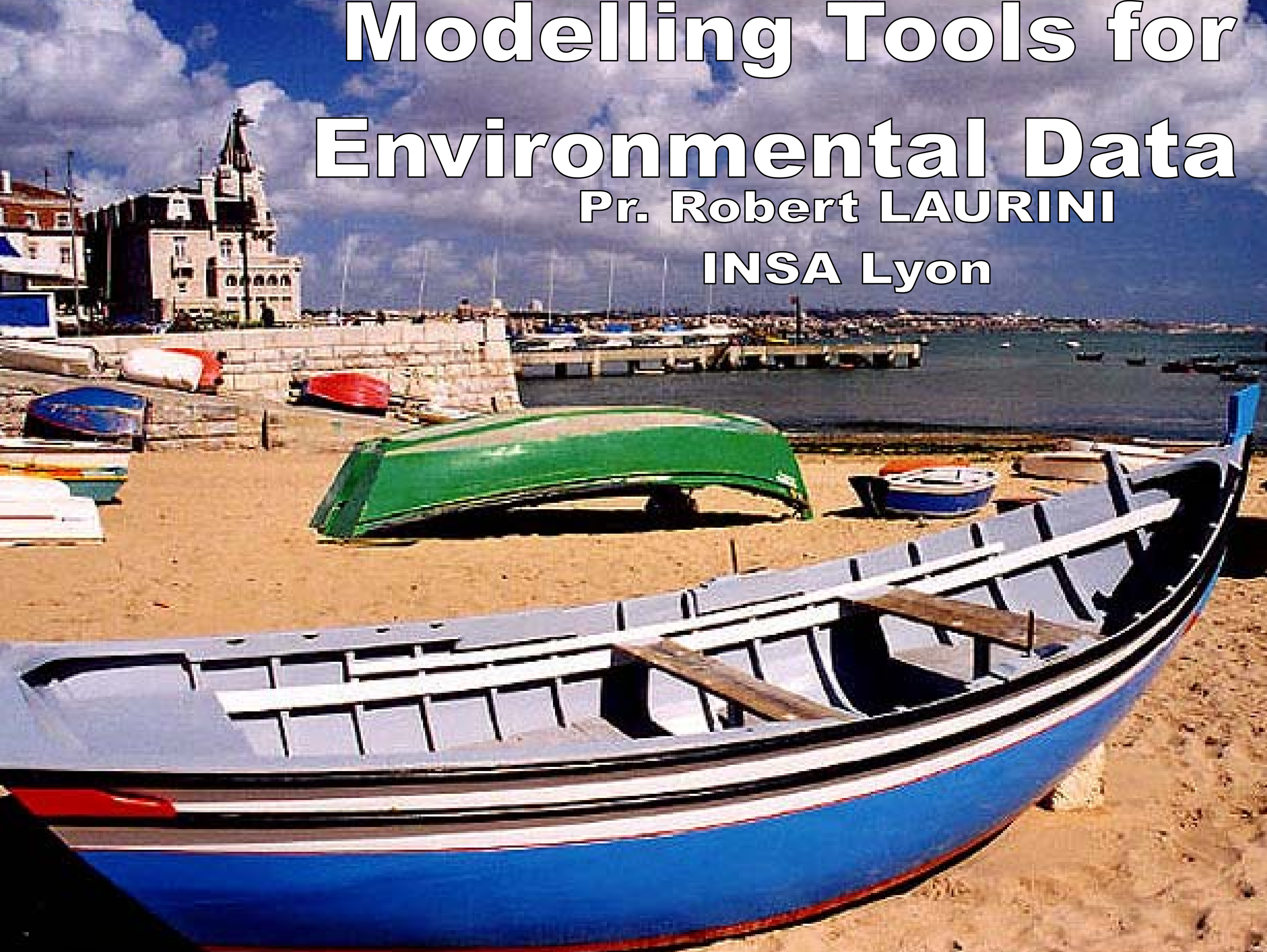
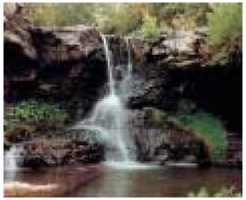






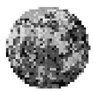


Disciplines

- Ecology
- Atmosphere
- Landscape
- Geology
- Hydrology
- Oceanography
- Study of pollution (air, water, etc.)
- etc.

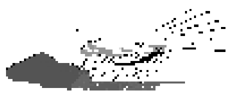
SCALE PROCESS

GLOBAL



- insulation → controls primary energy inputs to climate and weather patterns

MESO

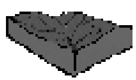


- prevailing weather systems
- elevation-driven lapse rates

} controls longterm mean monthly climate

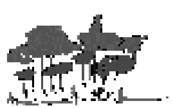
- geological substrate → exerts control on soil chemistry

TOPO



- surface morphology → controls catchment hydrology
- slope, aspect, horizon shading → controls surface insolation

MICRO



- vegetation canopy → controls light, heat, water for understorey
- vegetation, structure and plant physiognomy → nutrient conservation and storage

NANO

- soil microorganisms → control nutrient recycling

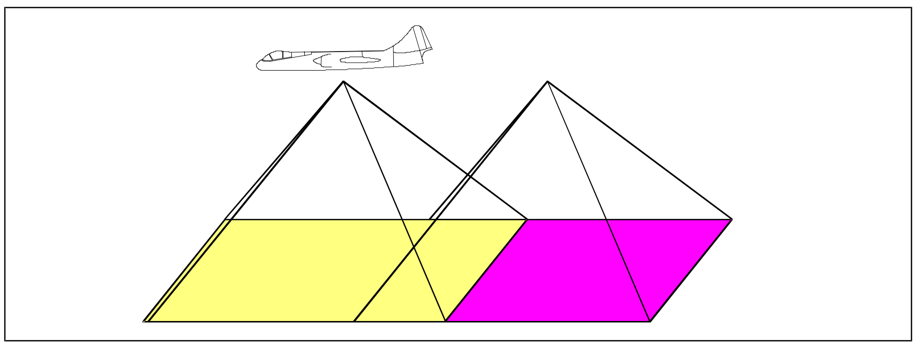
http://www.sbg.ac.at/geo/idrisi/gis_environmental_modeling/sf_papers/brendan_mackey/mackey_paper.html

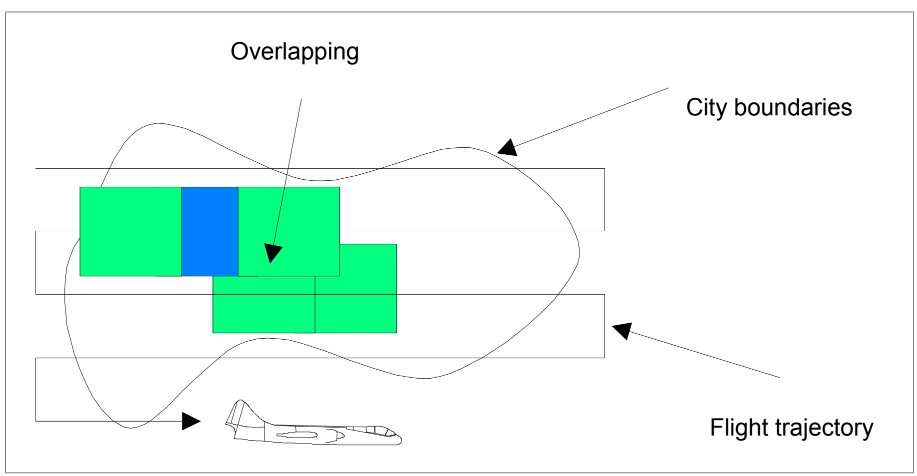
Contents

1 – Data acquisition

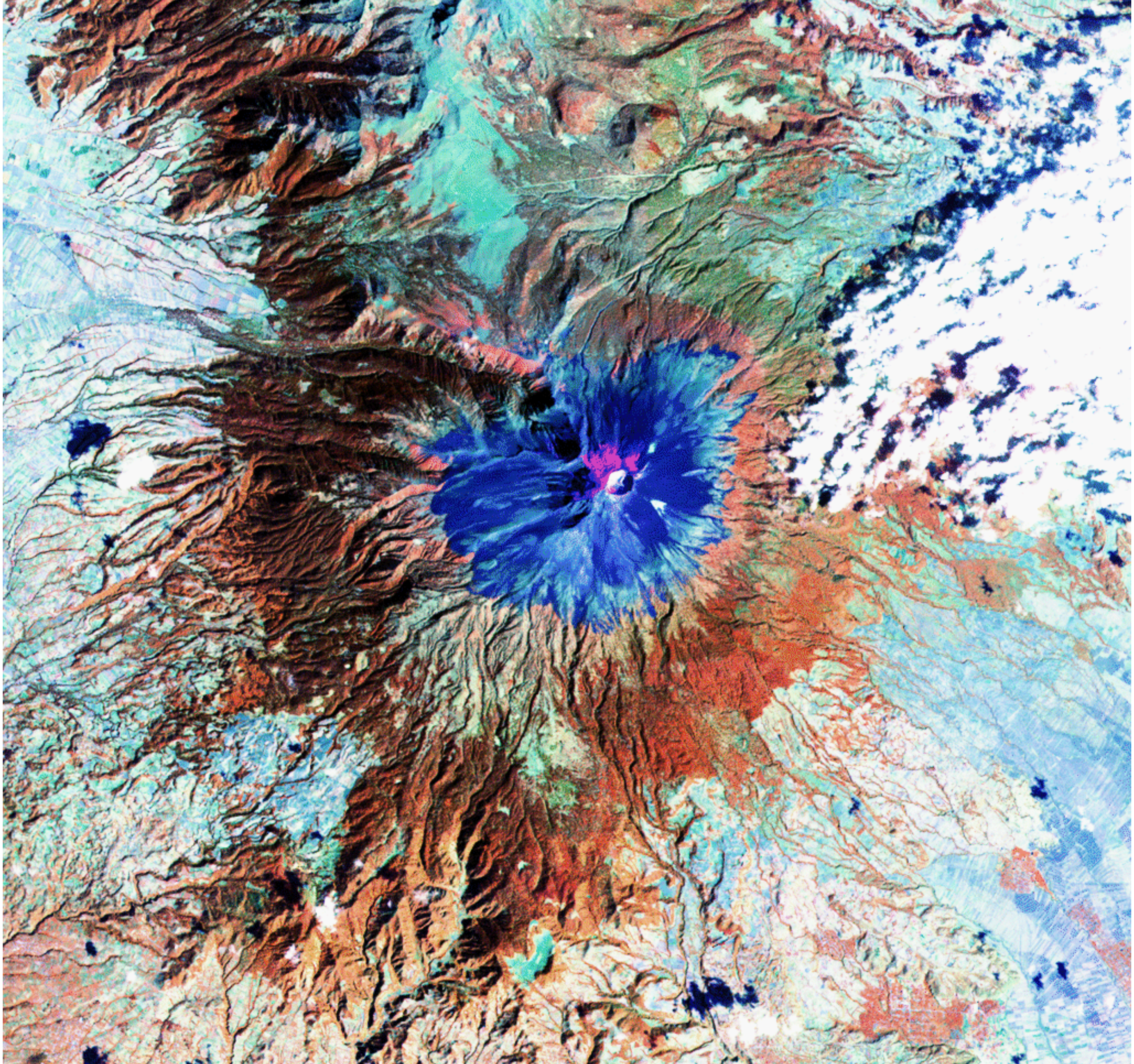
– Aerial photos
– Satellite images
– Laser
– GPS
– Sensors
– Voice
– etc.

Aerial photos





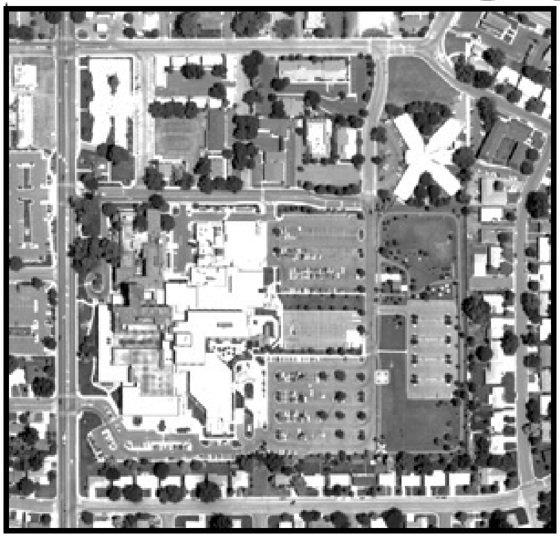
Example



Aerial photos Characteristics

- altitude : from 5 00 to 3,000 meters
- format 23 cm × 23 cm
- Scale from 1:3,000 to 1:25,000
- photos pair ➔ relief
- Parallaxes ➔ determination of altitudes
- Photo-interpretation
- Orthophotos (mosaicking)

Comparison of Aerial Photographic Resolutions



One Meter

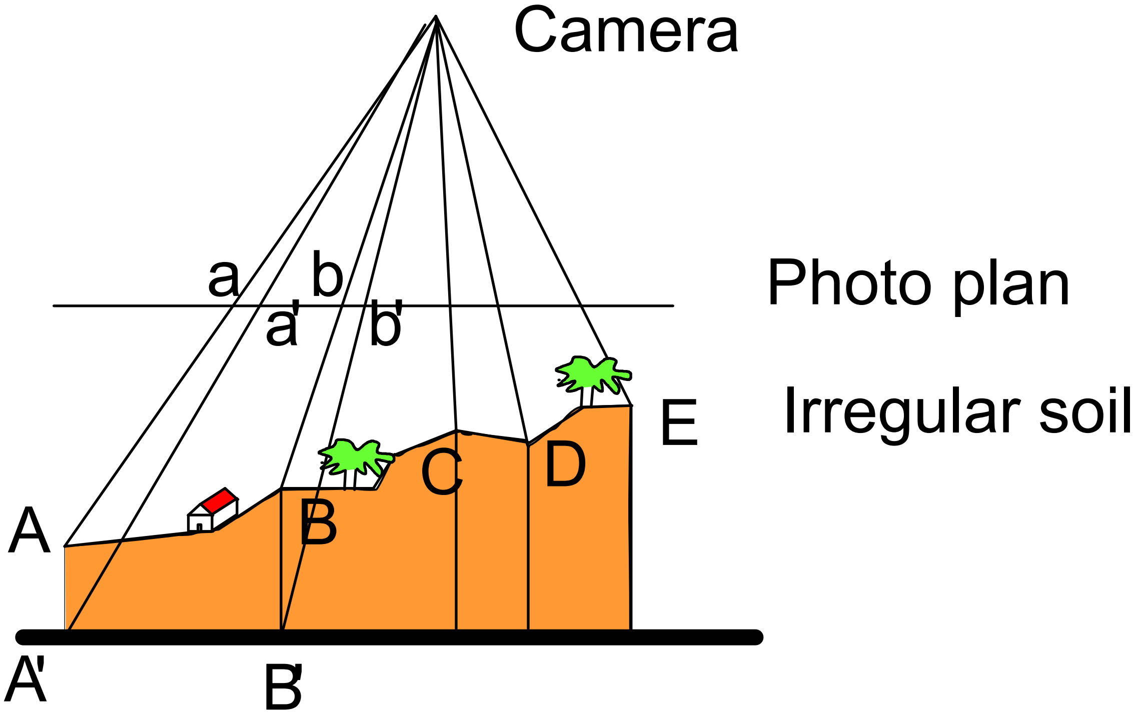
Three Meter

Six Meter

Ten Meter

Scale 1:24 000

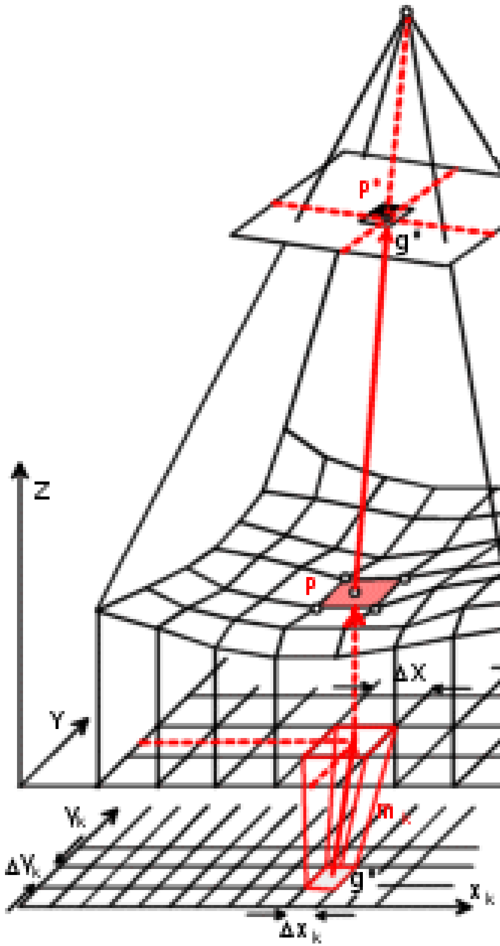
Distortions



Realization of orthophotos

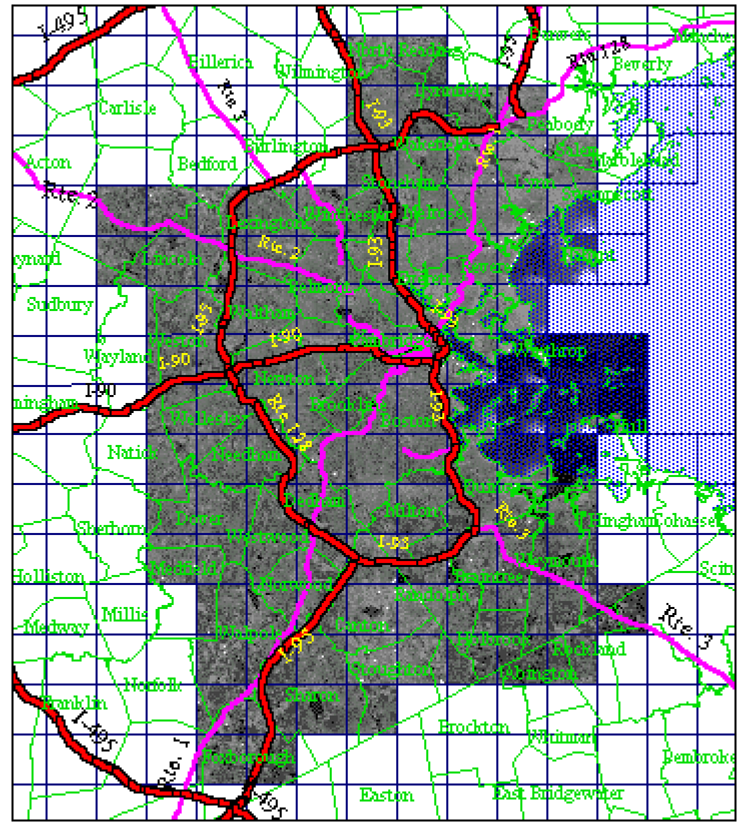
- Overlap : 60 % longitudinal
- 25 % latéral
- Selecting control points
- Elastic transformation (rubber sheeting)
- Corrections of distortions
- Cutting along roads or rivers

