Optimization on multidimensional hierarchies

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Outline

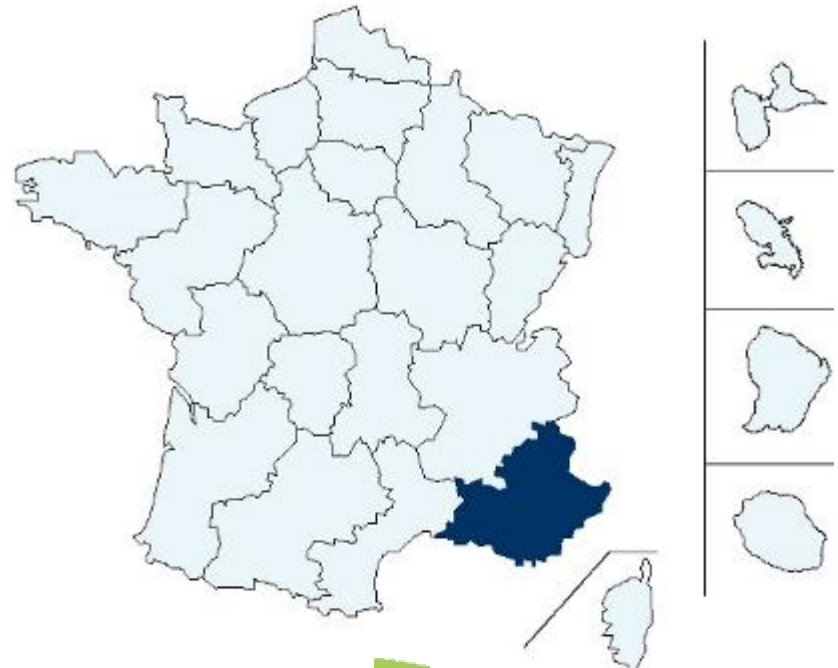
- Thesis outline
  - Objectives
  - Domain of Application
- Geographic Information Systems (GIS)
  - Data Sources and Features
- Optimization on Hierarchies
  - Theory
  - Examples

Objectives

- Multivariable optimization of pyramid of segmentations by Mathematical Morphology
- Mathematical Morphology for GIS type data
- Application to model the evolution of PACA(Provence-Alpes-Côte d'Azur)

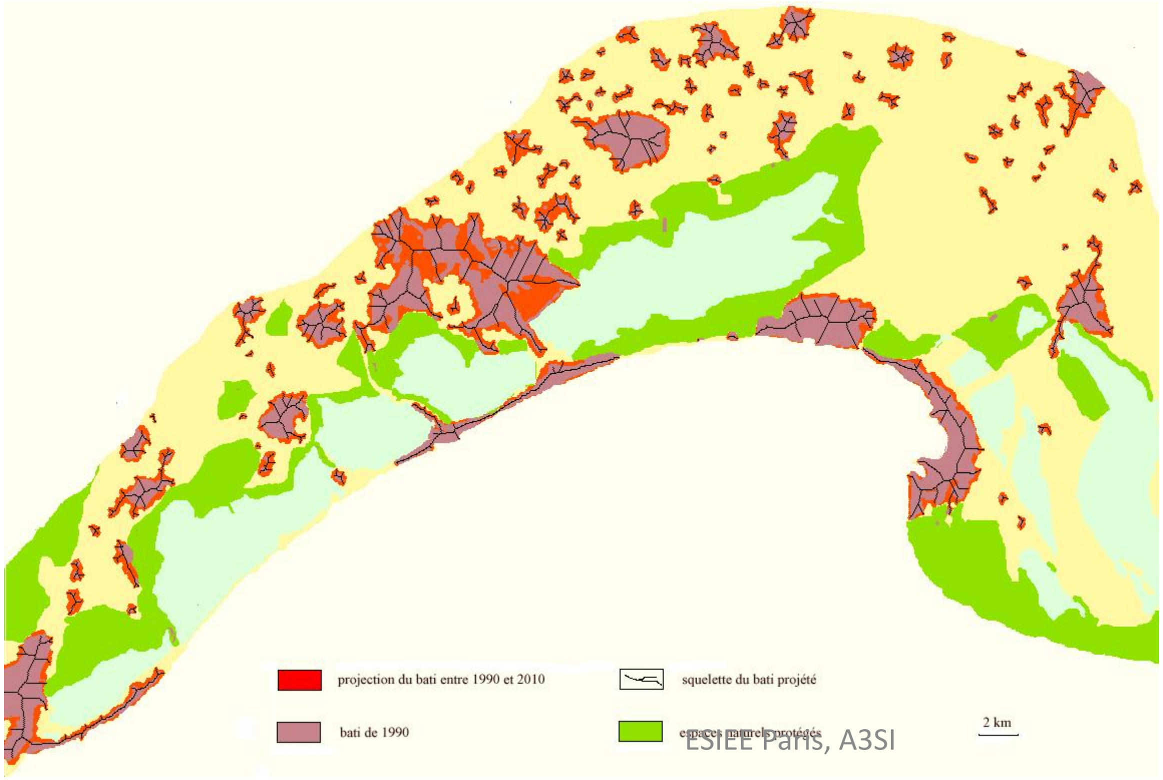
Domain of Application

- Water resources modeling in Region of PACA (Provence-Alpes-Côte d'Azur)
  - Evolution in Population (Usage of water in swimming pools, apartments, residences)
  - Usage of different types of agriculture methods (to optimize water usage)
  - Predictive Model for utilization of water resources



Domain of Application

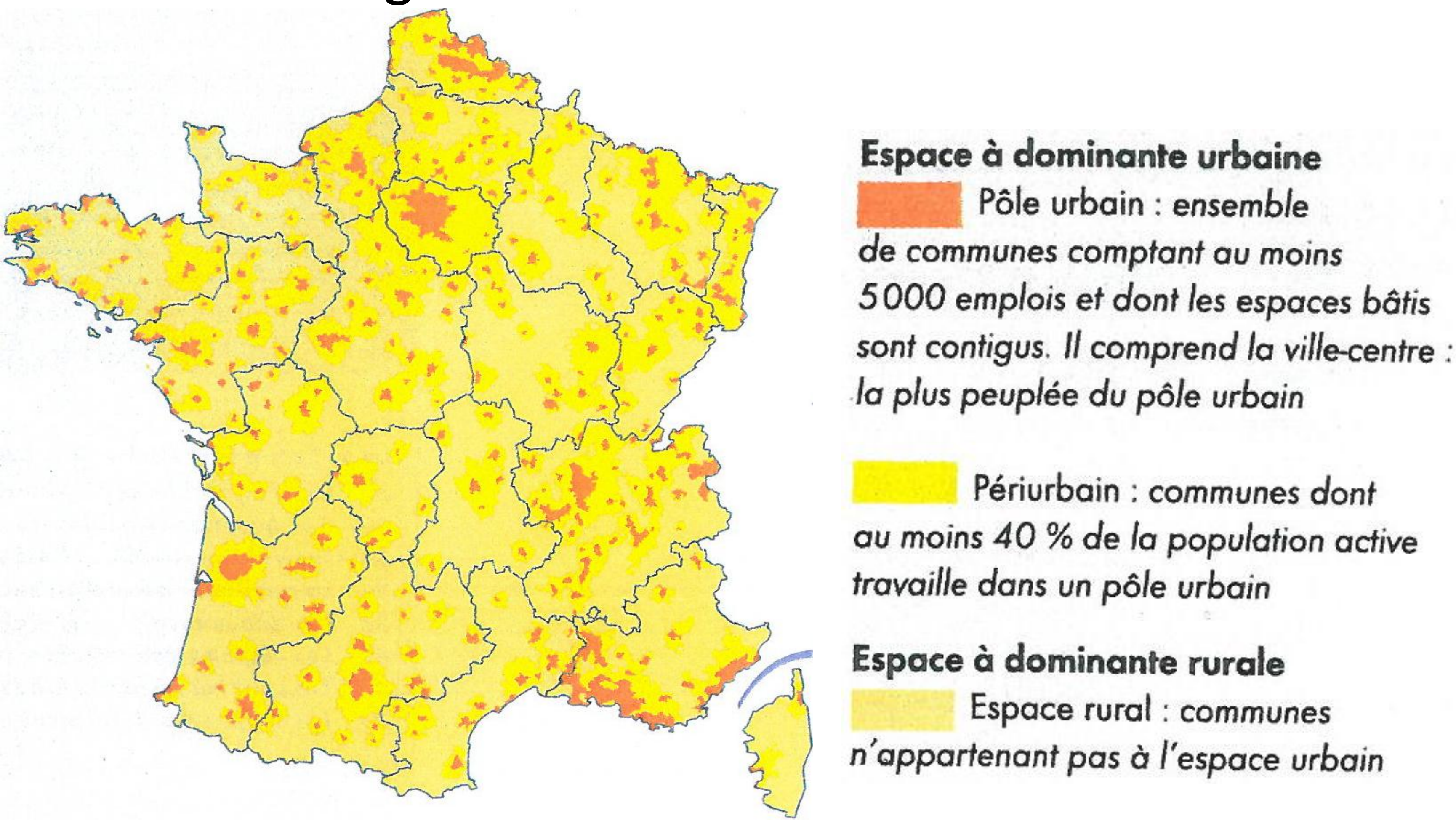
- Modeling the evolution of population
  - Modeling City growths, expansion, reduction
  - Modeling Suburb Evolution