Orthophoto principles

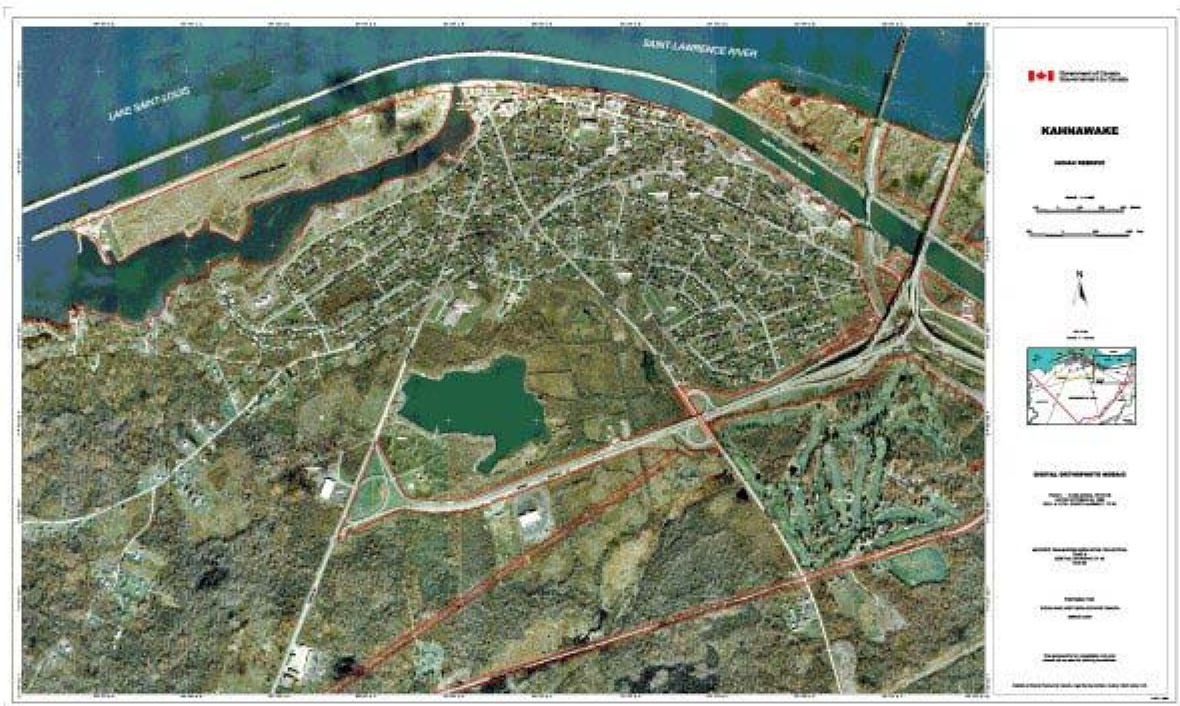


Original image

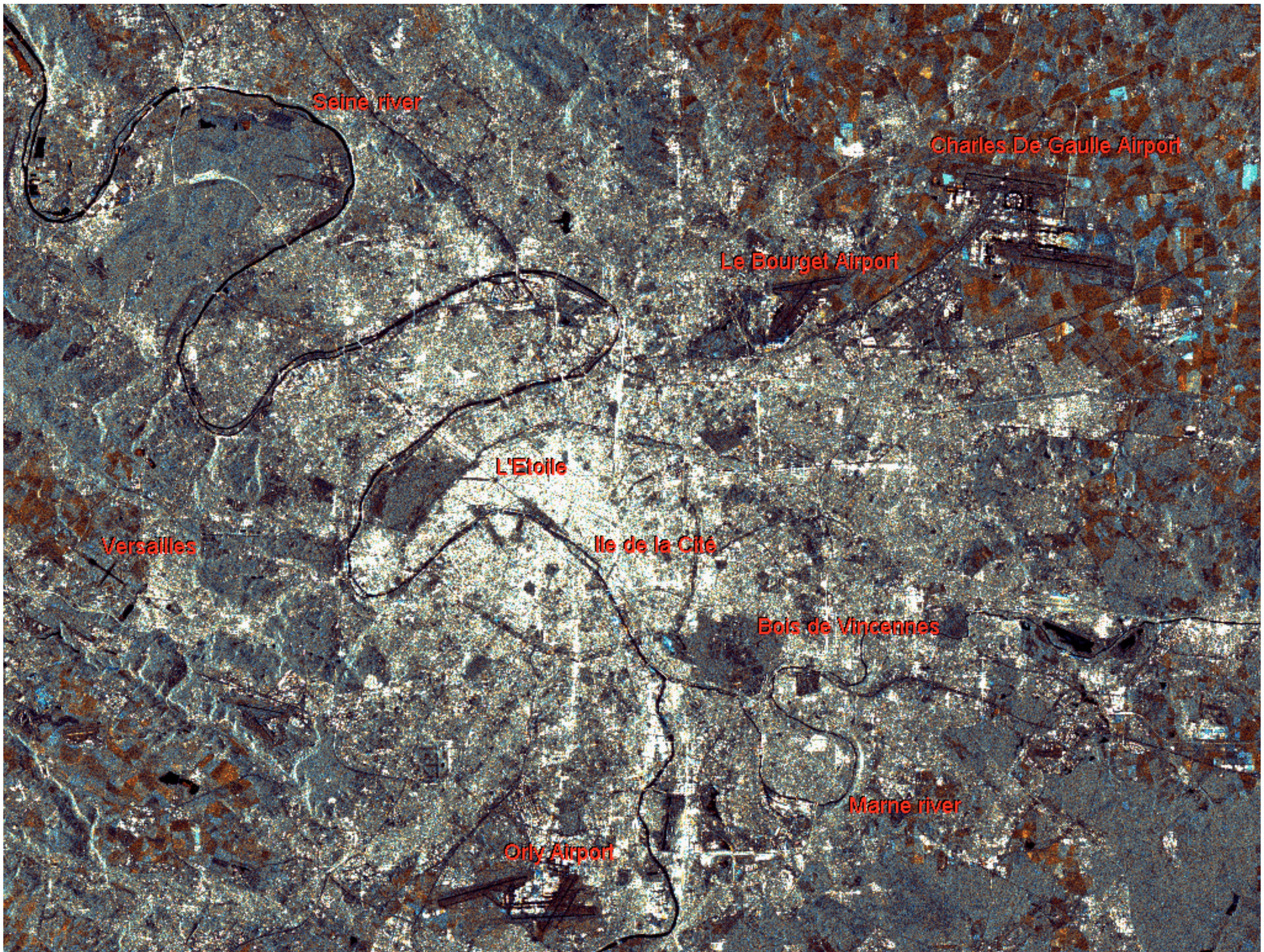
Ortho image



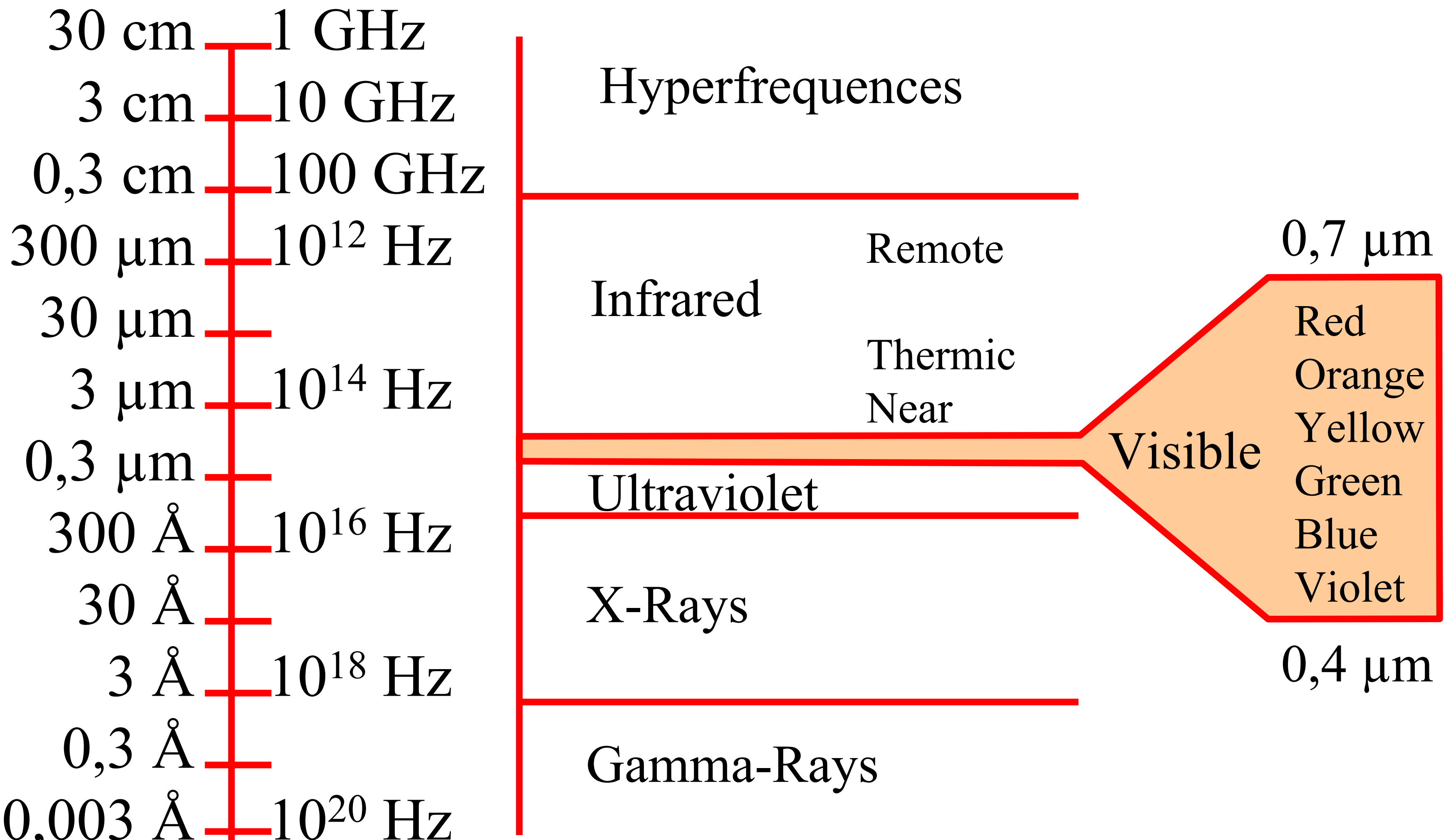
Orthophoto (result)



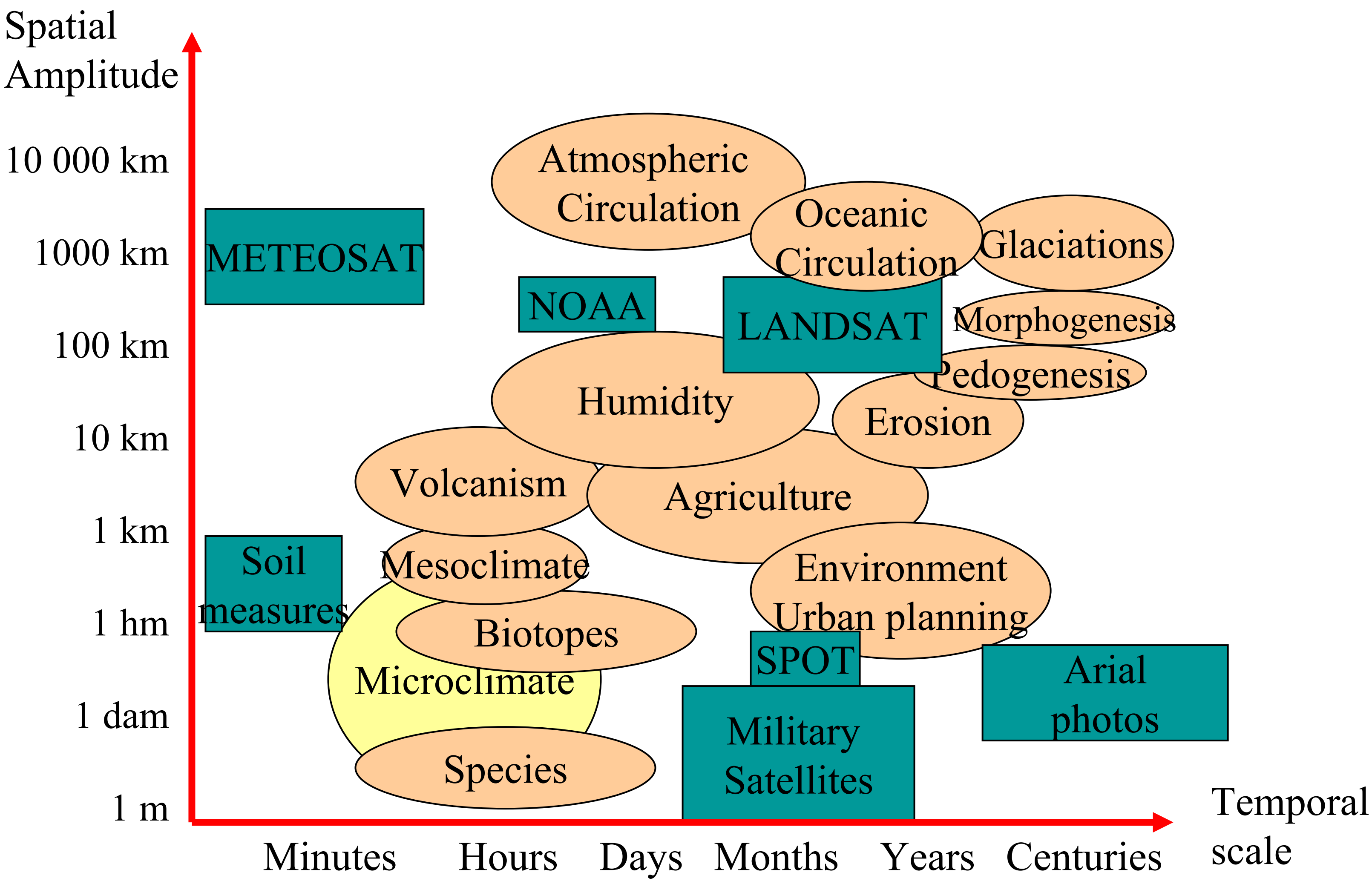
Satellite image



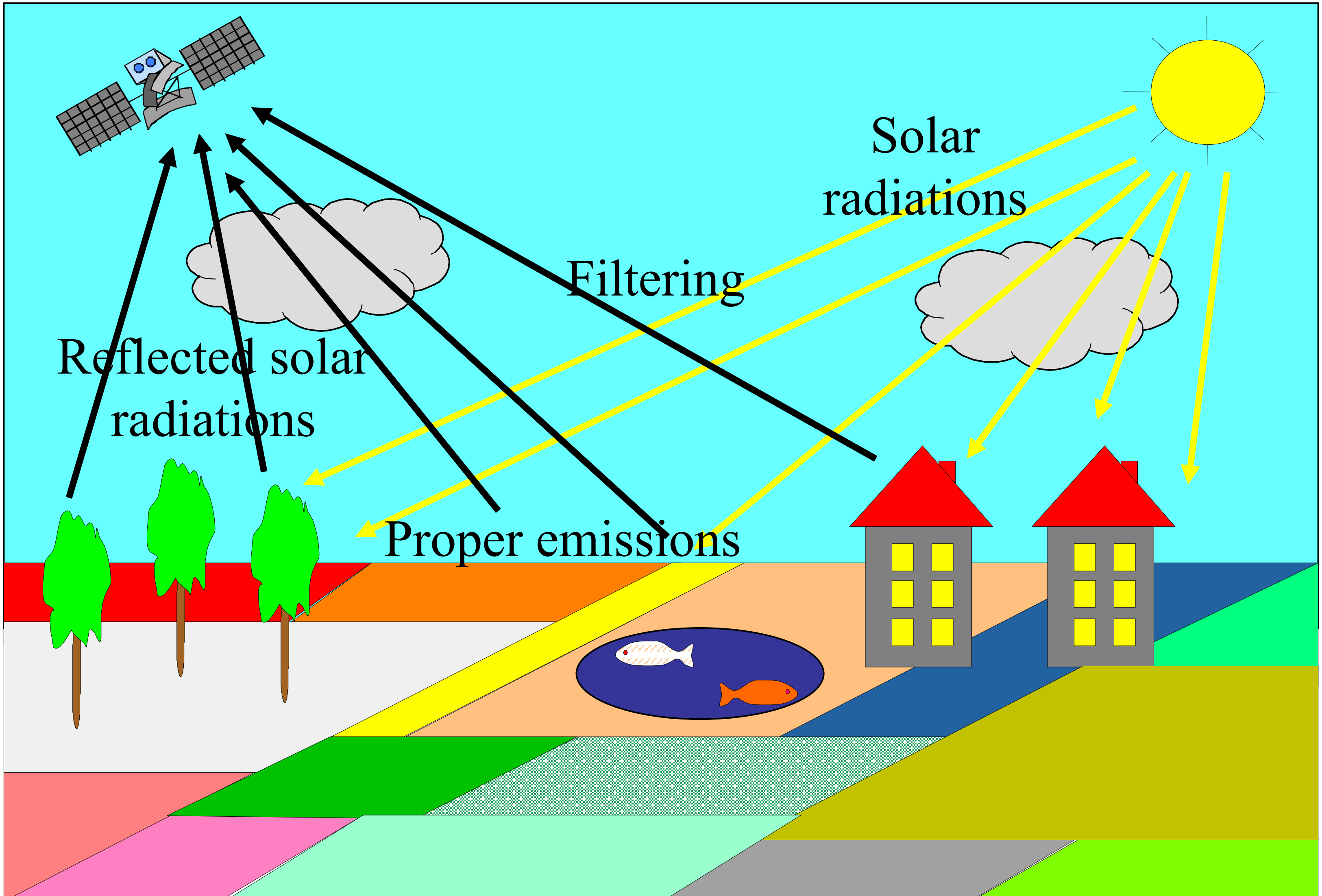
Waves

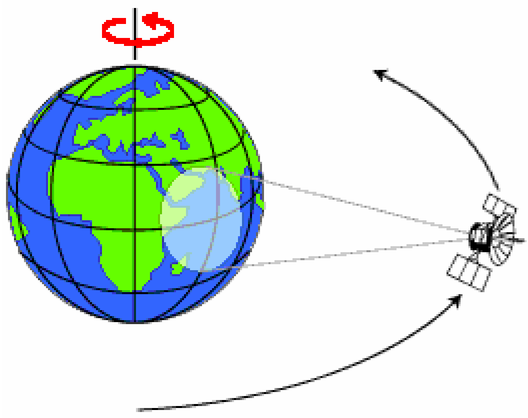

30 cm
1 GHz
3 cm
10 GHz
0,3 cm
100 GHz
300 µm
10^12 Hz
30 µm
3 µm
10^14 Hz
0,3 µm
300 Å
10^16 Hz
30 Å
3 Å
10^18 Hz
0,3 Å
0,003 Å
10^20 Hz
Hyperfrequences
Infrared
Remote
Thermic
Near
Ultraviolet
X-Rays
Gamma-Rays
Visible
0,7 µm
Red
Orange
Yellow
Green
Blue
Violet
0,4 µm

Satellites and usage



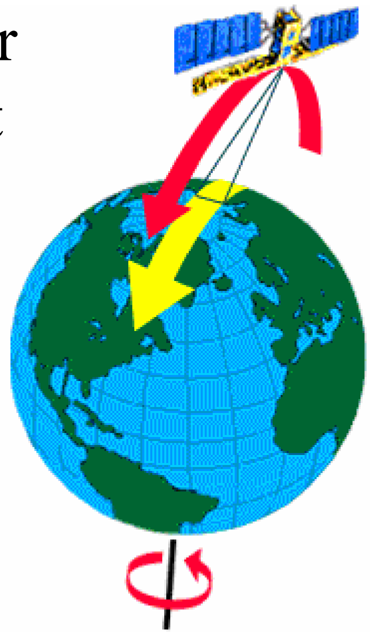
Remote sensing principles

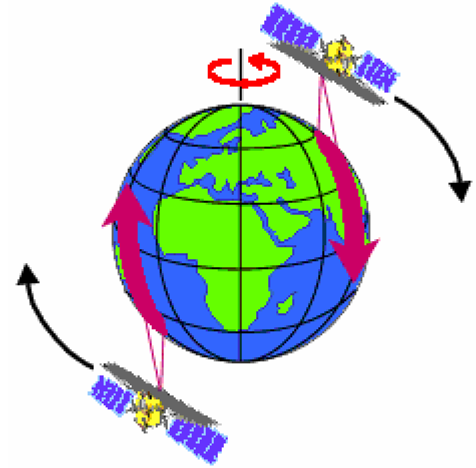




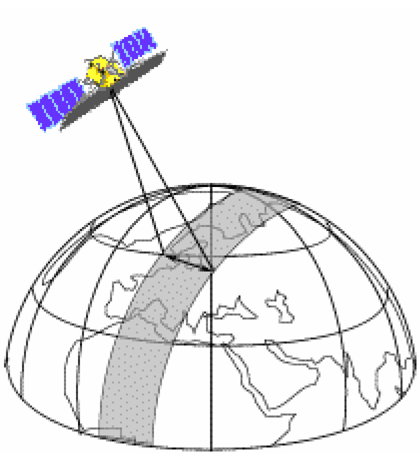
Geostationary orbit

Polar orbit

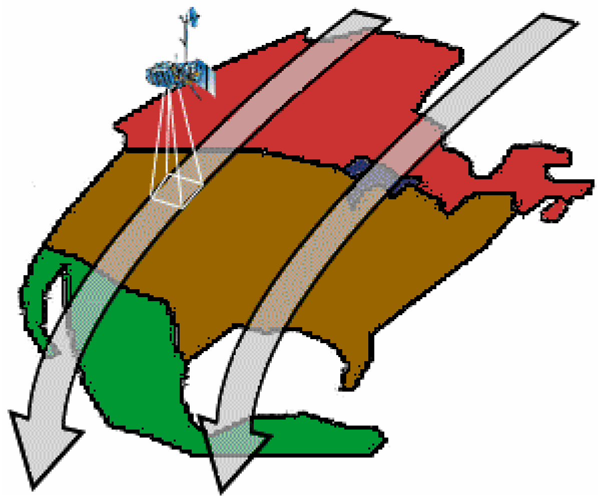




Phases



Tracking

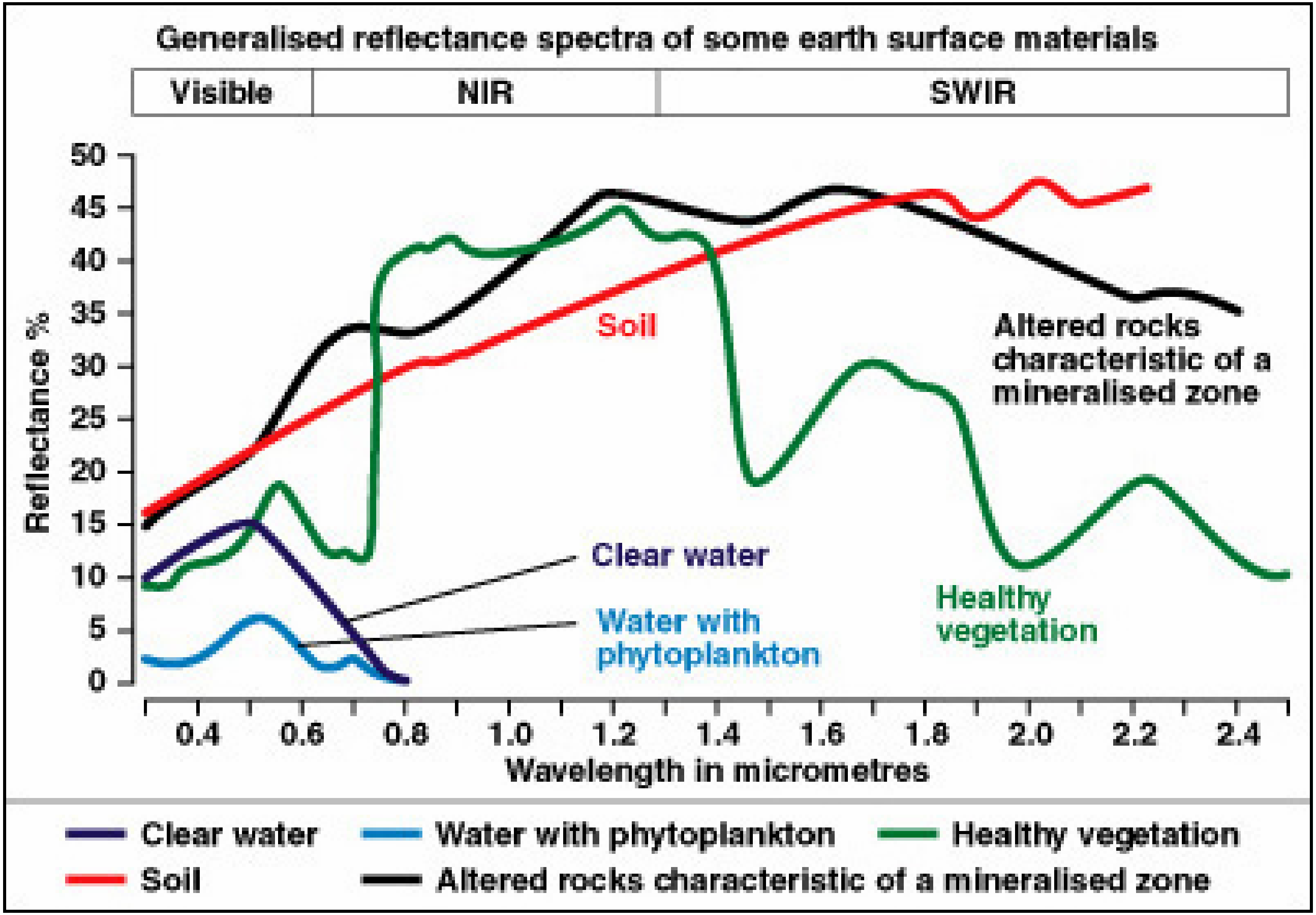


Subsequent passages

http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/chap2/c2p2e.html

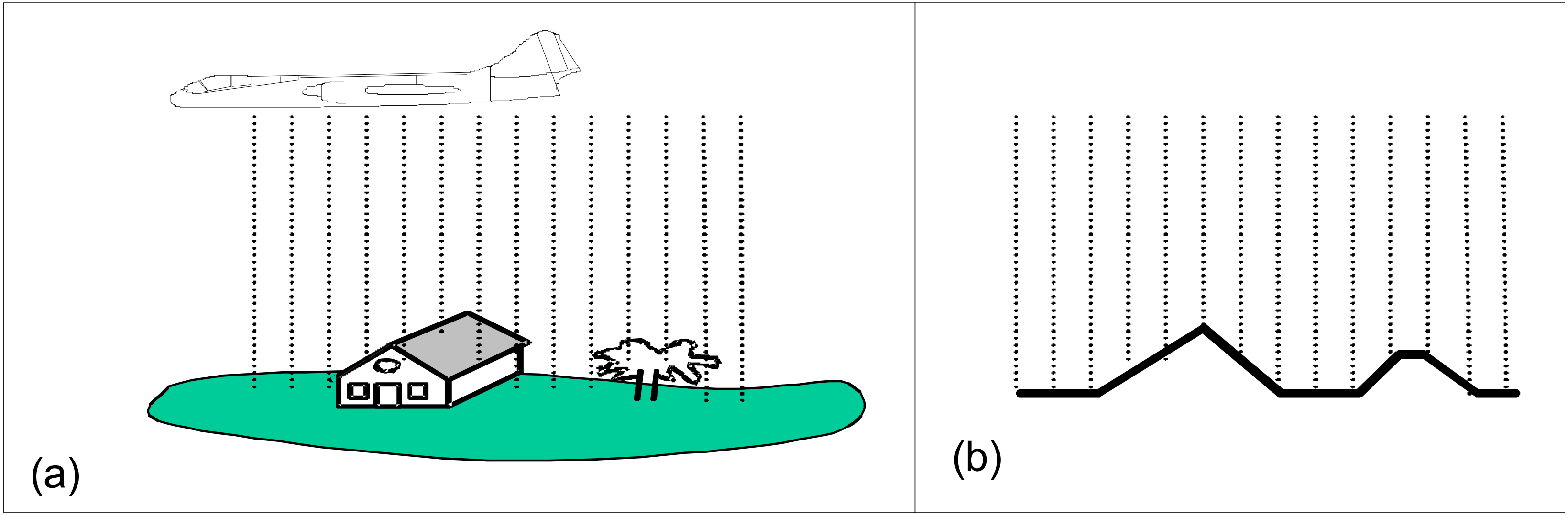
Spectral signature

http://www.rsacl.co.uk/remote_sensing/main.htm

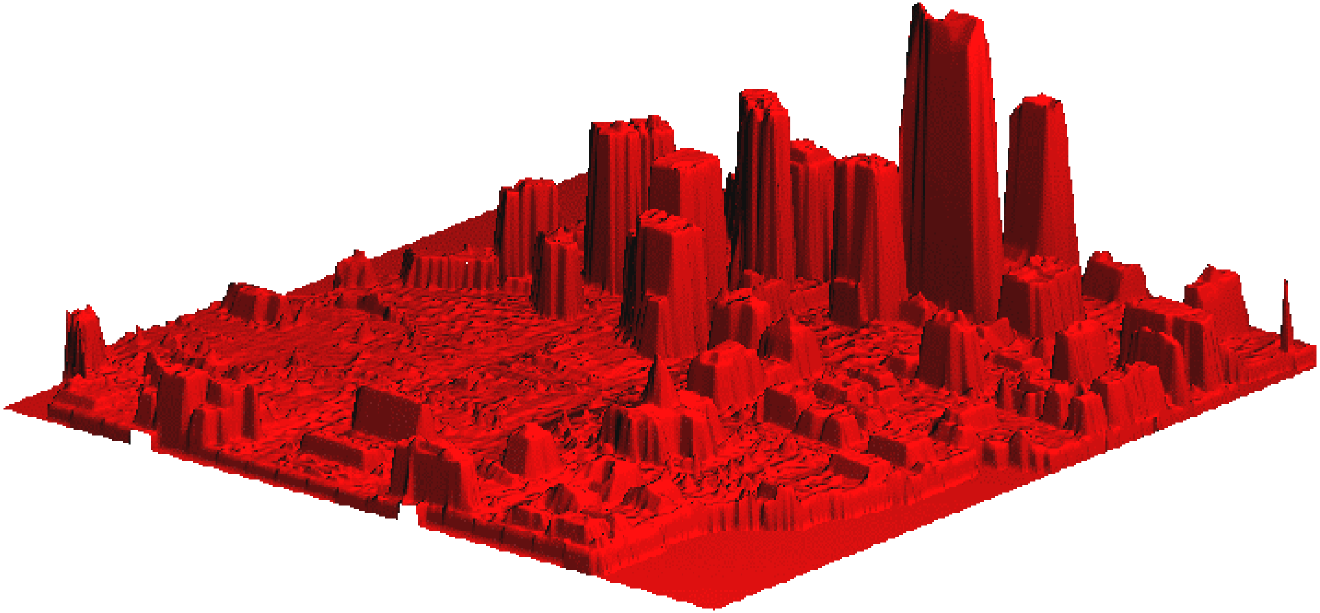


Ikonos

Laser range principle

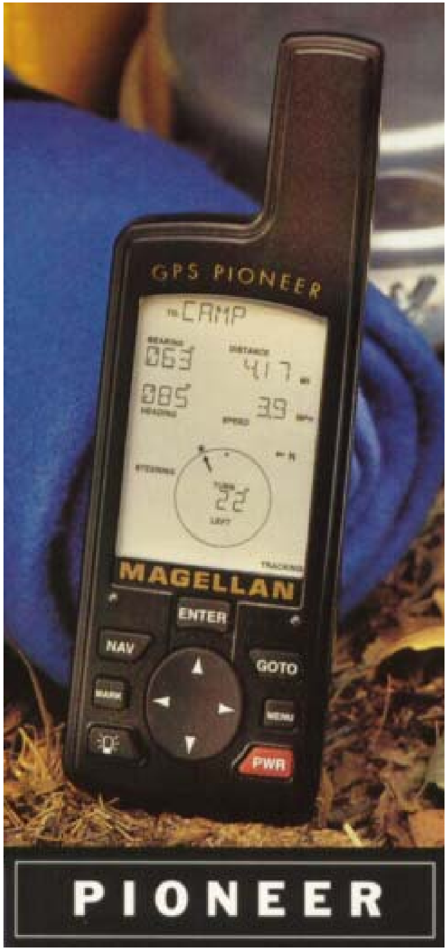


Laser range scanning

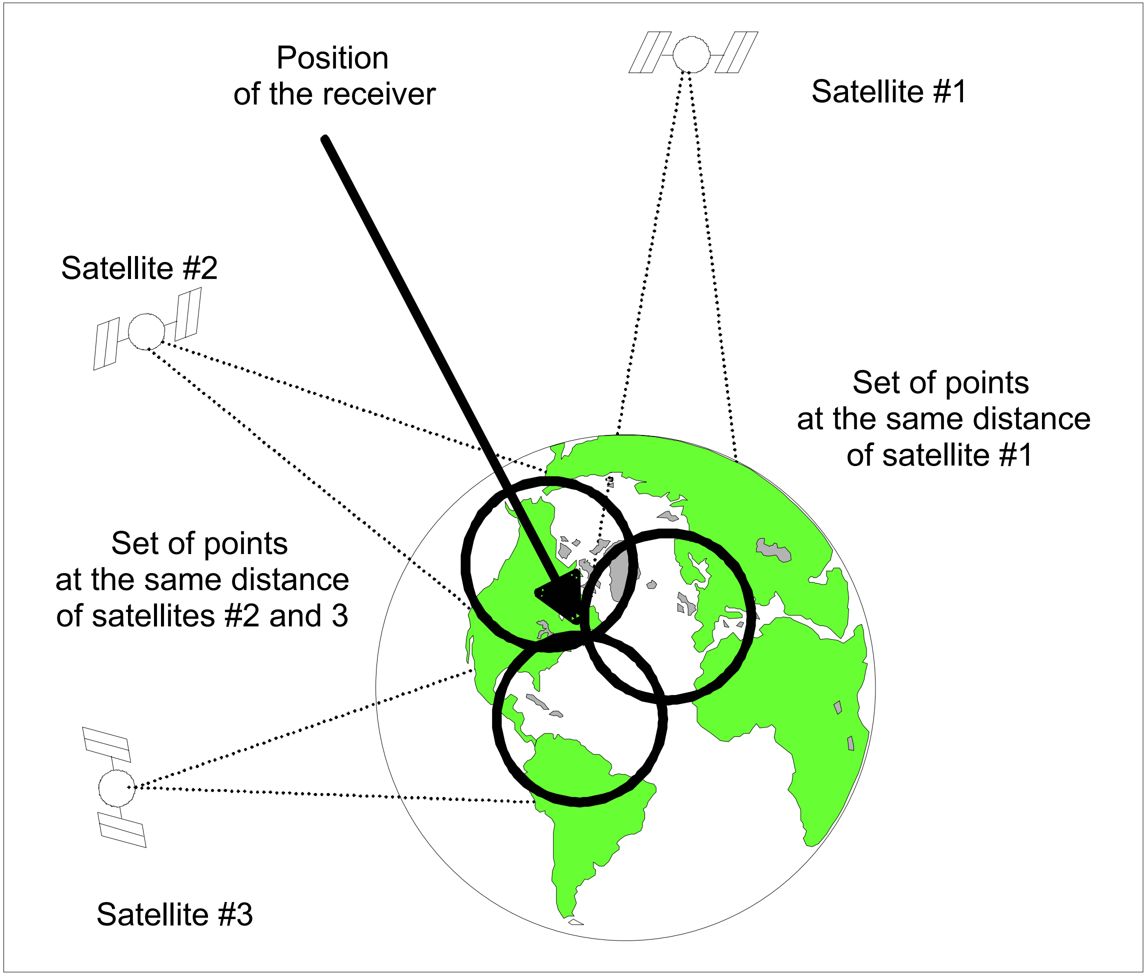


3-METER RESOLUTION

Global Positioning System



Principles of GPS



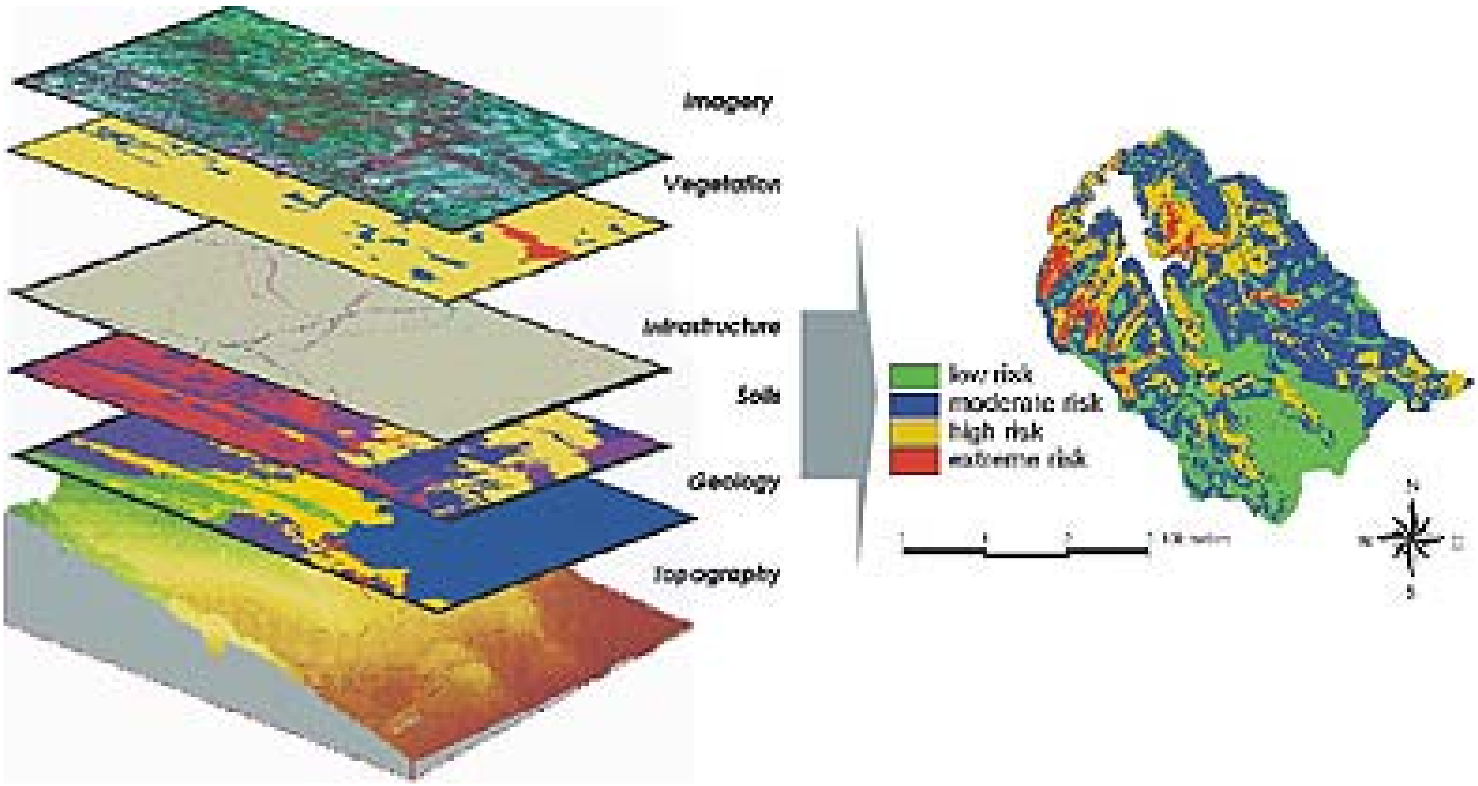
Voice Technology

- Provided by Datria / Stantec
- GPS-positioned messages are stored into computers
- Interesting for example to describe certain situations

2 – Environmental data modelling

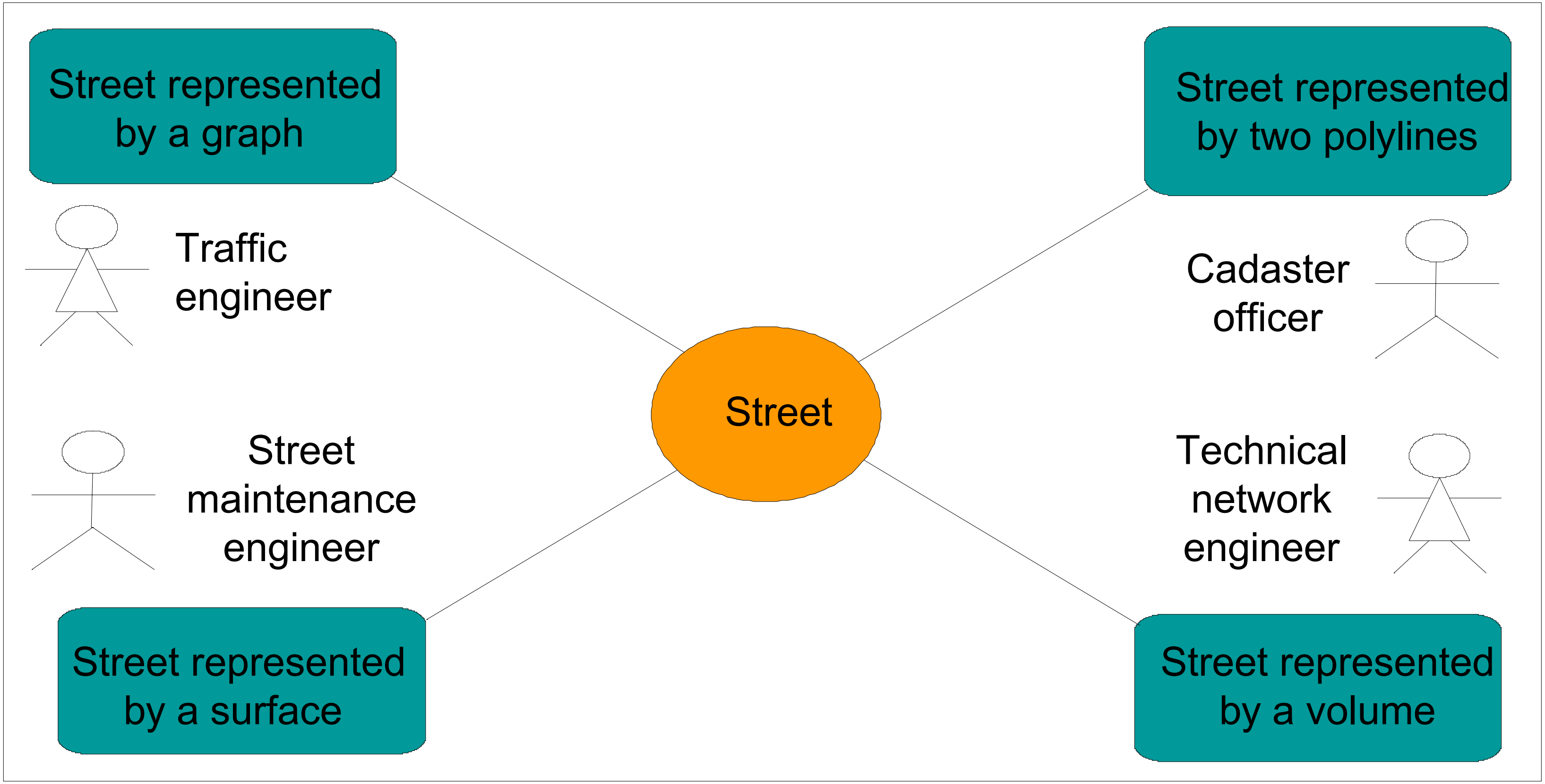
- Generalities
- Vector modelling
- Raster modelling
- Other representation tools