An example Forecast of the expansion of Montpellier

Domain of Application

Modeling Suburb Evolution

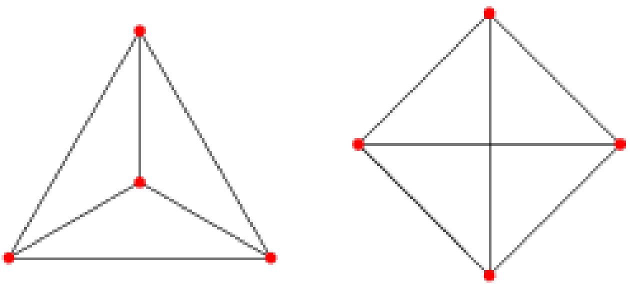


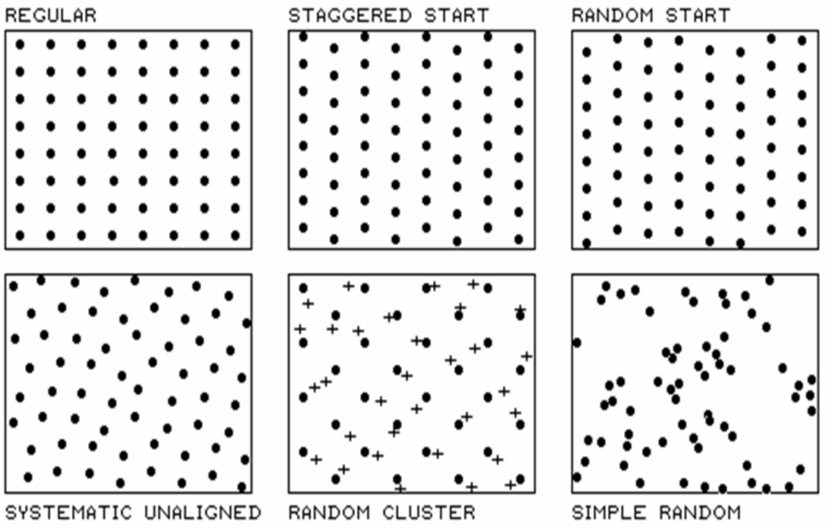
Atlas des nouvelles fractures sociales en France ; Les classes moyennes face à la mondialisation : la tentation du repli - Christophe Guilluy (Auteur), Christophe Noyé (Auteur), Dominique Ragu (Cartographer)

GEOSPATIAL DATA

Types of Geospatial Data

- Four Data Features:
  - Planar Graph (aggregated data - communes, departments …Eg: population)
  - Point-wise Geographical Information (Altitude Map,…)
  - Multivariable Sources (Population, Income, Water resources …)
  - Time Series (Population Censuses, and other time series)