Data layers

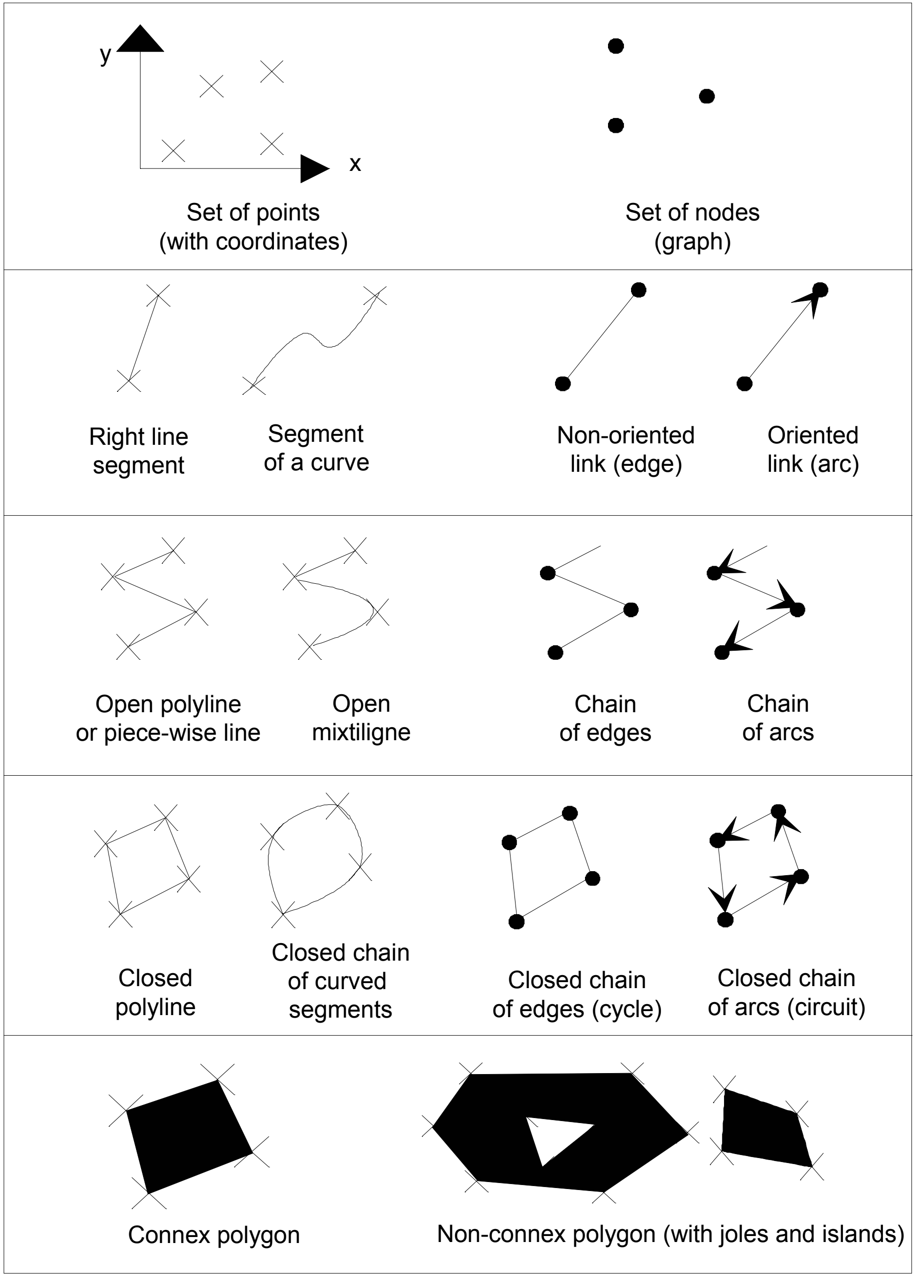


http://www.waite.adelaide.edu.au/spatial/4774.html

Multiplicity of representations



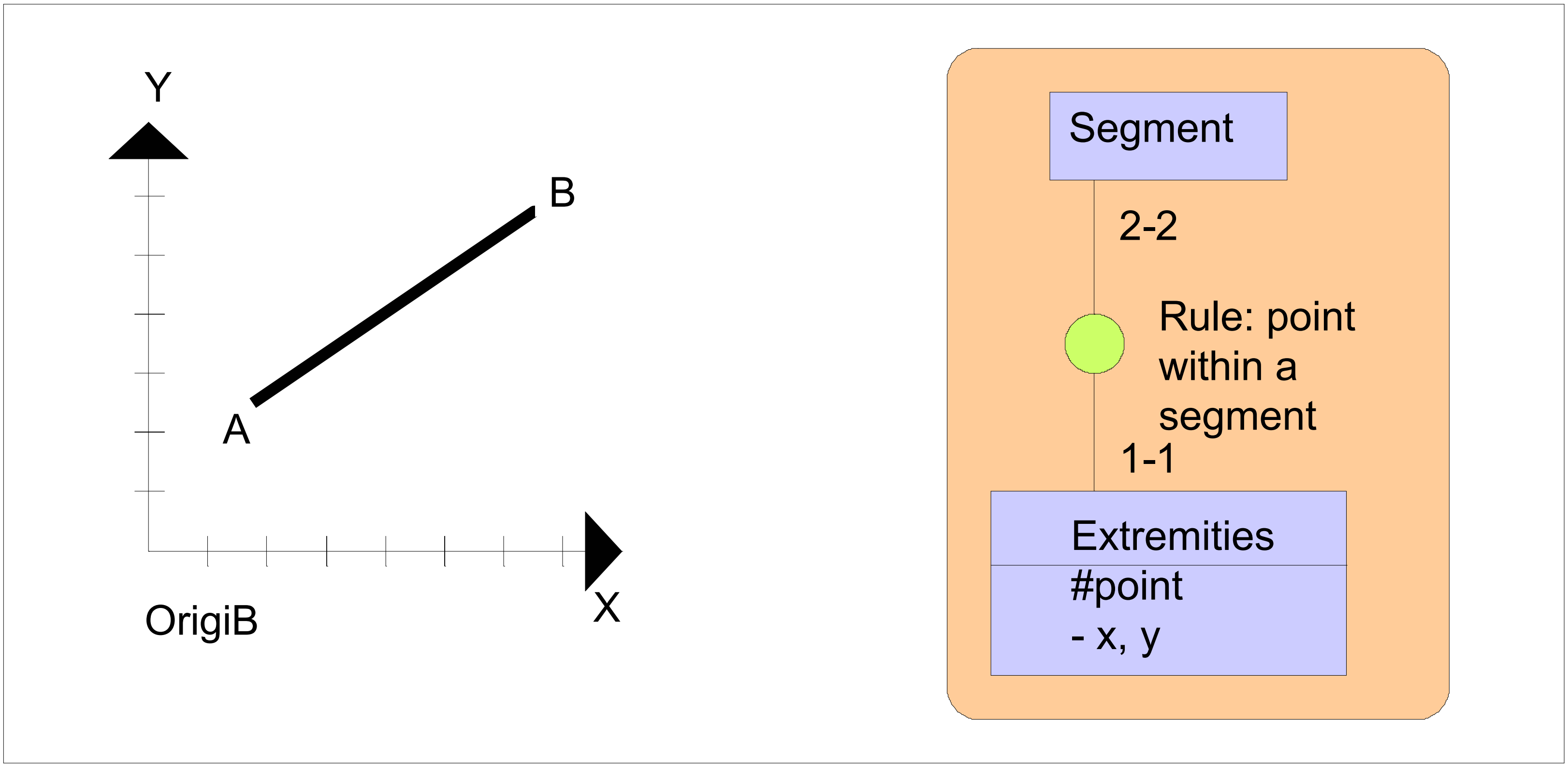
Structure and topology



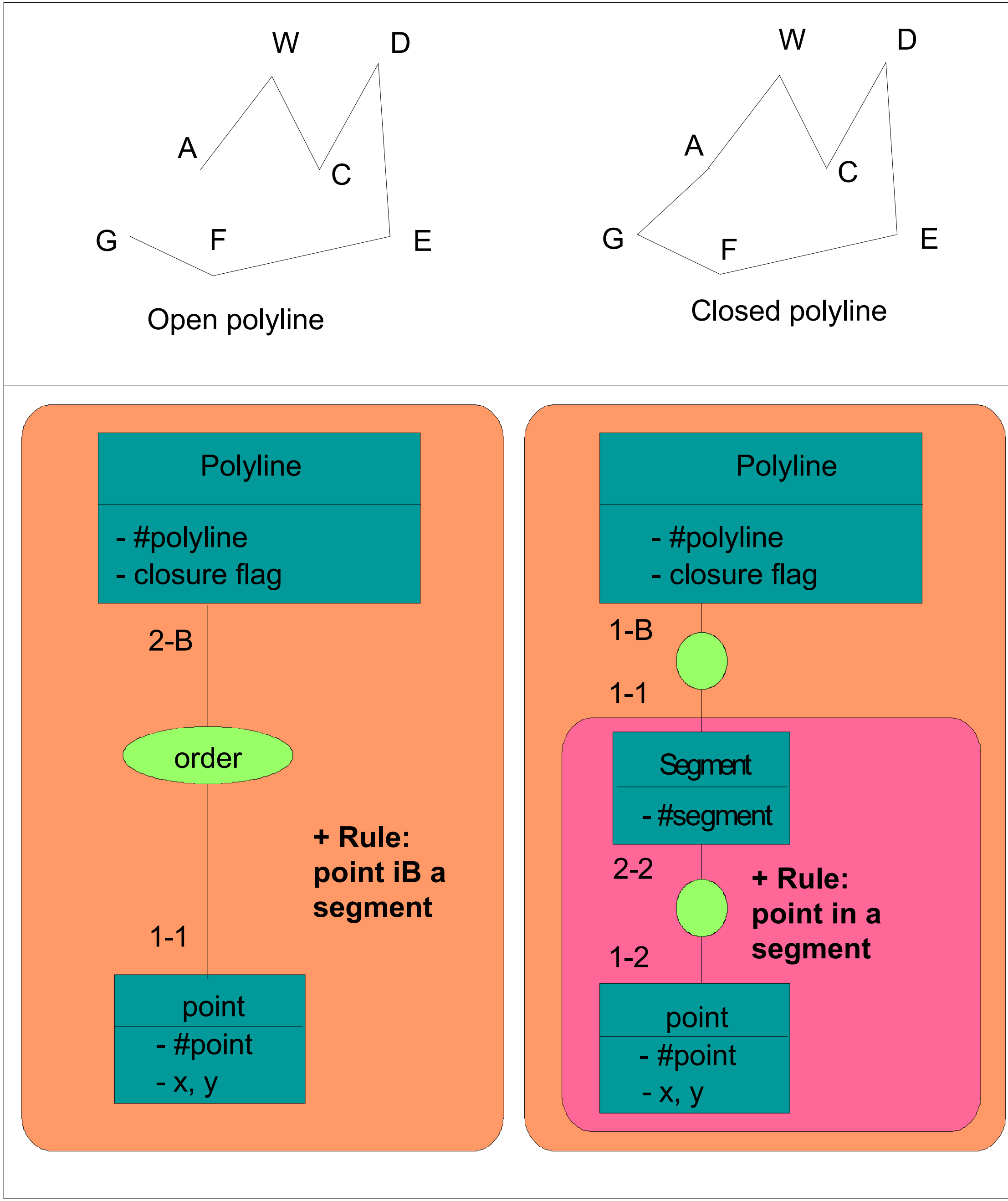
Vector modelling

- Modelling segments, polylines and mixtilines
- Modelling polygons
- Modelling terrains

Model of segment



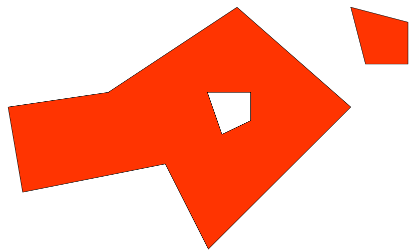
Model for polylines



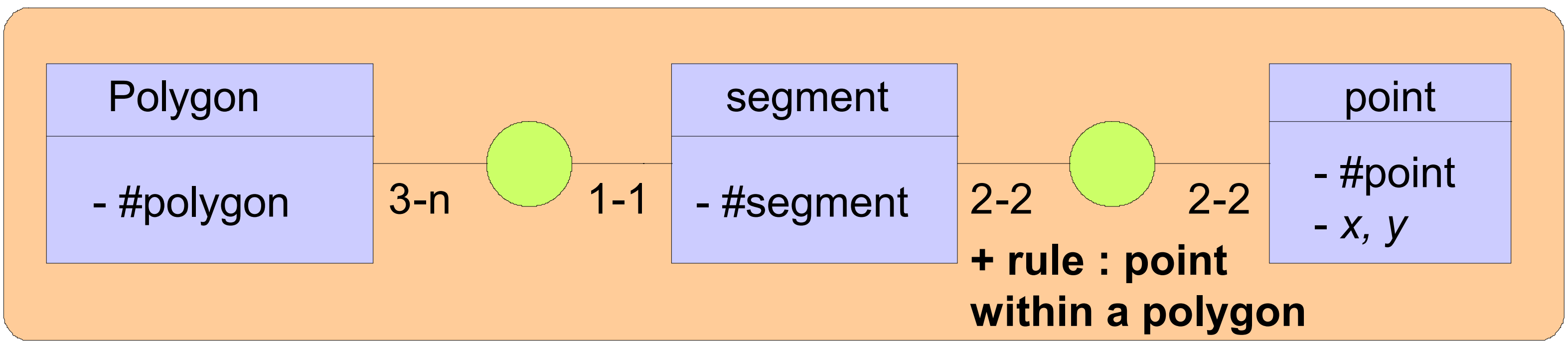
Polygon modelling

- Simple isolated polygon
- Complex isolated polygons
- Irregular tessellations
- Polygons limited by polylines
- Tesellation limited by mixtilines
- Orientating polygons within a tessellation
- Hierarchical organization of territories

Complex isolated polygon (non-connex) (segments)

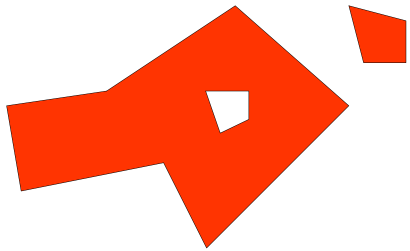


Isolated polygon with holes and islands

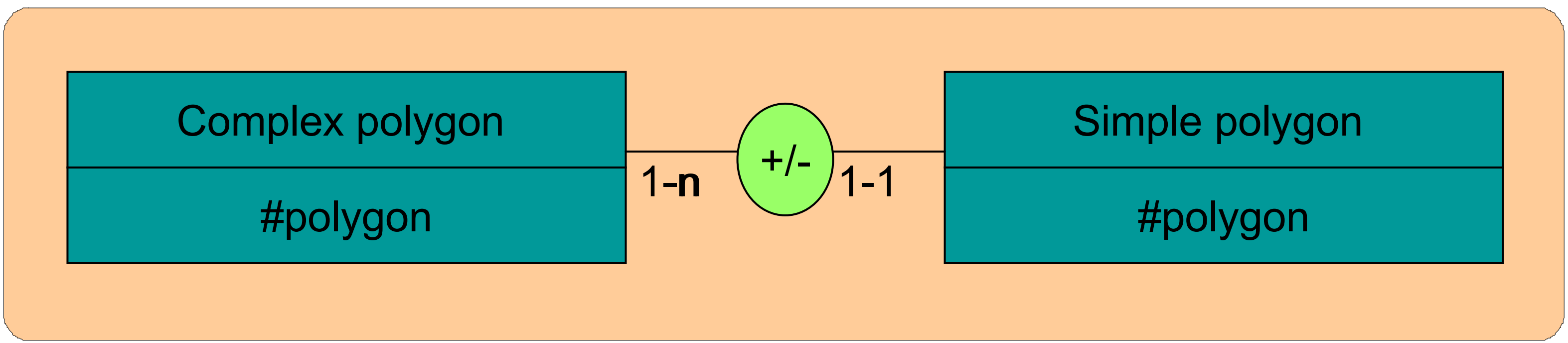



```
POLYGOB    (#polygon, #segment)
segment    (#segment, #point1, #point2)
point      (#point, x, y)
RULE : point within A POLYGON
```

Complex polygon (non connex) (piece)



Isolated polygon with holes and islands



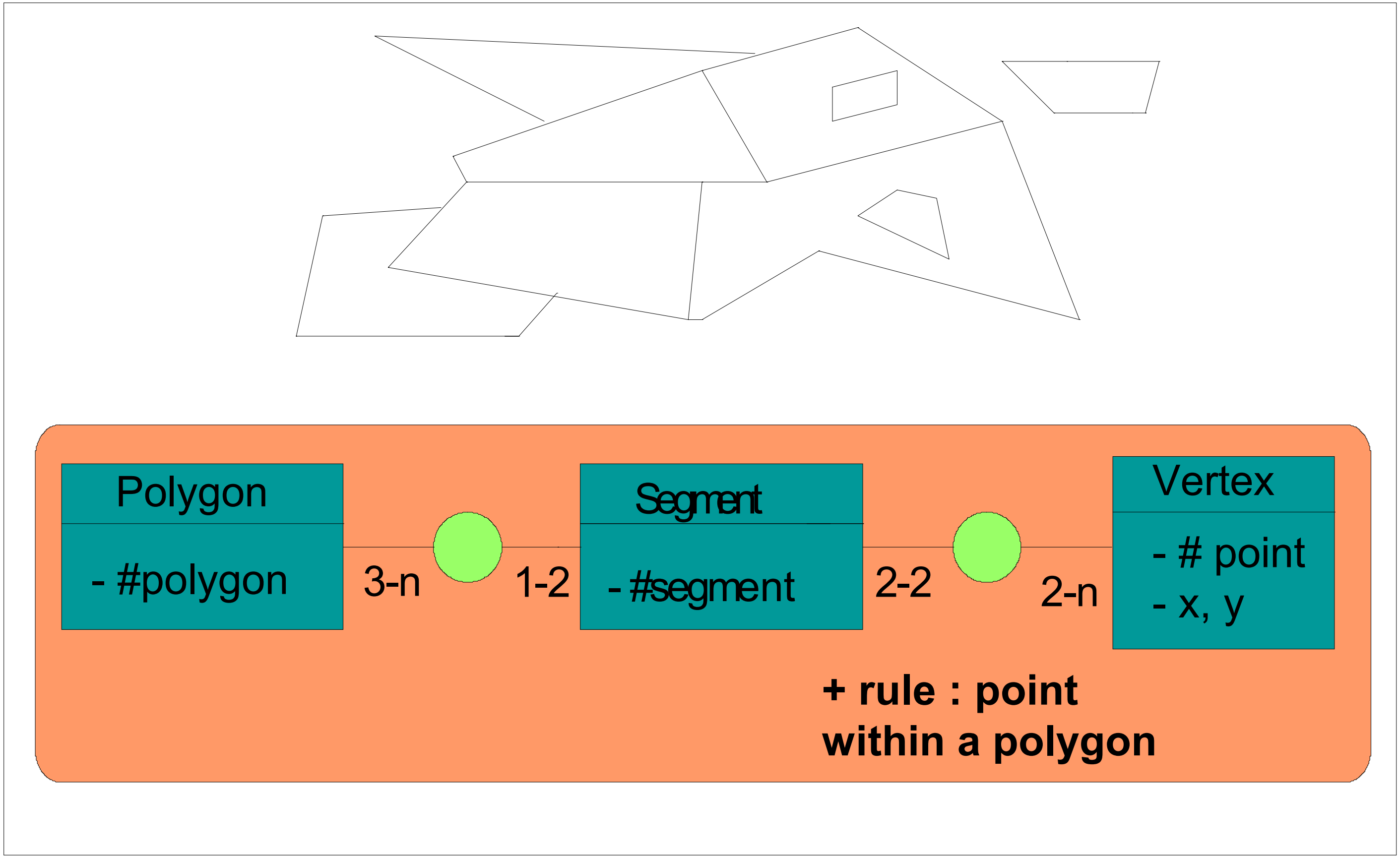

```
NON-CONNEX POLYGON  (#non-connex-polygon,
                               #polygon, connexity-flag)
POLYGON                       (#polygon, etc...)
```

```
RULE : point within a polygon
```

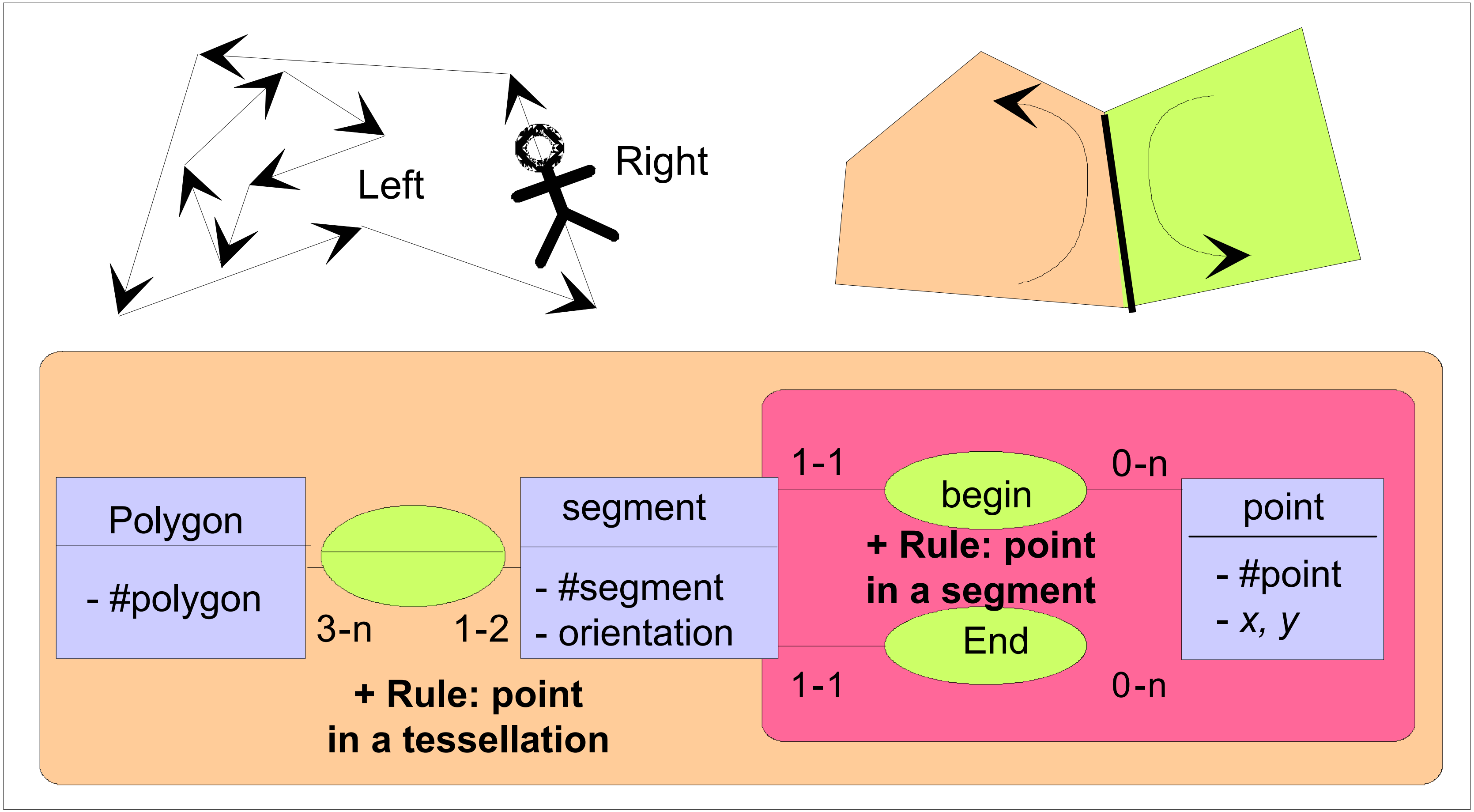
Orientating polygons

```
POLYGON      (#polygon, #segment, #next-segment)
segment      (#segment, #point1, #point2)
point        (#point, x, y)
RULE : point within A POLYGON
```

Model of a polygonal tessellation



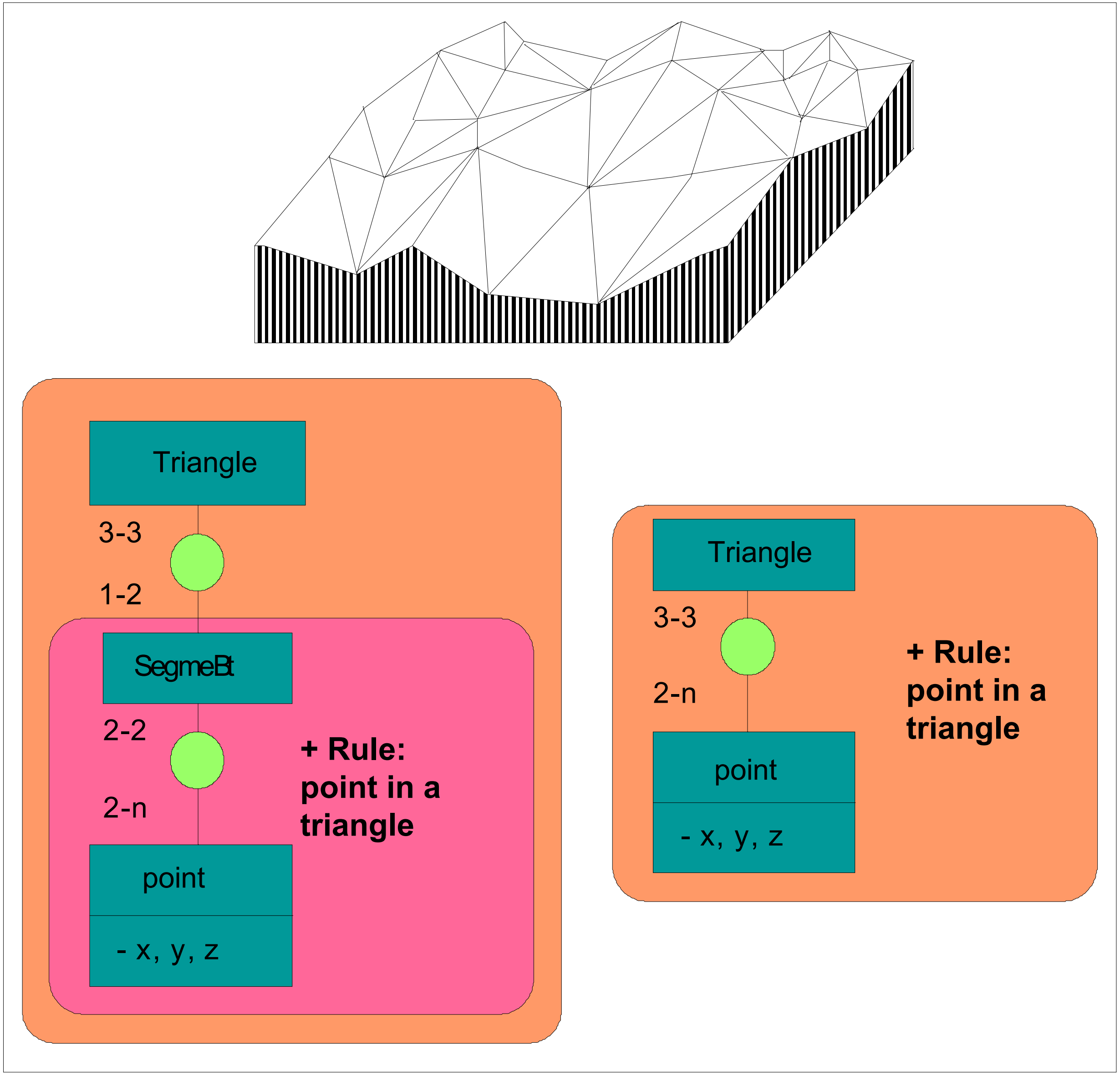
Tessellation with orientated segment



Terrain Modelling

- Triangulated Irregular Networks (TIN)
- Orthogonal grids

Example of a model for a terrain



/ Direct representation

```
RIANGLE     (#triangle, #vertex1, #vertex2, #vertex3)
ERTEX       (#vertex, x, y, z)
```

nd

```
ULE: point IN A TRIANGLE
```

V/ segment-oriented representation

```
RIANGLE     (#triangle, #segment1,#segment2,#segment3)
EGMENT      (#segment, #vertex1, #vertex2)
ERTEX       (#vertex, x, y, z)
```

nd

```
ULE: point IN A TRIANGLE
```

/ Including more topology

```
EGMENT (#segment, #point1, #point2, #left-triangle,
                                    #right-triangle)
```

Planar interpolation to compute z

- Each triangle is located on a plane, whose equation is:

$$z = Ax+By+C$$

- How to know the parameters A, B and C ?
- We have 3 vertices, so
  - 3 equations with 3 unknowns

/ Representation with parameters

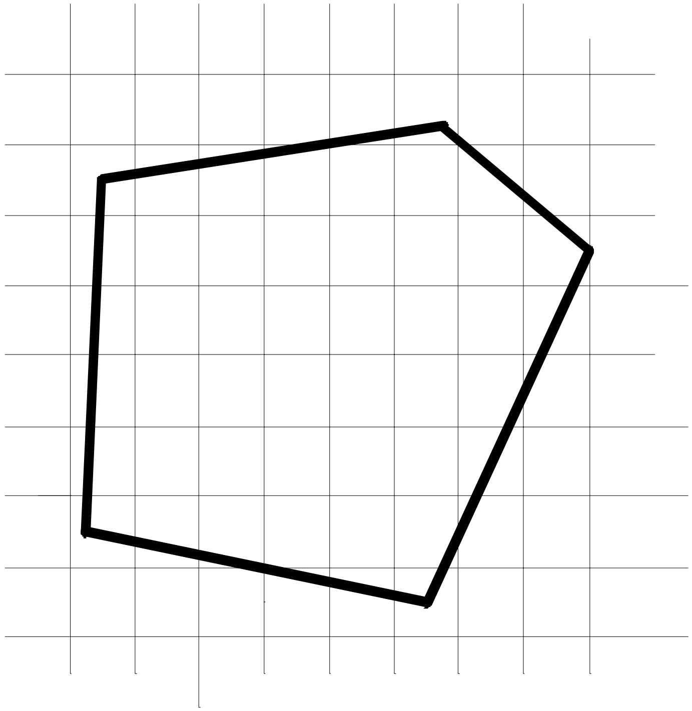
```
RIANGLE      (#triangle, #vertex1, #vertex2, #vertex3, A, B, C)
ERTEX        (#vertex, x, y, z)
```

V/ Representation segment-oriented with parameters

```
RIANGLE      (#triangle, #segment1,#segment2,#segment3, A, B, C)
EGMENT       (#segment, #vertex1, #vertex2)
ERTEX (#vertex, x, y, z)
```

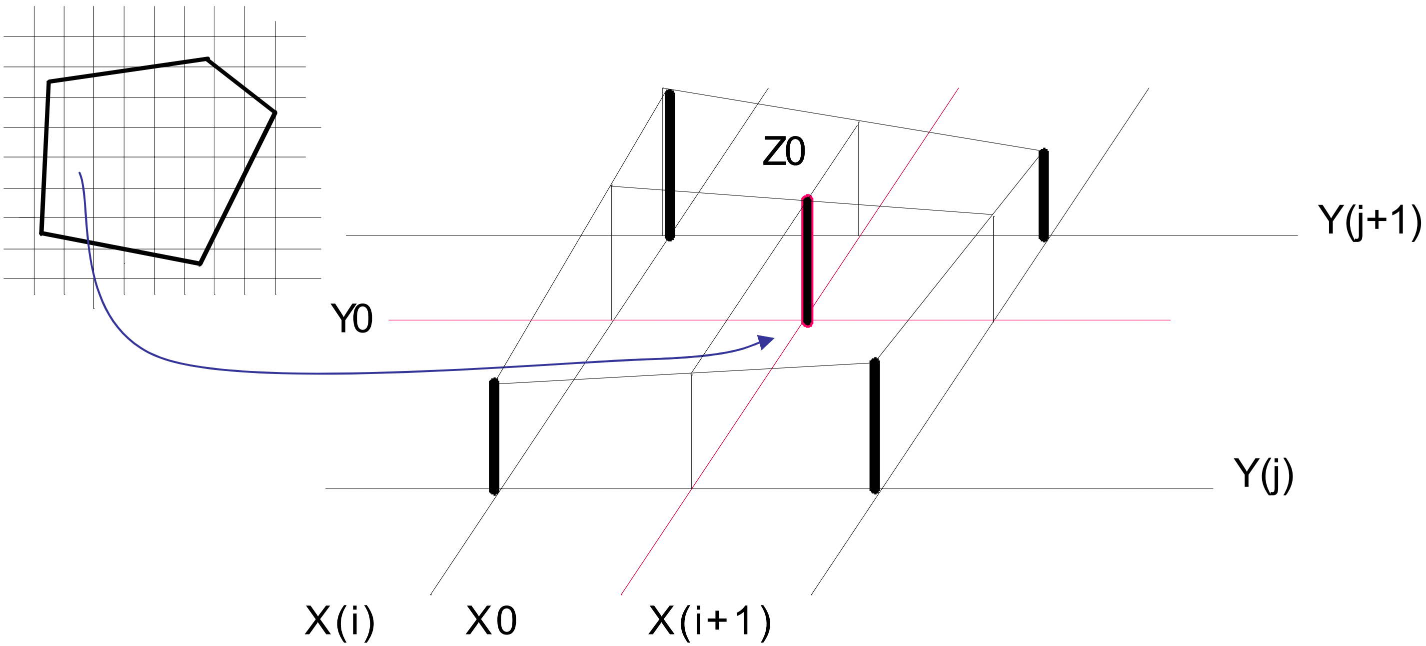
/ Etc.

Simple grid



For example: 100 meters

Interpolation within a grid



Formula of Bilinear interpolation : $z = Axy + Bx + Cy + D$

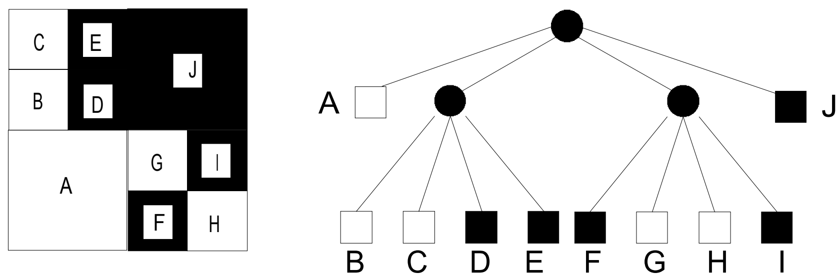
Raster modelling

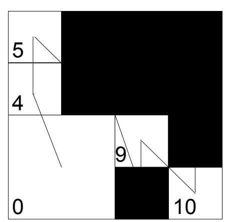
- Quadtrees
- Octrees

Quadtrees

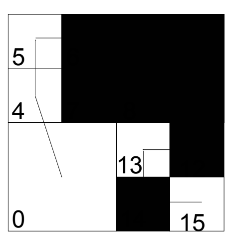
- Hierarchical representation of quadtrees
- Linear quadtrees
- Applications