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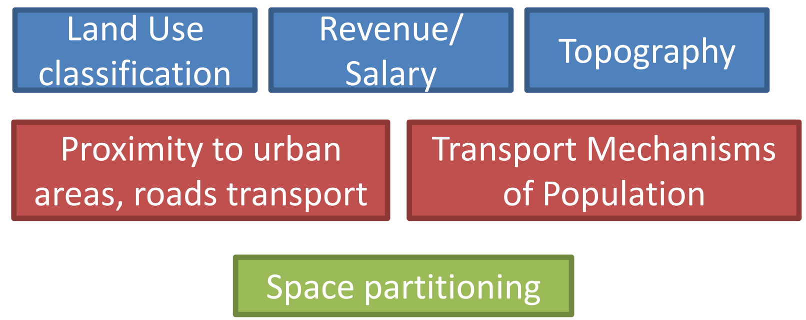
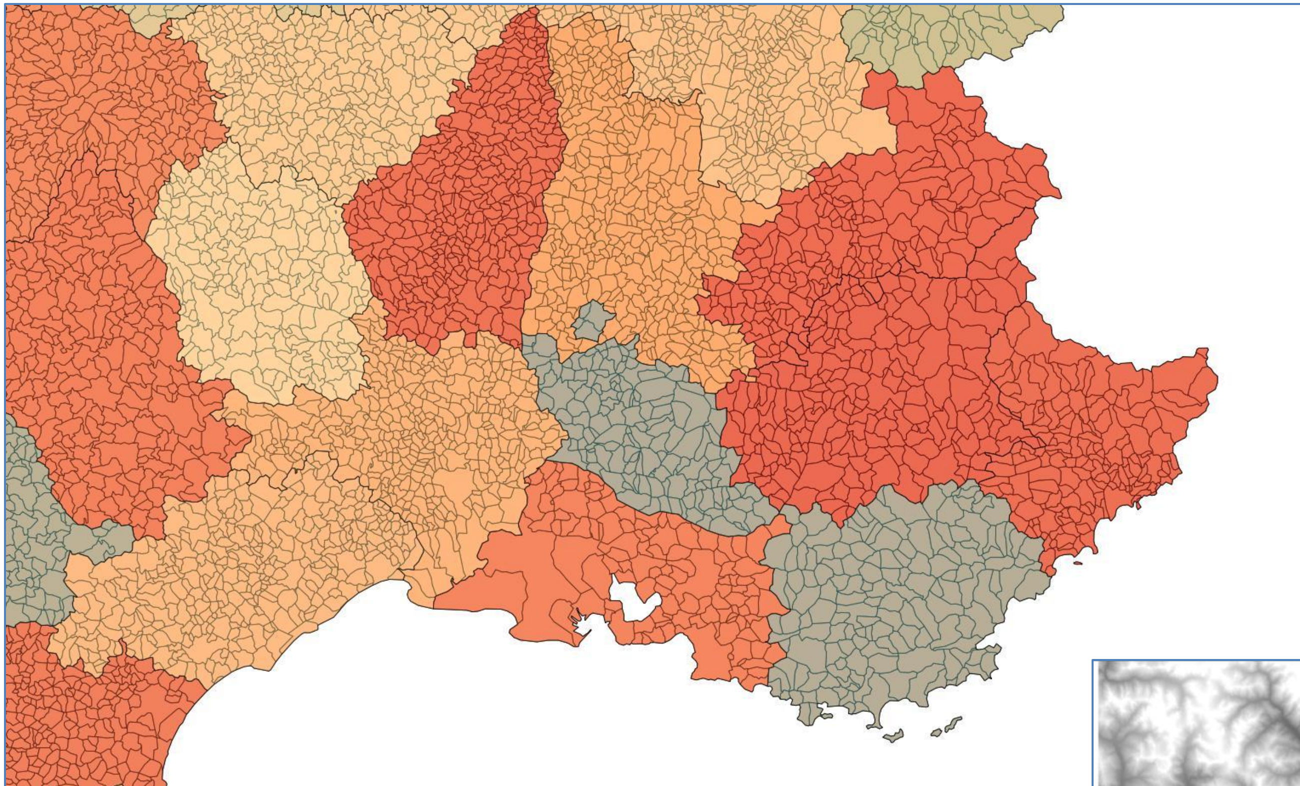
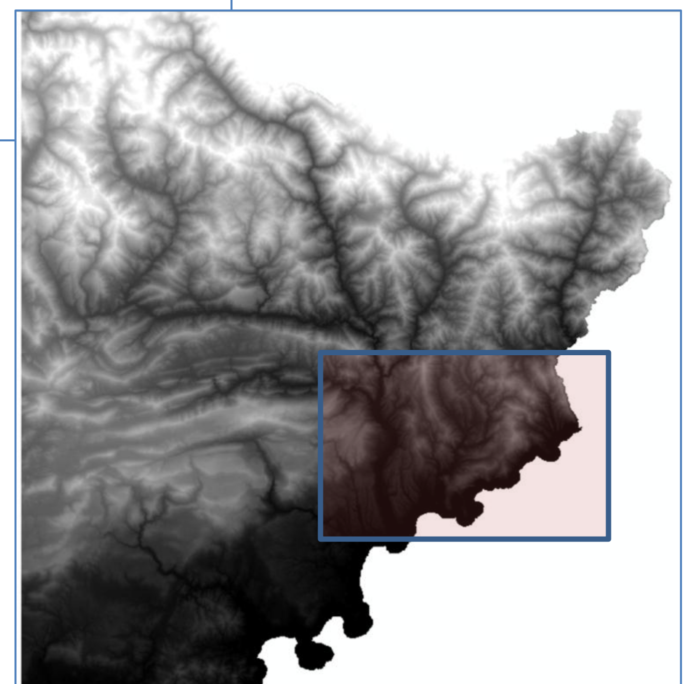


Spatio-Temporal Series





Communes in PACA (Planar Graph)
Relief of the zone in PACA (Pixel Data)