Quadtrees



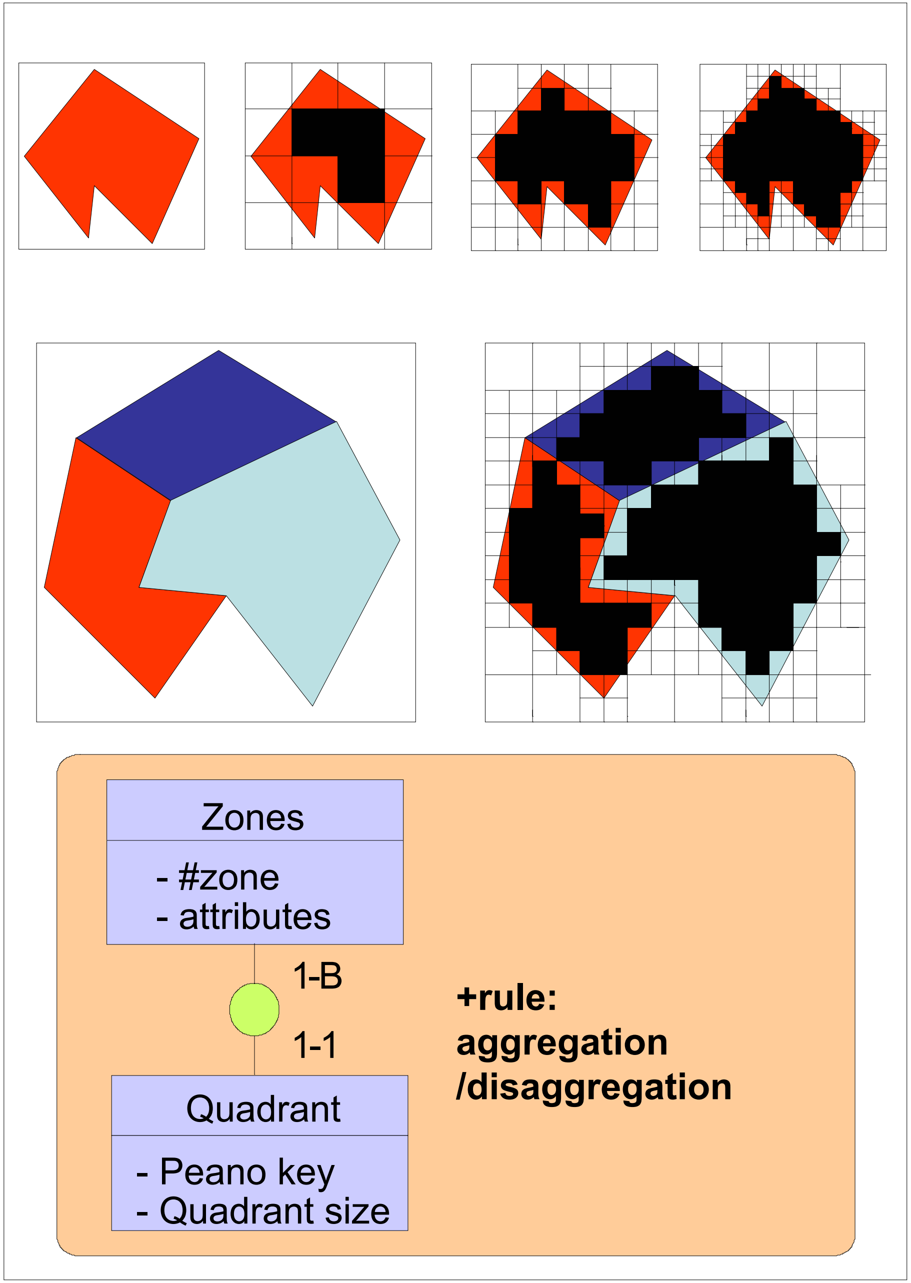


object	Peano key	Size
A	6	1
A	7	1
A	8	1
A	11	1
A	12	2



object	Hilbert key	Size
A	6	1
A	7	1
A	8	2
A	12	1
A	14	1

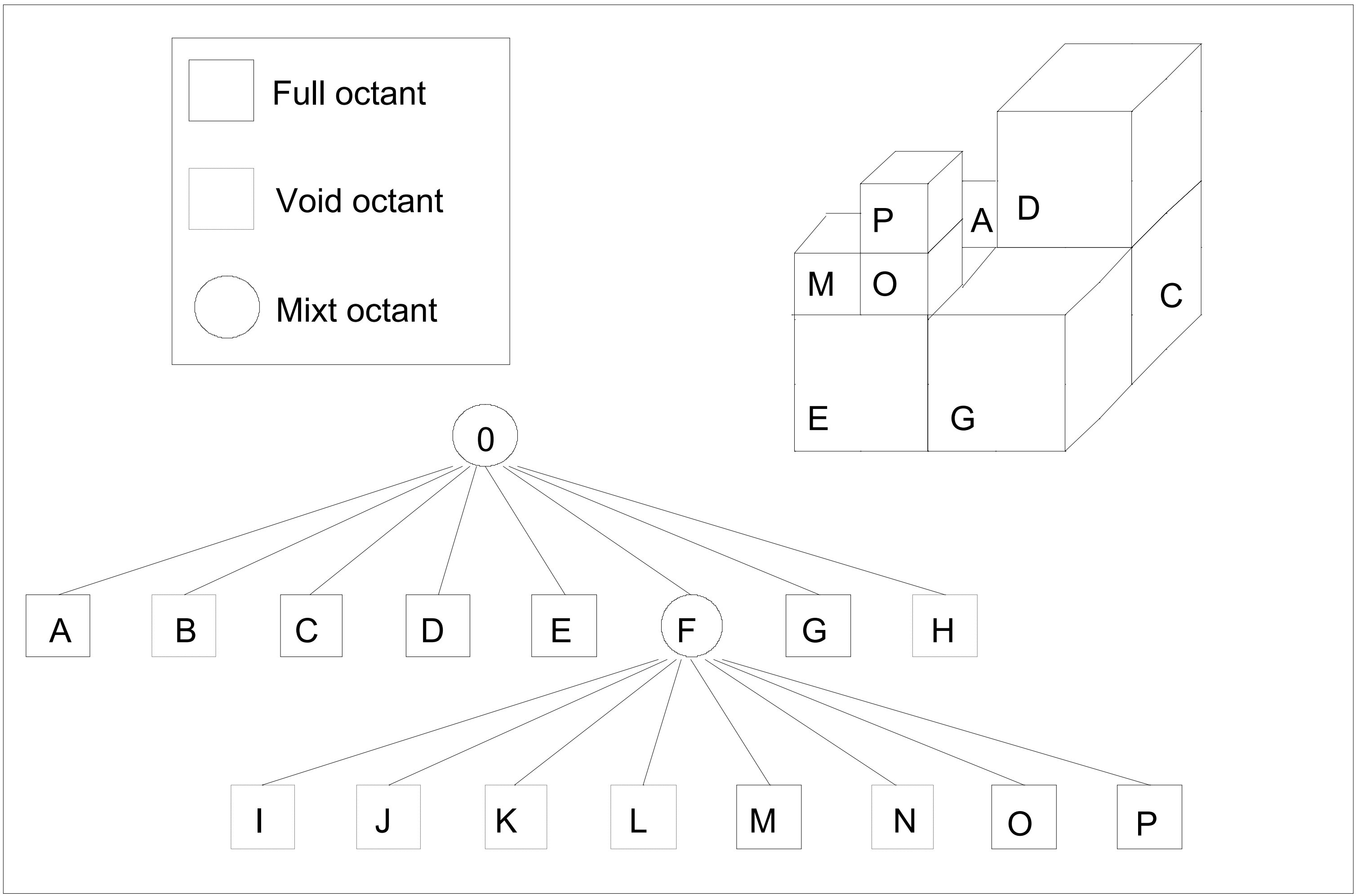
Zone modelling based on quadtree



Octrees

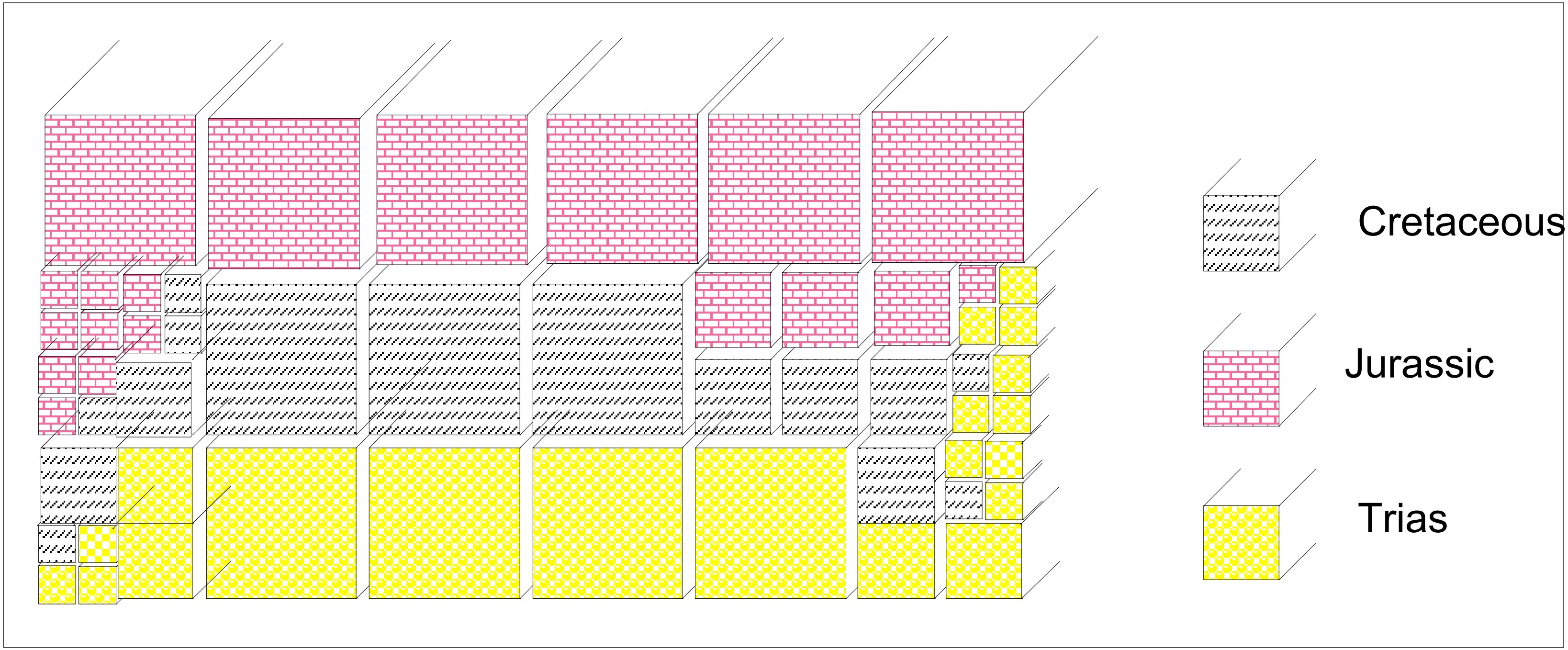
- Hierarchical representation of octrees
- Linear octrees

Octree



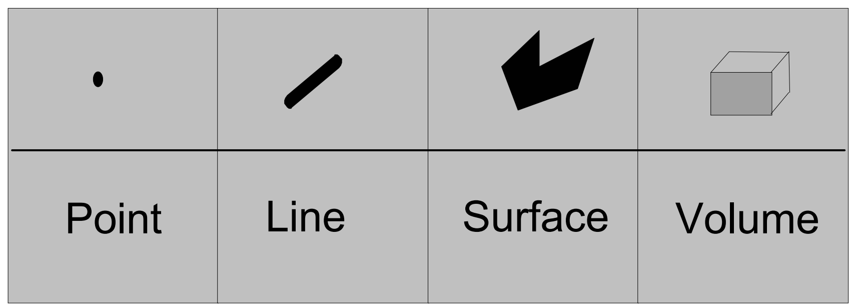
Full octant
Void octant
Mixt octant
P
A
D
M
O
C
E
G
0
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P

Geological strata

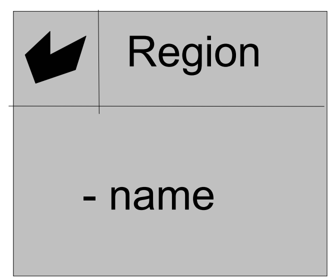


Formalisms with spatial pictograms

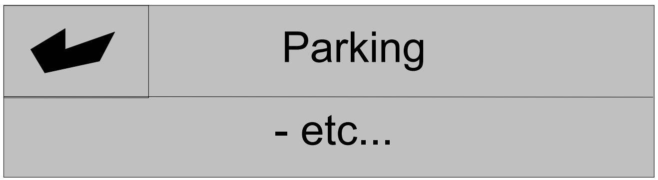
- Small drawing (small icon) representing a geometric type
- Spatial pictogram



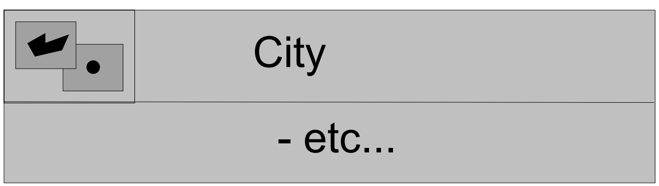
- Example



Other examples

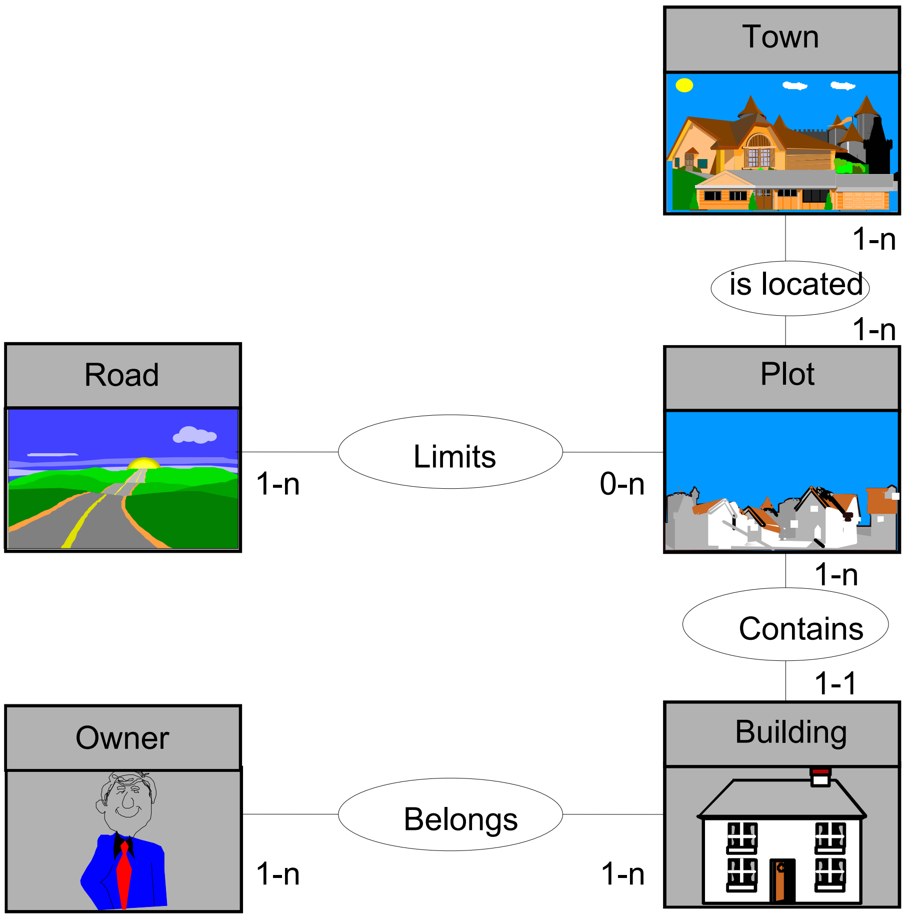


Simple pictogram

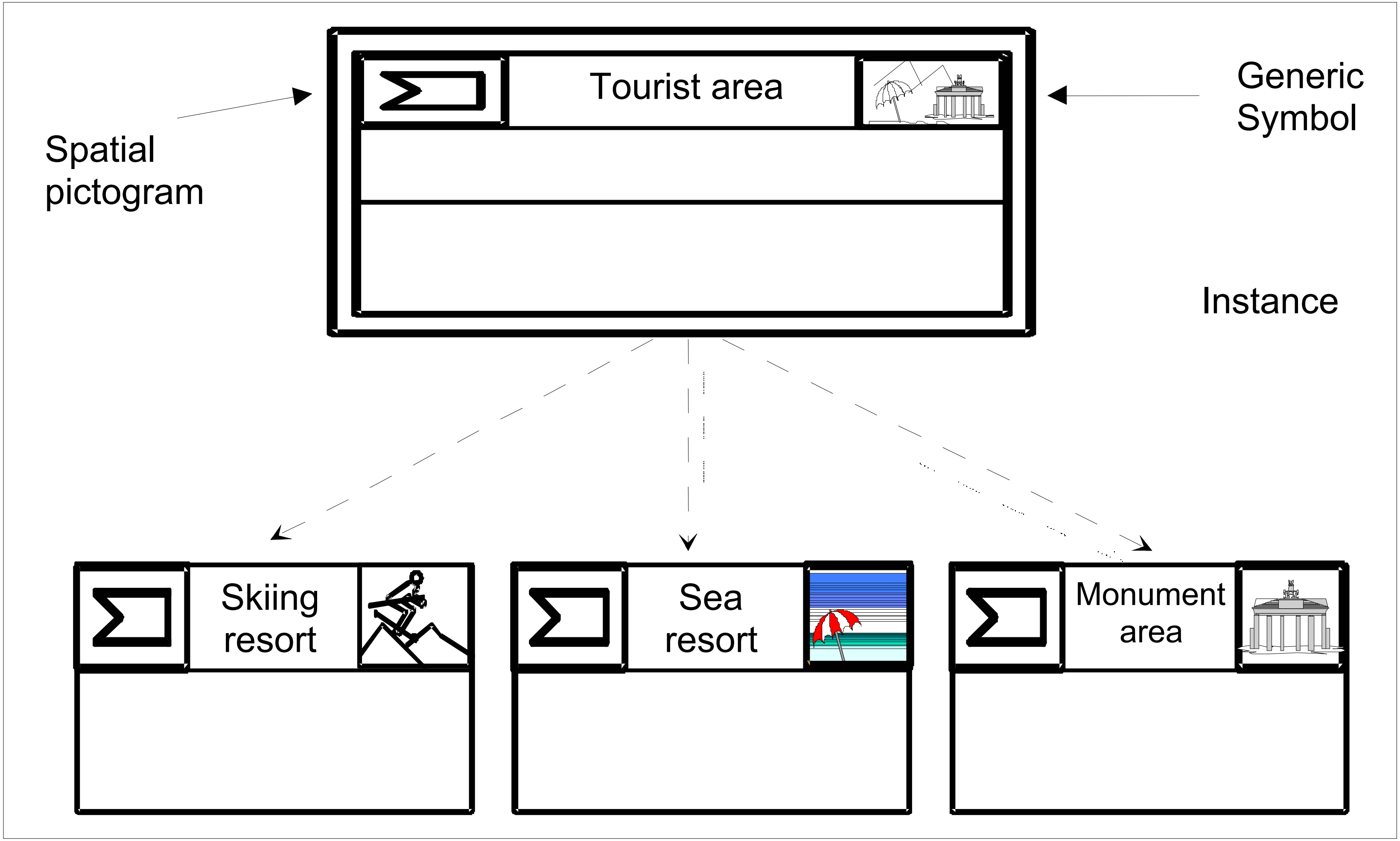


Alternative pictogram

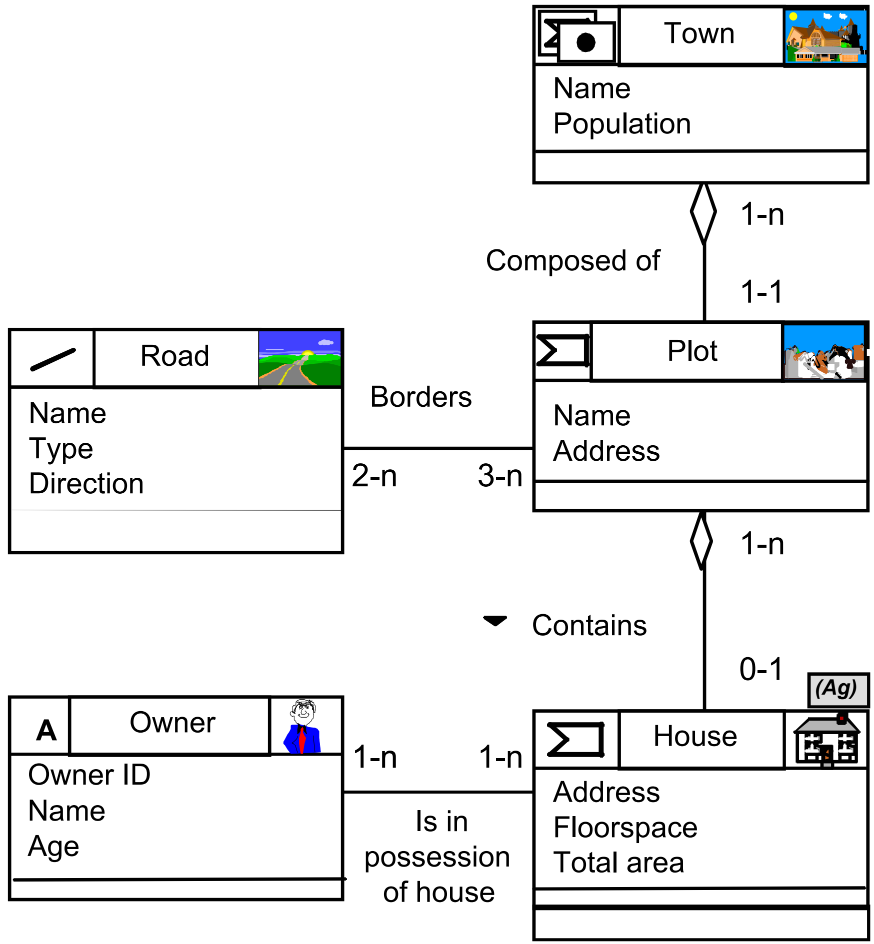
Conceptual model with icons



Pictogram and icons



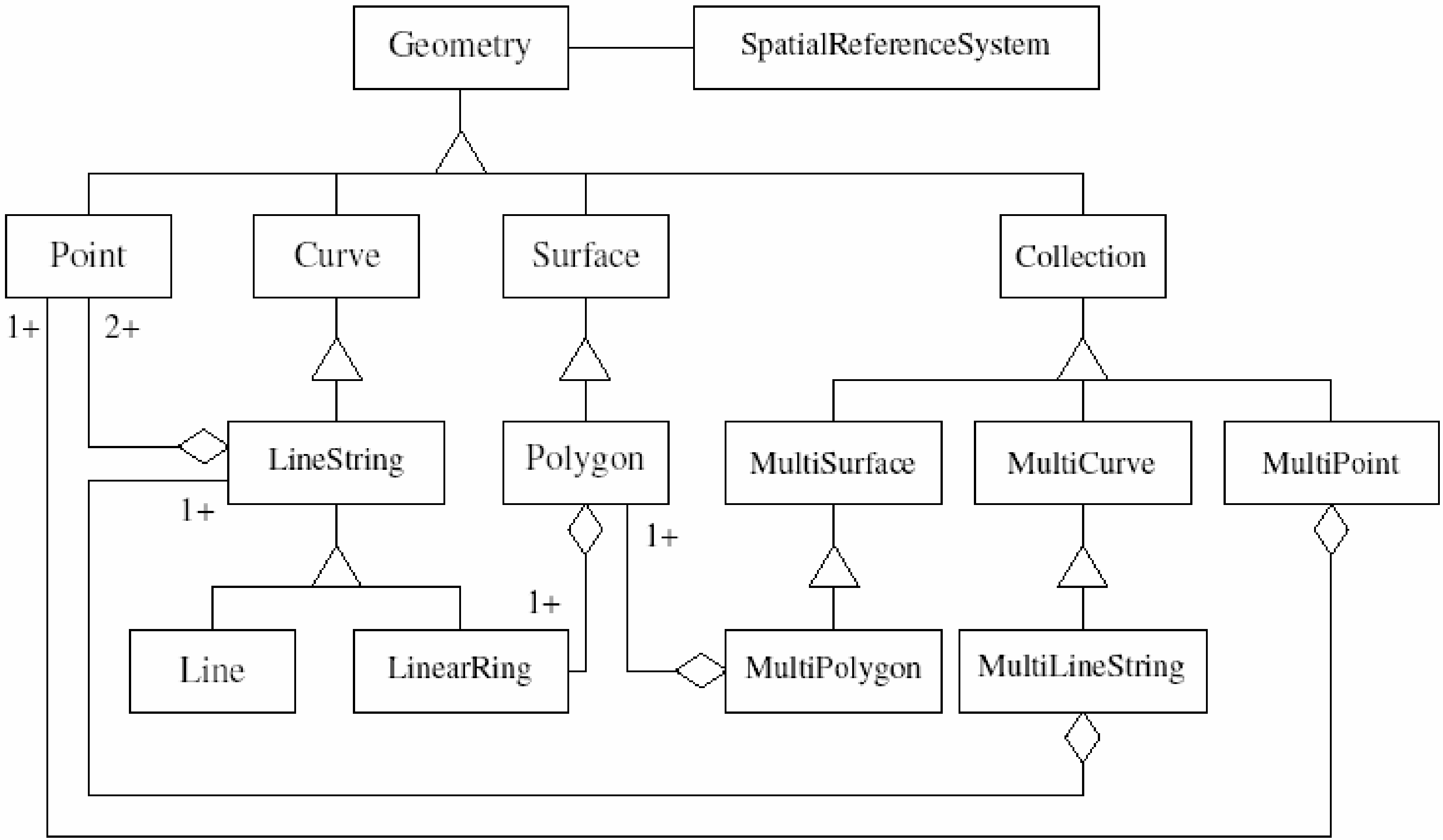
Model with pictograms and icons



OpenGIS Model

- Consortium of companies, research centers and administrations
- Interoperability of geographic applications
- Standards
- http://www.opengis.org

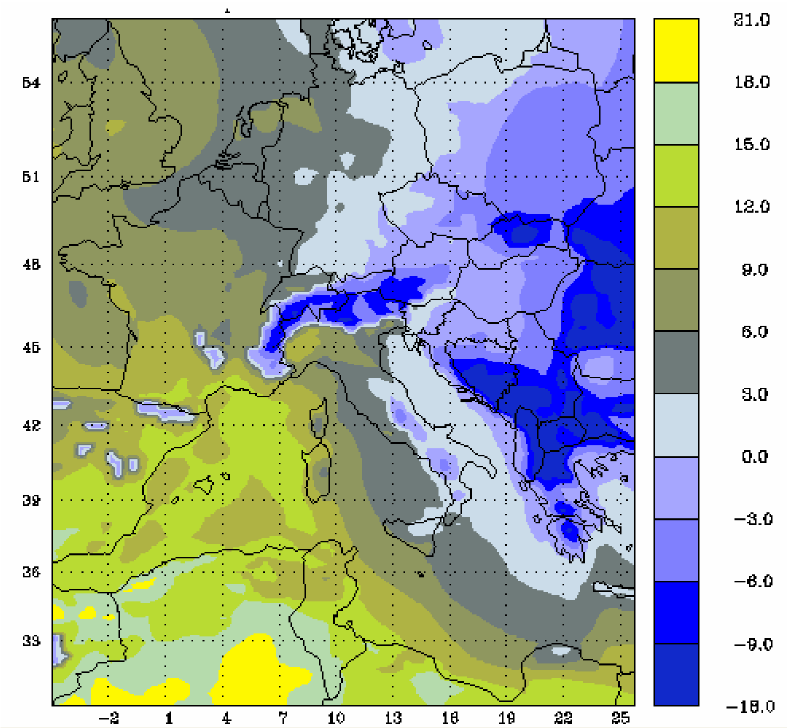
Modèle de l'OpenGIS

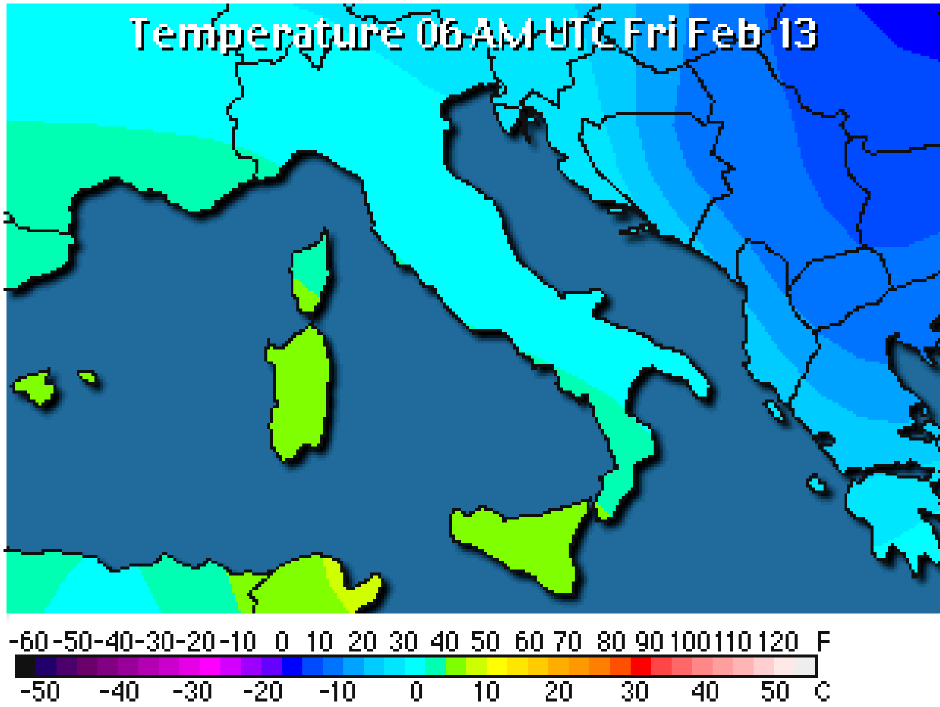


3 – Continuous Phenomena

- Continuous fields theory
  - Scalar fields
  - Vector fields
  - 1D, 2D, 3D, 3D+T
- Applications
  - Environmental modelling
  - Meteorology
  - Sea
  - Terrains, sols
  - Etc.