Nature of Multivariable Data

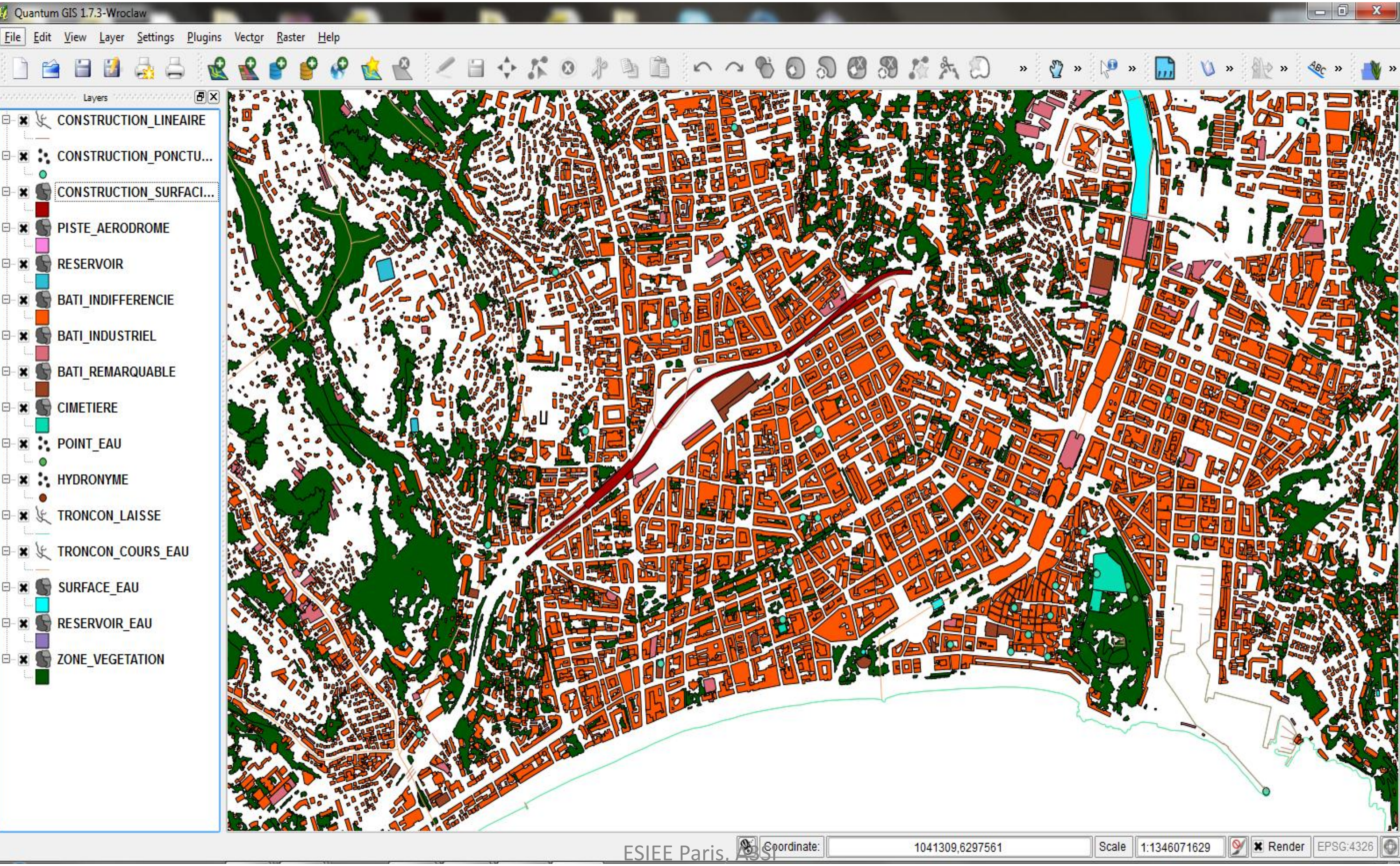
DATASET TITLE	Type of data	Comments
Population	- per 200x200 meter sq tile - per 1x1 km sq tile	Data is in the form of <x y value> raster
Population	- per commune/dept/region/	data is a list <commune value> - Time series 2008, 1999, 1990, 1982, 1975, 1968
Revenue Salaries	- per commune	data is a list <unit (comm/dept) value> - Time series 2005,2006,2007,2008,2009 Source: <C>

Nature of Multivariable Data

Administrative boundaries	Data contains indexed commues/cantons/arrondisement/depts with their boundaries in XY locations	data contains various values: <commune idx [xy] centroids of polygons, [xy] of polygon>
Altitude	- per 50x50 meter sq tile	<x y altitude> Altitude sampling is not registered with population sampling
Other Maps	- Vector file defined per department	Equipment, Occupation Sol, Hydrographie, Toponymie, road/path/routes,

Classified Data
Land Use in PACA

Classified Data - Land Use in PACA



GIS Software tools

- ArcGIS, QGIS (since the 1980s)
- Problems in having well “registered” maps
- Coordinate systems and Projection systems?
- Data types and Datastructures (MIF, MID …)

Processing Geospatial Data

- For one spatial variable, two steps are performed
  - Image Segmentation
  - Pyramid of Segmentations (captures scale)
- Segmentation is performed to delineate
  - Zones in which a given criterion is uniform
  - Border between uniform zones
- This results in a **partition** of the space

PYRAMIDS

Generation of a hierarchy of partitions (Pyramids)

The input image is represented as a Edge weighted graph

One calculates a sequence of minima by successive floodings.

At each step a watershed is created

The partitions of the vertices increase so that watershed lines are associated with a saliency

Therefore the saliency is a compact representation of the whole hierarchy.