Examples


54
51
48
45
42
39
36
33
-2
1
4
7
10
13
16
19
22
25
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
-3.0
-6.0
-9.0
-15.0


Temperature 06 AM UTC Fri Feb 13
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 F
-50 -40 -30 -20 -10 0 10 20 30 40 50 C

Continuous field modelling

- Impossible to know everywhere
- Existence of sampling points
- Need for interpolation functions
- Two levels of modelling
  - field as an object (temperature of a region)
  - field as an abstract data type (value of the temperature in a given point)

Modelling

- Regularly spaced measures: grid-like
- Irregularly spaced measures: TIN-like
- Problems of 2D, 3D or 3D+T interpolation

4 – XML, GML

- XML = Extensible Markup Language
- Generalization of HTML distinguishing contents and presentation
- Example:
  - <parcel>
  - <parcel_number> 457 LM 89 </parcel_number>
  - . . . .
  - </parcel>

Goals of XML

- It shall be easy to write programs which process XML documents.
- The number of optional features in XML is to be kept to the absolute minimum, ideally zero.
- XML documents should be human-legible and reasonably clear.
- The XML design should be prepared quickly.
- XML documents shall be easy to create.
- Terseness in XML markup is of minimal importance

Advantages

- human-legible contents
- unstructured contents
- mixing data and metadata
- allowing interoperability

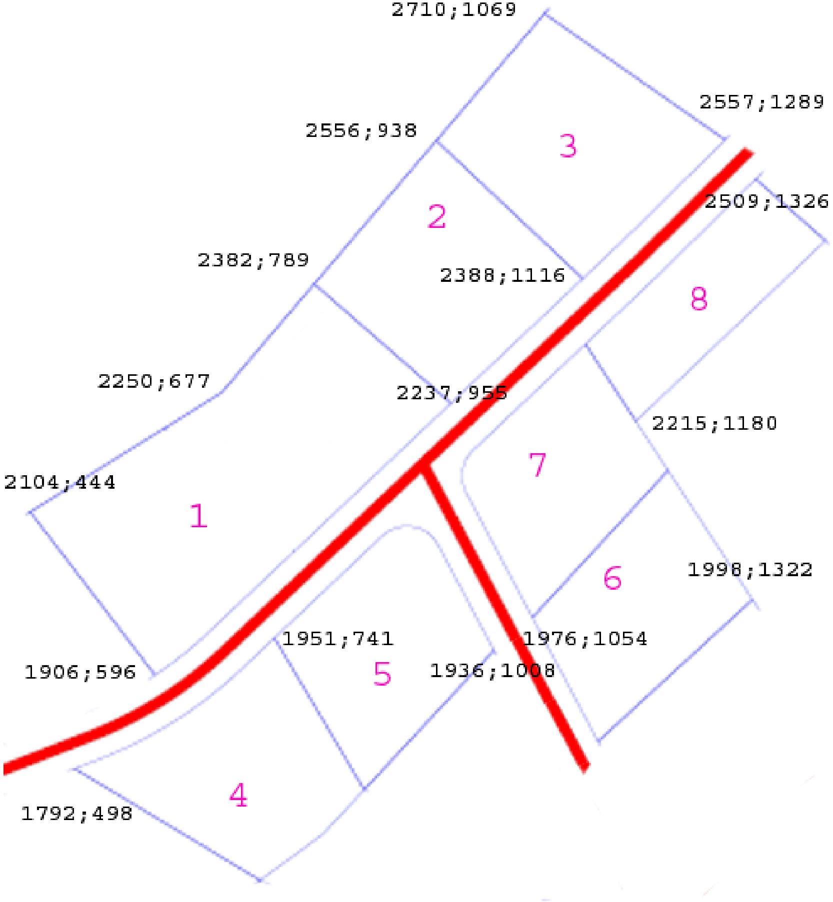
Drawbacks

- very long description
- absence of indexing
- difficulties of encoding very large geographic databases.

XML and geodata

- SVG
  - Scalable Vector Graphics (SVG)
  - Only 2D data
  - Animation is possinle
- GML
  - Geographic Markup Language
  - OpenGIS
- LandXML
  - Cadasters, engineering and land surveys works

Example of encoding



Example with GML

```
<desc>Parcel Lot #4</desc>
  <g>
     <polyline points="741,-1951 700,-1913"/>
     <polyline points="528,-1804 498,-1792"/>
     <polyline points="498,-1792 724,-1657"/>
     <polyline points="724,-1657 799,-1712"/>
     <polyline points="7994,-1712 850,-1767"/>
     <polyline points="850,-1767 741,-1951"/>
  </g>
```

5 – Metadata

- Data about data
  - lineage
  - quality
  - consistency
  - completeness
  - updating
- Standards
  - CEN
  - FGDC

Dublin Core Elements

- Title
- Subject
- Description
- Creator
- Publisher
- Contributor
- Date
- Type
- Format
- Identifier
- Source
- Language
- Relation
- Coverage
- Rights

Dublin Core - HTML Example

<HTML><HEAD>

<TITLE>UKOLN Home Page</TITLE>

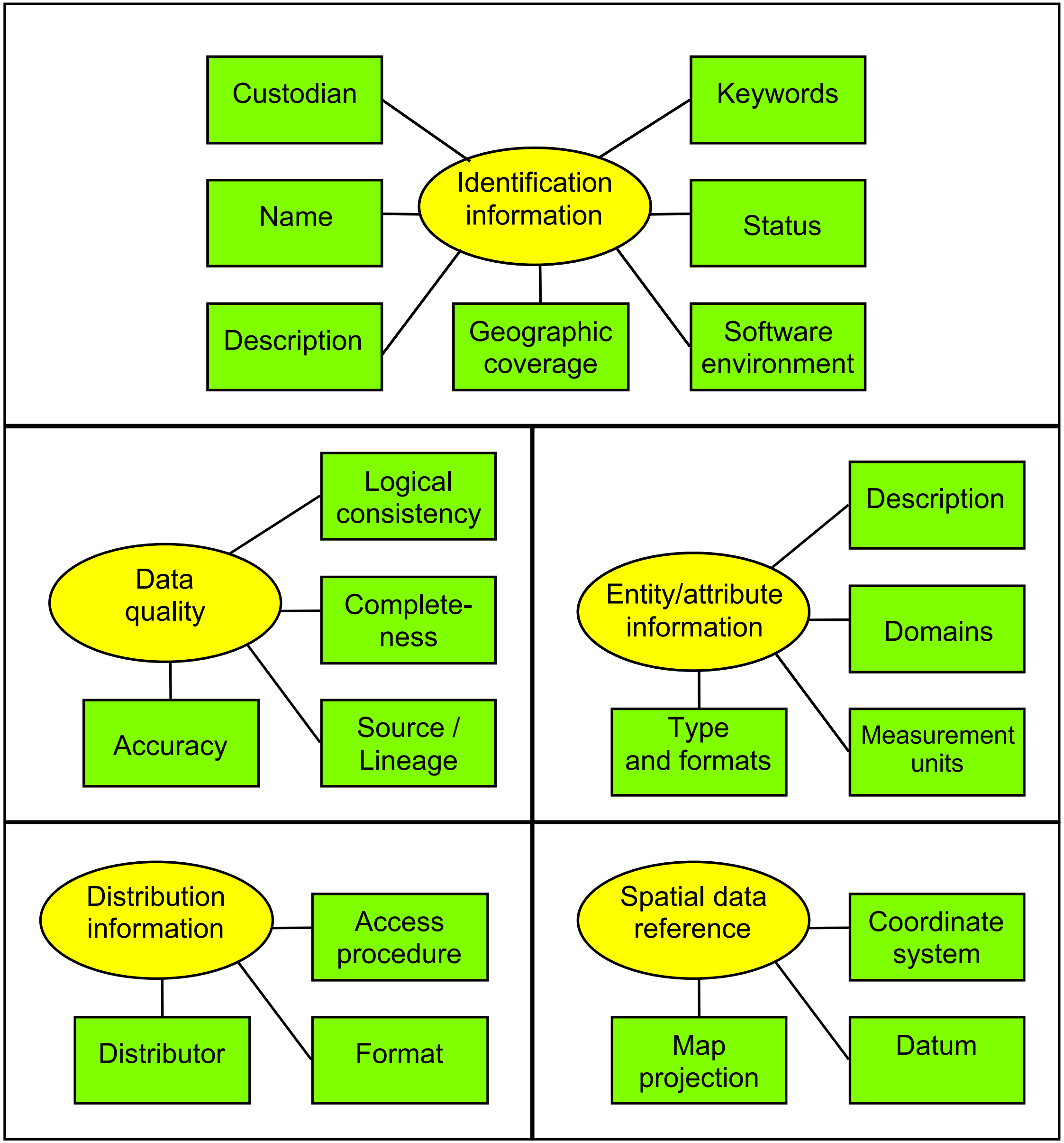
<META NAME="DC.Title” CONTENT="UKOLN: UK Office for Library and Information Networking">

<META NAME="DC.Subject" CONTENT="national centre, network information support, library community, awareness, research, information services, public library networking, bibliographic management, distributed library systems, metadata, resource discovery, conferences, lectures, workshops">

<META NAME="DC.Description" CONTENT="UKOLN is a national centre for support in network information management in the library and information communities. It provides awareness, research and information services">

<META NAME="DC.Creator" CONTENT=”Isobel Stark">

</HEAD>



FGDC Metadata

European CEN Metadata Standard

- Identification
- Spatial Data Organization
- Spatial Reference
- Data Quality
- Content
- Distribution
- Metadata Reference

Mandatory metadata elements

	CEN	ISO	FGDC
metadata language	+	+	-
metadata character set	-	+	-
standard name	-	+	+
standard version	-	+	+
data set name	+	+	+
abstract	+	+	+
data set language	+	+	+
data set character set	+	+	+
spatial schema	+	-	-
date of metadata born	+	+	+
date of metadata update	+	-	-
date of metadata revision	+	-	-
spatial extent	+	-	+
temporal extent	+	-	+
quality elements	+	-	-
organisation	+	+	+
point of contact	-	+	+
category	-	+	+
purpose of production	-	-	+
frequency of updates	-	-	+
restriction of metadata access and usage	-	-	+

Ruzicka, J.: Comparison of CEN, FGDC and ISO standards for metadata

http://www.lmu.jrc.it/Workshops/7ec-gis/presentations/Ruzicka.pdf

6 – Ontologies

- Modelling the semantics of the vocabulary
- Different definitions of concepts ➔ consensus
- Examples
- Ontological engineering
- TOWNTOLOGY project

Definition

- Οντος = Being ; Λογια = discourse
- **Def1**: theory of objects of and their relations
- **Def2**: theory concerning entities, and especially entities in languages
- **Def3**: An ontology is an explicit specification of a conceptualization (Gruber)

What is an ontology?

- A semantic network
- A formal description of a vocabulary
- According to Gruniger et al., ontologies can provide the following:
  - Communication between humans and machines,
  - Structuring and organizing the virtual libraries, and the receptacles of the plans,
  - Reasoning by inference, particularly in very large databases

Why ontologies?

- Data integration
  - Semantic integration of n databases
  - without the great “o” would require *n*n* integration attempts
  - with the great “o” would require *n* attempts
- Data annotation
  - full-fledged ontology not required
  - since main purpose is fixed unique reference point in the for of controlled vocabulary

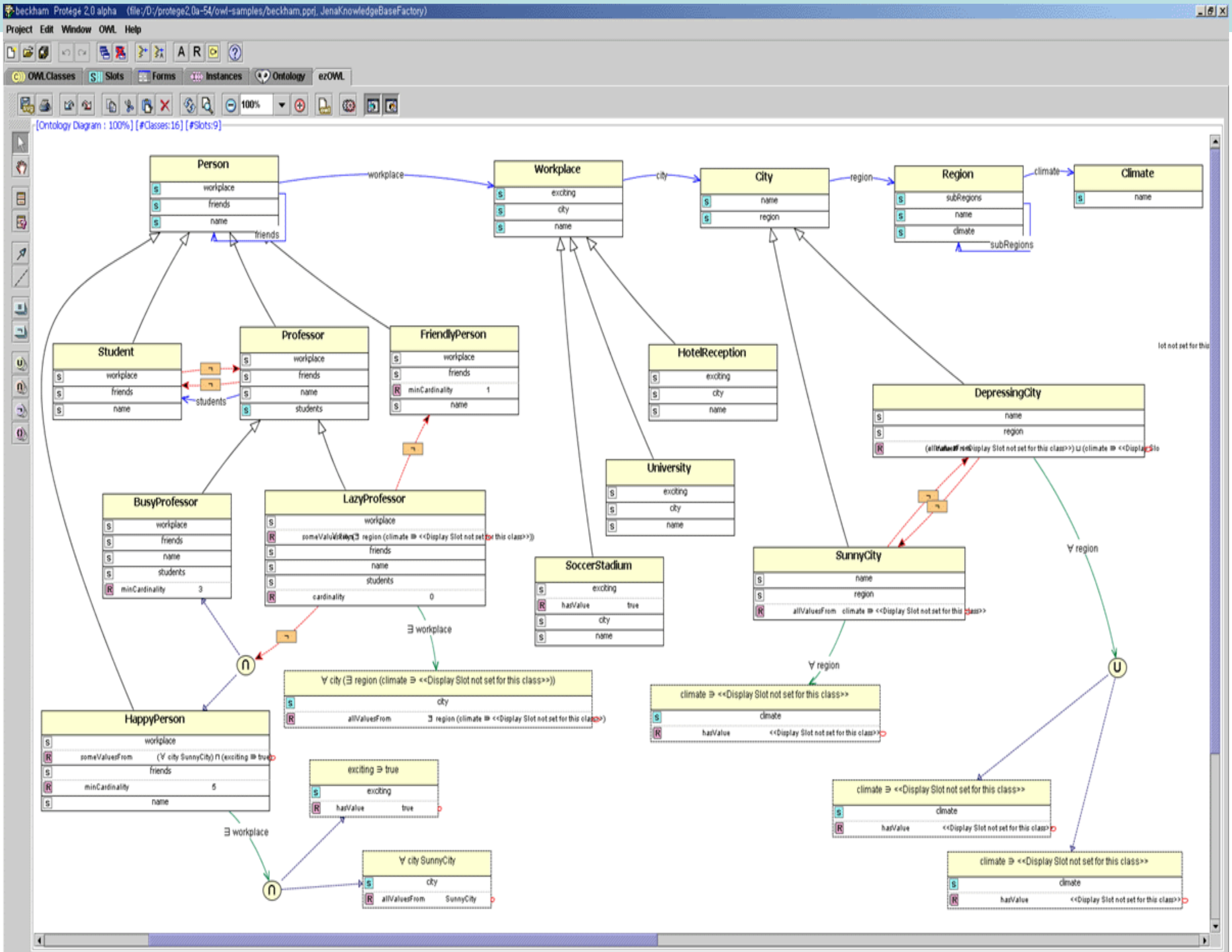
Domain or application ontologies

- Building an ontology is similar to data conceptual modelling
- At application/domain level, an ontology can include constraints, rules and derived rules
- No storing problem

Different classifications (Kavouras)

Ontology	Category_type
CORINE Land Cover	Peat bog
	Water course
	Water body
MEGRIN	Bog
	Canal
	Lake/ pond
	Salt marsh
	Salt pan
	Watercourse
WordNet	Body of water
	Bog
	Canal
	Lake
	Pond
	Salt pan
	Watercourse
	Watercourse

Ontology with OWL



Example with OWL

```
<owl:Class rdf:ID="Church">
     <rdfs:subClassOf rdf:resource="#Building"/>
     <rdfs:subClassOf>
           <owl:Restriction>
               <owl:onProperty rdf:resource="#hasFunction"/>
               <owl:hasValue rdf:resource="#Religion"/>
           </owl:Restriction>
     </rdfs:subClassOf>
  </owl:Class>

  <owl:Class rdf:ID="Cathedral">
        <rdfs:subClassOf rdf:resource="#Church"/>
  </owl:Class>
```

Ontological engineering

- How to build an ontology?
- Possible approaches
  - Top-down
  - Bottom-up
  - Dictionaries
  - Etc.
- How to find a consensus between actors?
- How to verify?