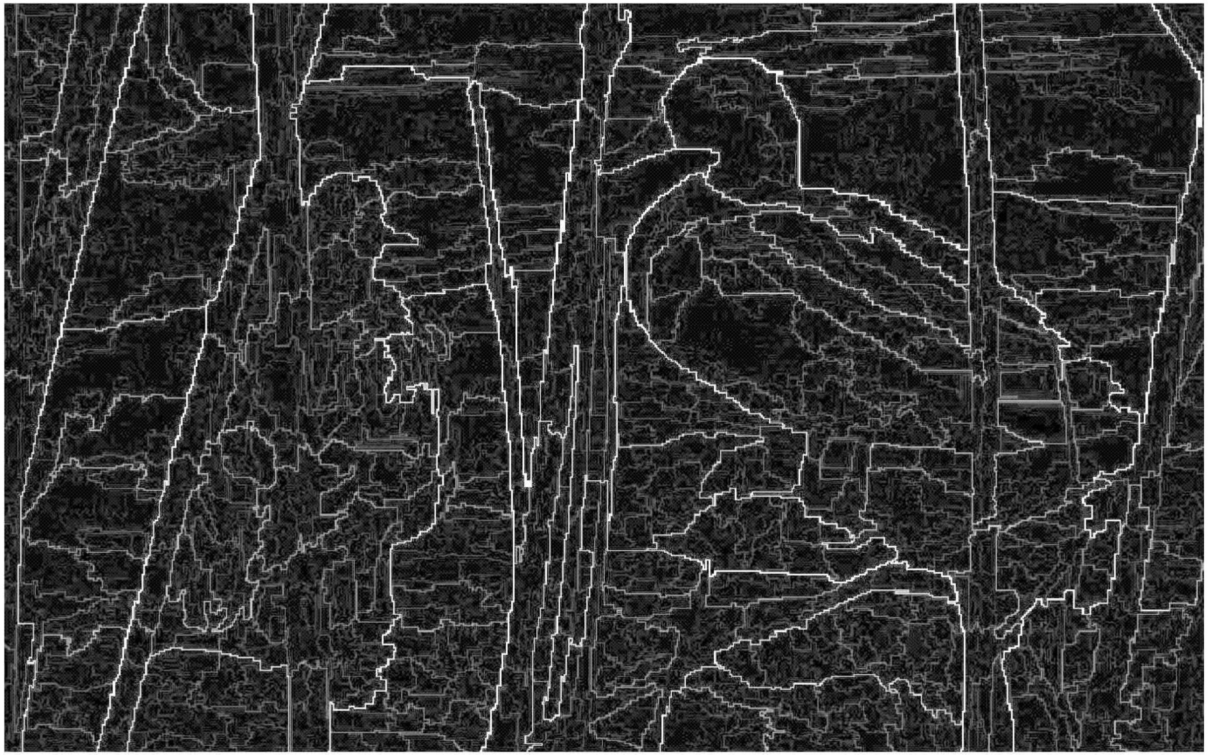
Input Image

(R+G+B)/3 -
Luminance

RGB

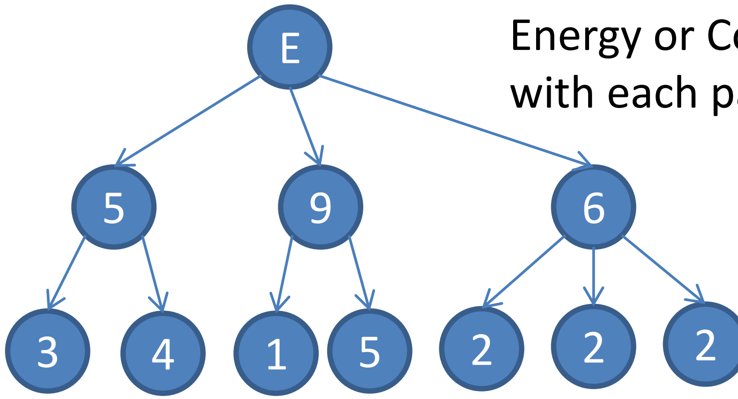
Honeymoon on the Danube River in Budapest ☺

Saliency and Hierarchy

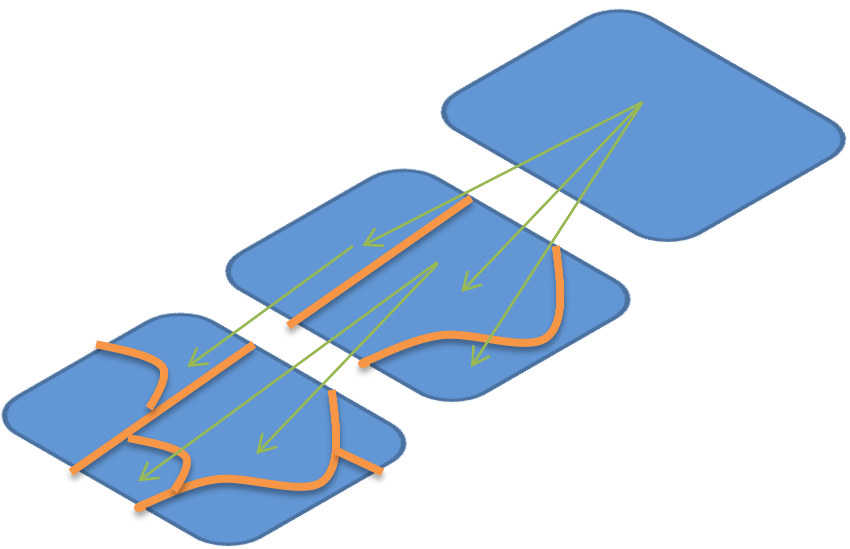


Thresholding the Saliency gives the partitions of the different levels of the Hierarchy of Duck Image