Ontological engineering

- Approaches
- Building the consensus

Top-down approach

- Define high level concepts
- Build the semantic network from the top
- Add specific concepts from more generic ones
- Sometimes, difficulties to include real object

Bottom-up approach

- Start from real existing objects
- Aggregate into more generic objects
- Finally arrive to the top level concepts

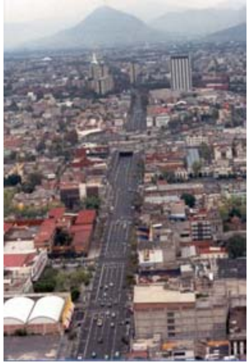
Consensus

- Two actors have two visions of the worlds
- « *Ad ognuno la sua verità* »
- Solve conflicts
- When we have several definitions of the same concepts
  - Define different concepts
  - Keep all definitions until consensus

Advocacy for urban ontologies

- Vocabulary difficulties between actors in urban applications

- Creation of an ontology for cities and for urban planning



- Initial objective: 1000 terms

Principles of the Towntology project

- Creating an ontology for urban planning
- First steps in Lyon (2002-2003)
  - Street planning (French language)
  - Starting from existing dictionaries
  - $\cong$ 800 concepts
- Second step (2003-2004)
  - Setting a COST network
  - Extension to other languages
  - Public space description

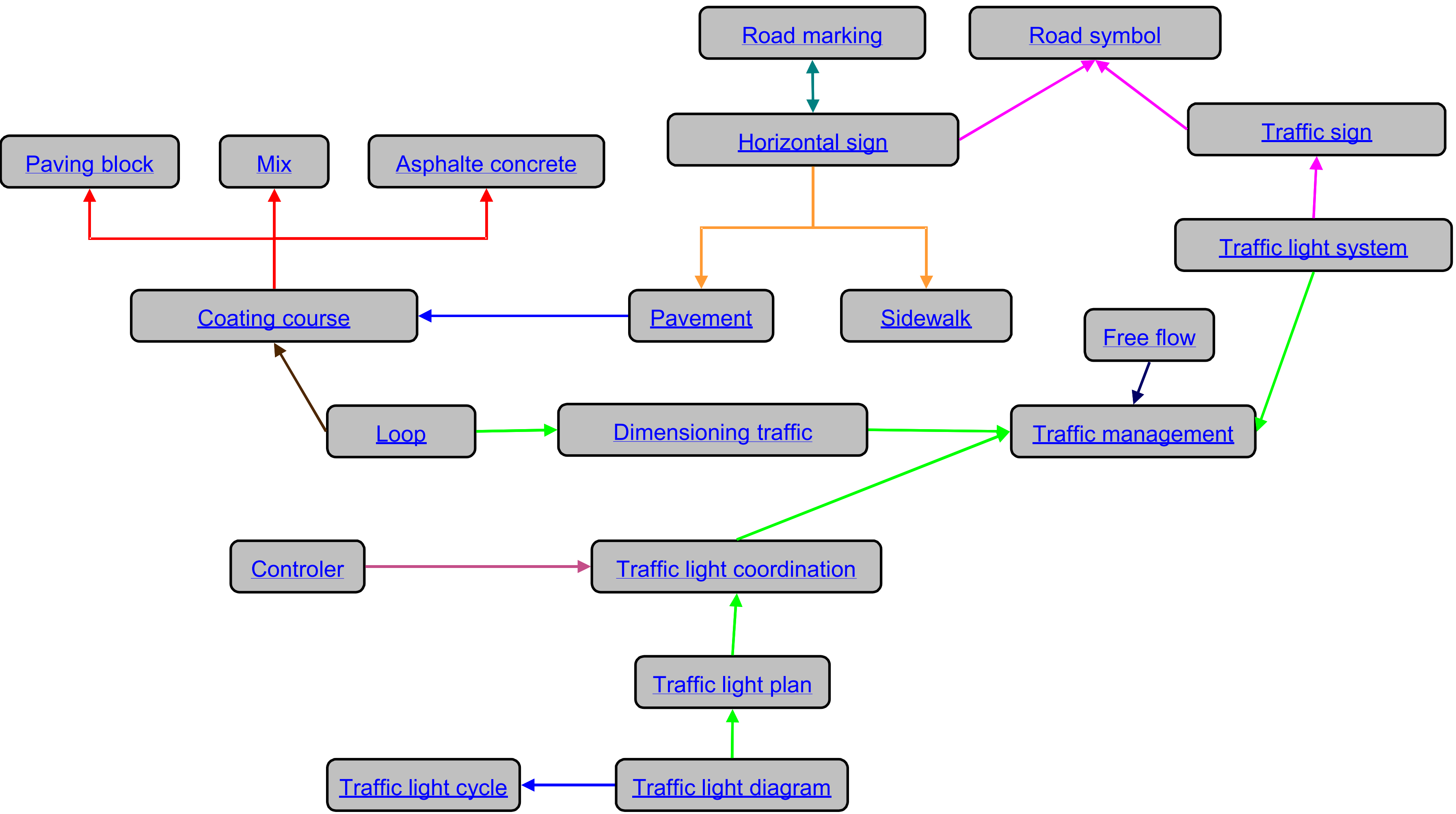
Towntology principles

- Visual presentation
- Semantic network
- Hypertext structure
- Multiple definitions
- Origin and lineage of definitions
- Possibility of updating
- Photos and drawings

Towntology relations

- 9 relations:
  - *is made of*
  - *is composed of*
  - *is located in*
  - *is used for*
  - *is located on*
  - *is a*
  - *is a subset of*
  - *depends on*
  - *is a tool for*

Excerpt of the ontology



MIX

Aggregates gravel, sand...) of variable size, mixed with lime and closely bound by a called bitumen binder bituminizes. The bituminous mix is used mainly in carriageway surfacing. One distinguishes two main categories of bituminous mix :

• Hot-mix, used in courses and underlayers of coating in the structures of roadway. These products are implemented and compacted at a temperature varying between 135 and 160°C.

• Cold-mix generally used to stop the "potholes" or provisional repair of the trenches.

Roadway dictionnary

From : http://www.lequotidienauto.com

Example of textual and visual description

Beginning of the urban ontology

```xml
<ONTOLOGY>
  <HEAD>
    <TITLE>Transports</TITLE>
    <LANGUAGE>français</LANGUAGE>
    <CUSTODIAN>Christophe BERTHET</CUSTODIAN>
    <LAST_MODIF_DATE>2004/6/25</LAST_MODIF_DATE>
  </HEAD>
  <BODY>
    <RELATION_TYPES>
      <RELATION_TYPE ID="100001" ORIGINATOR="Christophe BERTHET" INSERTION_DATE="2004/06/21">
        <RELATION_NAME>dépend de</RELATION_NAME>
        <TERMS />
        <RELATION_DEF />
        <RELATION_PROPERTIES SYMMETRIC="false" TRANSITIVE="false" MAYBEOPTIONAL="false" />
      </RELATION_TYPE>

        .........

  </BODY>
</ONTOLOGY>
```

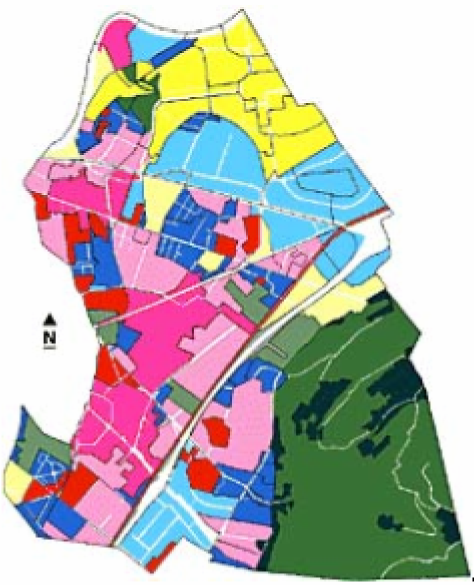
Description of a concept

```xml
<CONCEPT_NAME>Accident de la route </CONCEPT_NAME>
<TERMS />
<CONCEPT_DOMAIN ID="200001" />
<CONCEPT_DEFS>
  <CONCEPT_DEF ORIGINATOR="Christophe BERTHET" INSERTION_DATE="2004/06/21">
    <CONCEPT_DEF_SOURCE>
      <AUTHORS />
      <REF>Glossaires - Promotion Of Results in Transport Research and Learning</REF>
    </CONCEPT_DEF_SOURCE>
    <CONCEPT_DEF_TEXT>Définition utilisée pour les statistiques dans la plupart des pays : il
      s'agit d'une collision ayant lieu sur la voie publique et qui implique au moins un véhicule
      roulant. Sont considérés comme accidents de la route les accidents provoquant
      uniquement des dégâts matériels et les accidents occasionnant des
      blessures.</CONCEPT_DEF_TEXT>
  </CONCEPT_DEF>
</CONCEPT_DEFS>
<MULTIMEDIA />
</CONCEPT>
```

Example: Land use plan

PLAN D'OCCUPATION DES SOLS (P.O.S.)
Document d'urbanisme opposable aux tiers qui fixe les règles générales et les servitudes d'utilisation des sols. Composé de documents graphiques qui localisent des zones, d'un règlement qui fixe le droit des sols applicable à chaque zone et d'annexes techniques.

Dictionnaire de la voirie

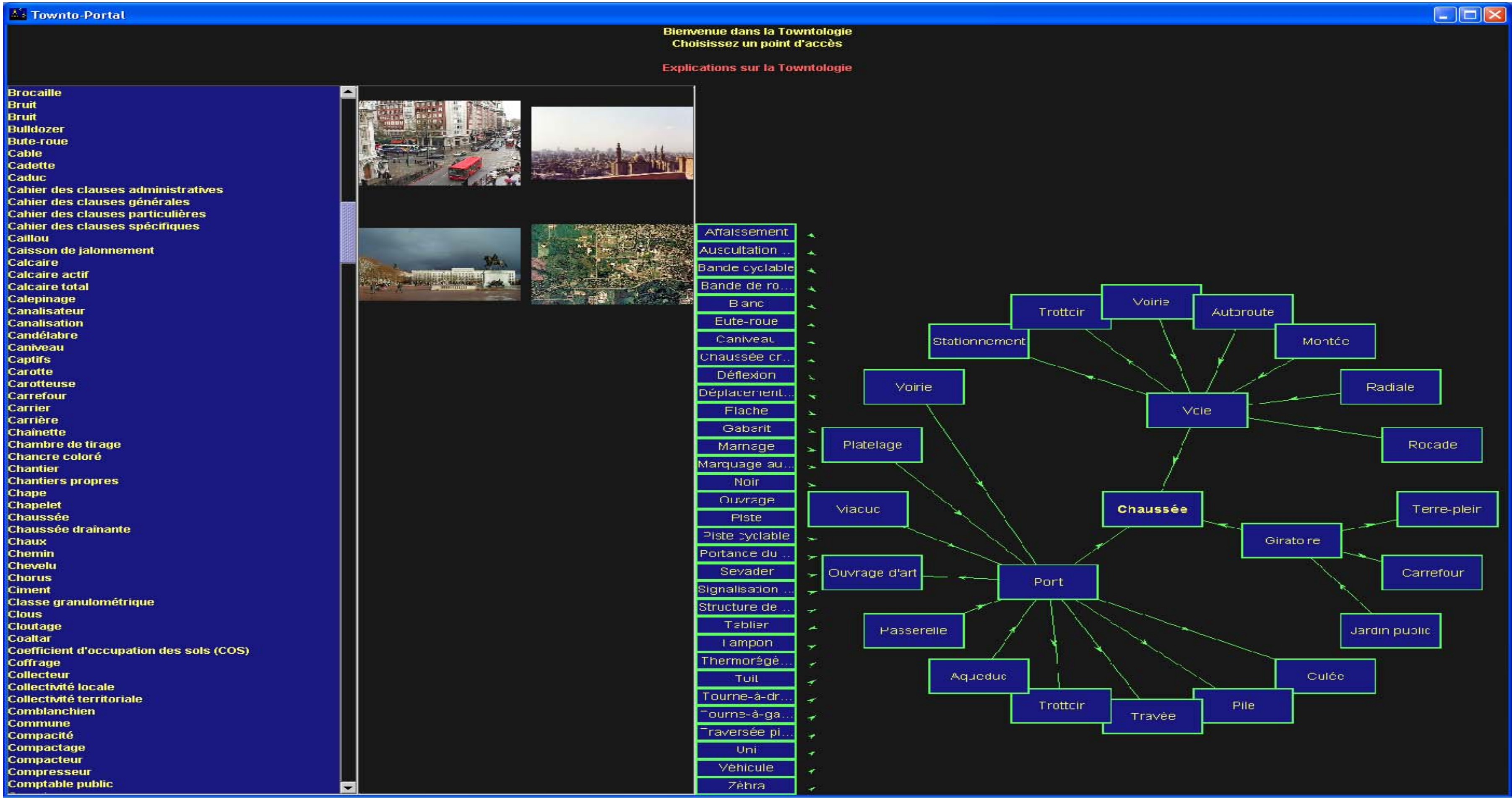


Source : http://www.ville-st-martin-dheres.fr/images/photos/pos.gif

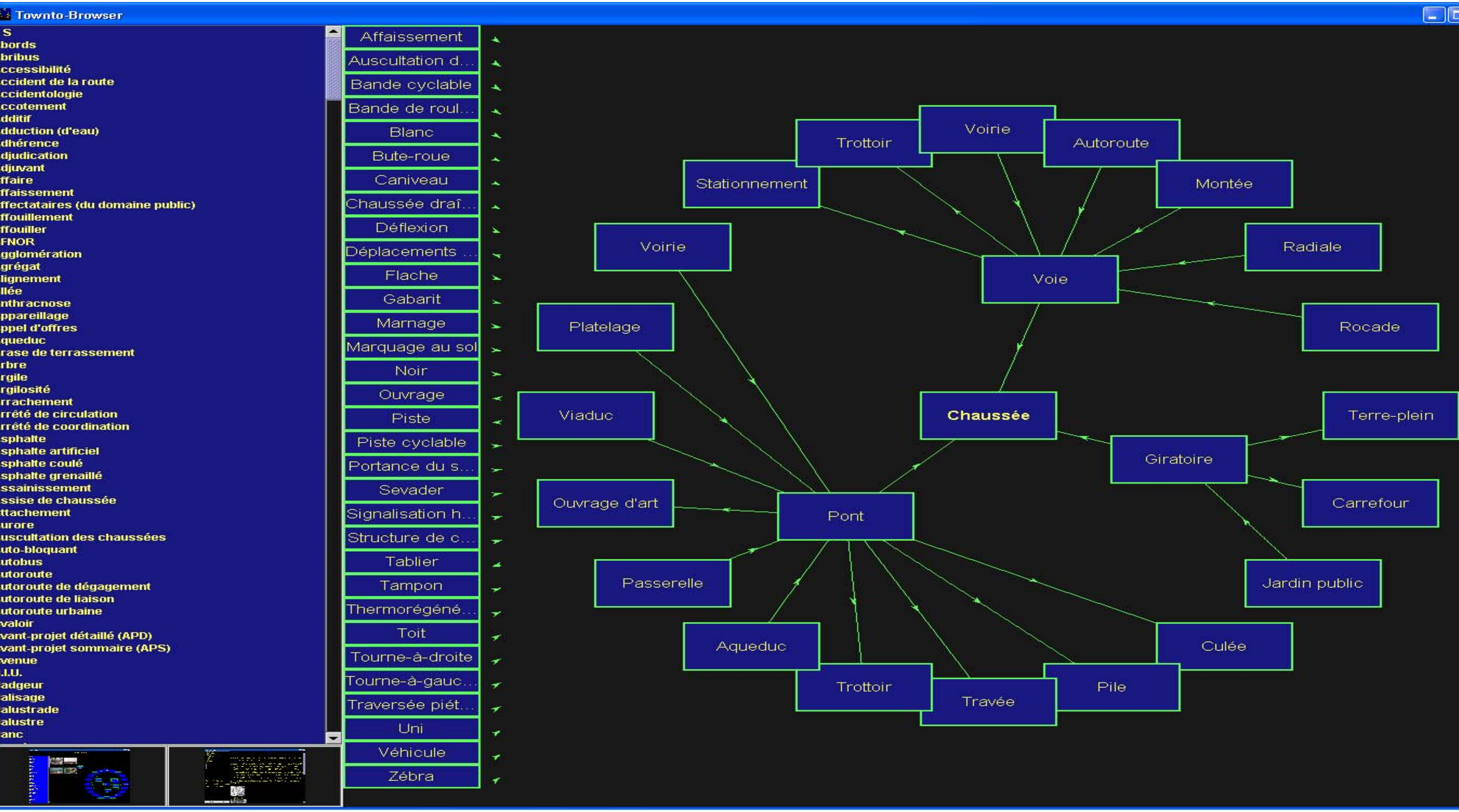
Visual interfaces

- Portal for navigating and querying
- Portal for updating
- Portal for photo-based access

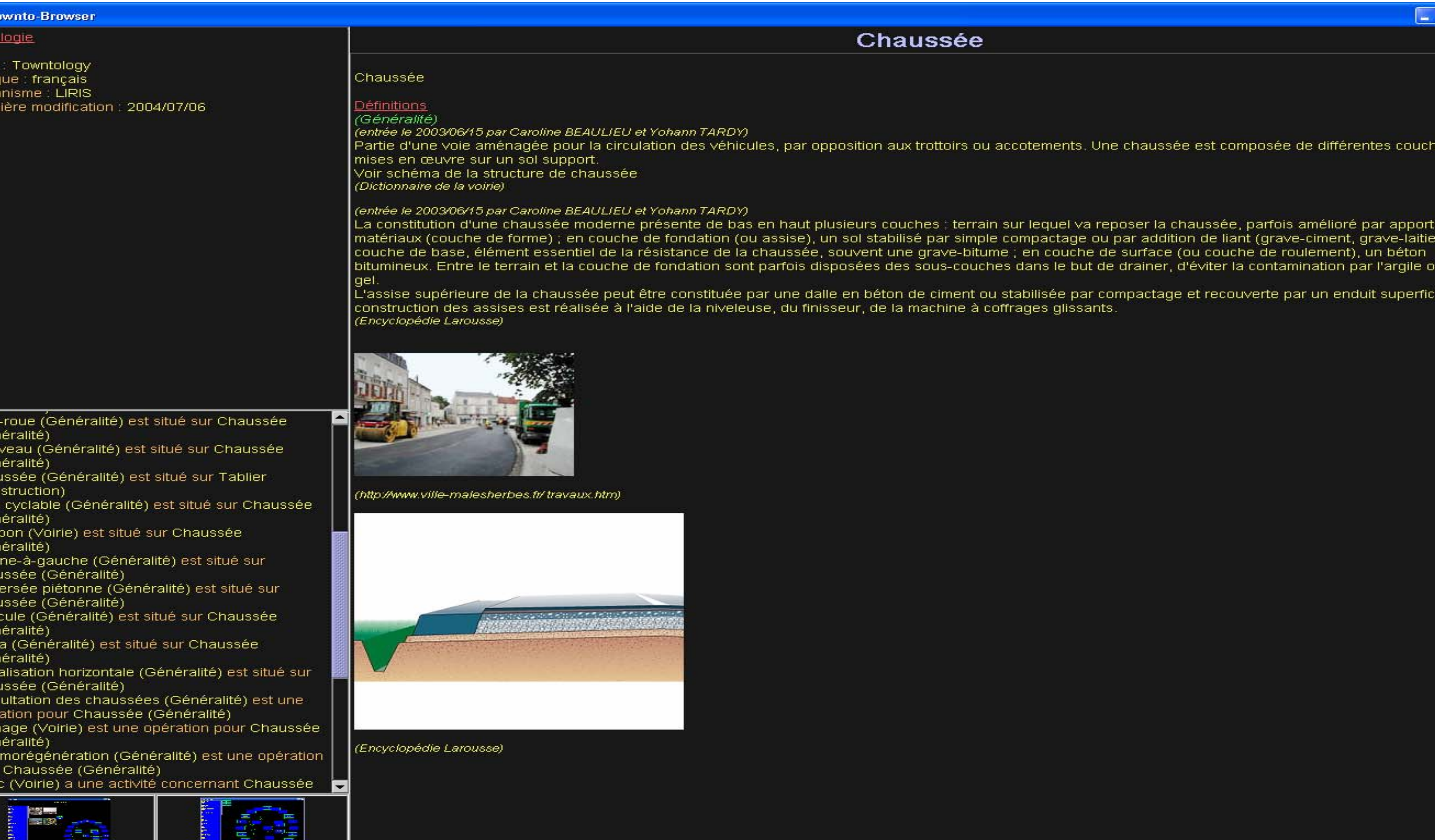
Portal


Townto-Portal
Bienvenue dans la Towntologie
Choisissez un point d'accès
Explications sur la Towntologie
Brocaille
Bruit
Bruit
Bulldozer
Bute-roue
Cable
Cadette
Caduc
Cahier des clauses administratives
Cahier des clauses générales
Cahier des clauses particulières
Cahier des clauses spécifiques
Caillou
Caisson de jalonnement
Calcaire
Calcaire actif
Calcaire total
Calepinage
Canalisateur
Canalisation
Candélabre
Caniveau
Captifs
Carotte
Carotteuse
Carrefour
Carrier
Carrière
Chaînette
Chambre de tirage
Chancre coloré
Chantier
Chantiers propres
Chape
Chapelet
Chaussée
Chaussée drainante
Chaux
Chemin
Chevelu
Chorus
Ciment
Classe granulométrique
Clous
Cloutage
Coaltar
Coefficient d'occupation des sols (COS)
Coffrage
Collecteur
Collectivité locale
Collectivité territoriale
Comblanchien
Commune
Compacité
Compactage
Compacteur
Compresseur
Comptable public
Affaissement
Auscultation ...
Bande cyclable
Bande de ro...
Banc
Bute-roue
Caniveau
Chaussée cr...
Déflexion
Déplacement...
Flache
Gabarit
Marnage
Marquage au...
Noir
Ouvrage
Piste
Piste cyclable
Portance du ...
Sevader
Signalisation ...
Structure de ...
Tablier
Tampon
Thermorégé...
Tuil
Tourne-à-dr...
Tourne-à-ga...
Traversée pi...
Uni
Véhicule
Zébra
Voirie
Trottoir
Autoroute
Stationnement
Montée
Voirie
Radiale
Voie
Platelage
Rocade
Viaduc
Chaussée
Terre-plein
Giratoire
Ouvrage d'art
Port
Carrefour
Passerelle
Jardin public
Aqueduc
Culée
Trottoir
Pile
Travée

Visual interface (browser)



Content visualization



7 – Conclusions

- Importance of data modelling
- Various perspectives
  - for database management
  - for semantic retrieval
- Data conceptual model
- Metadata
- Ontologies


Thanks for your attention!
http://lisi.insa-lyon.fr/~laurini