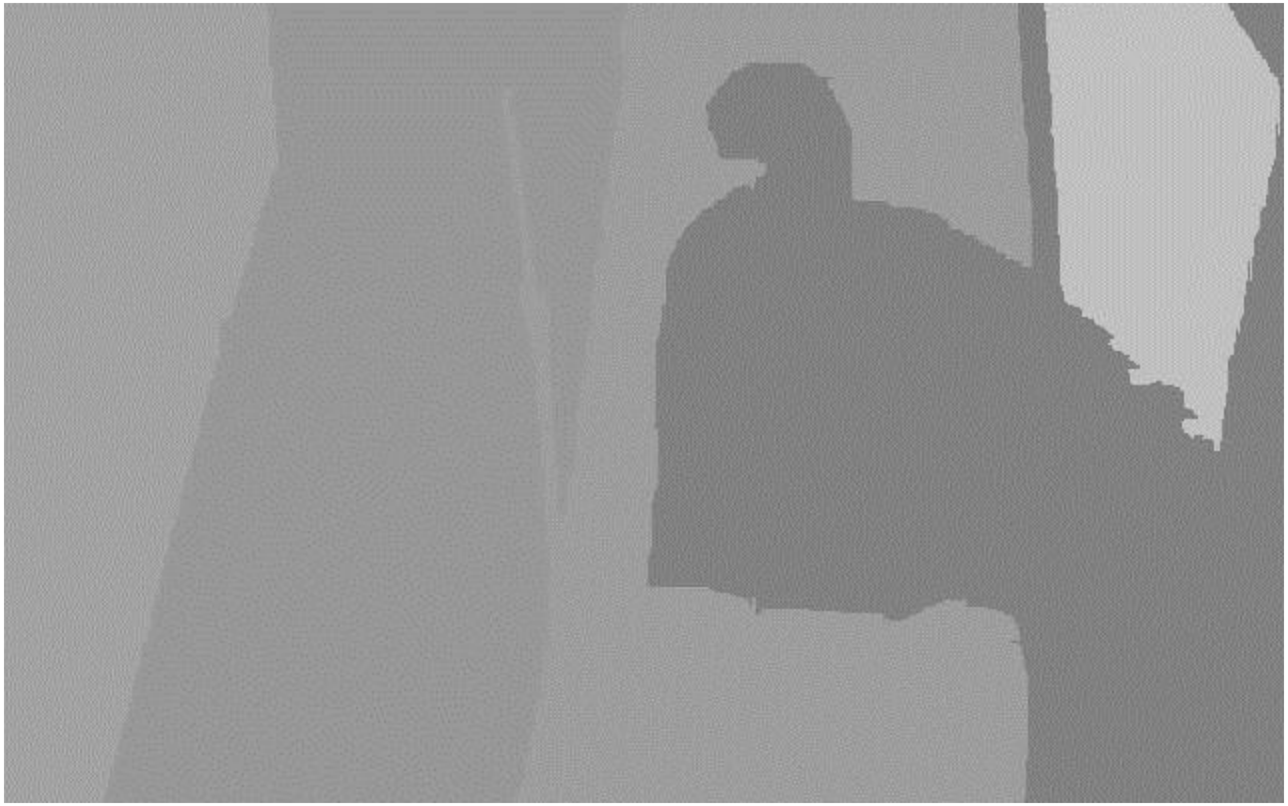
Generating the hierarchy

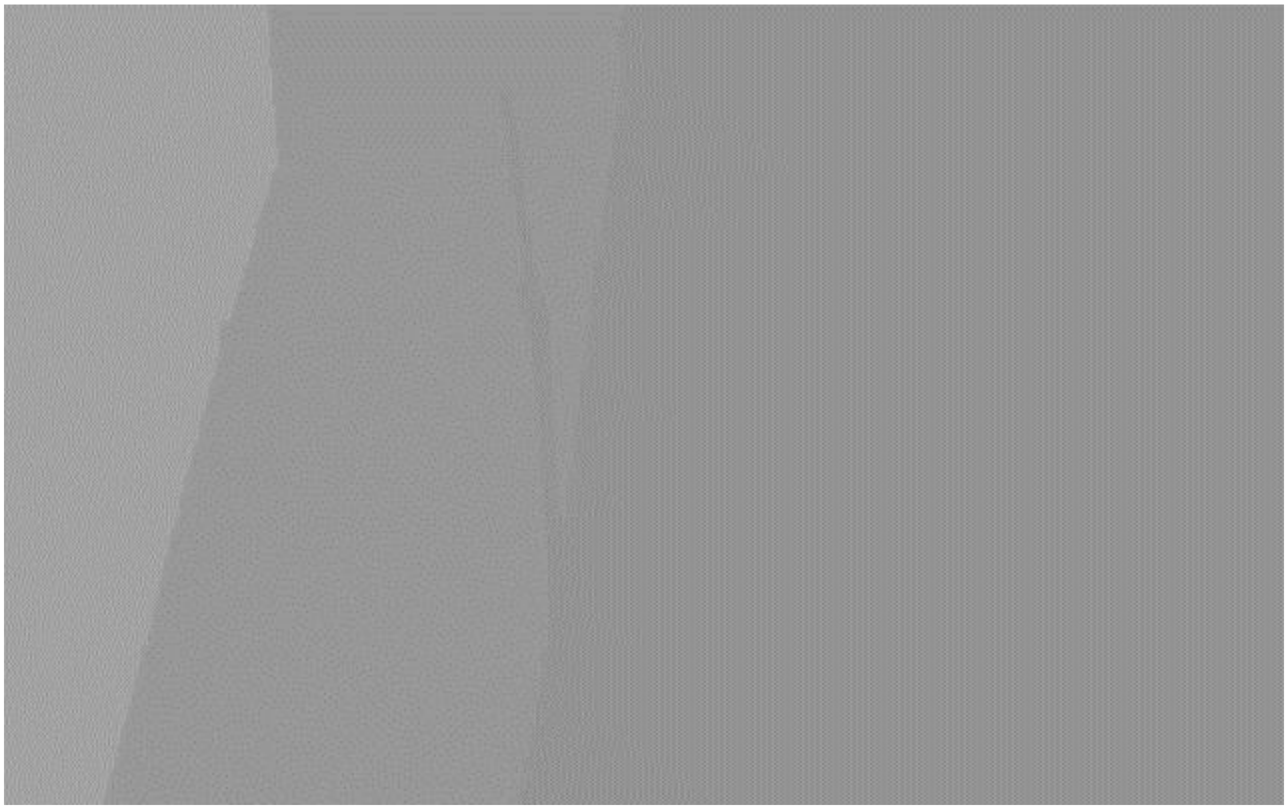


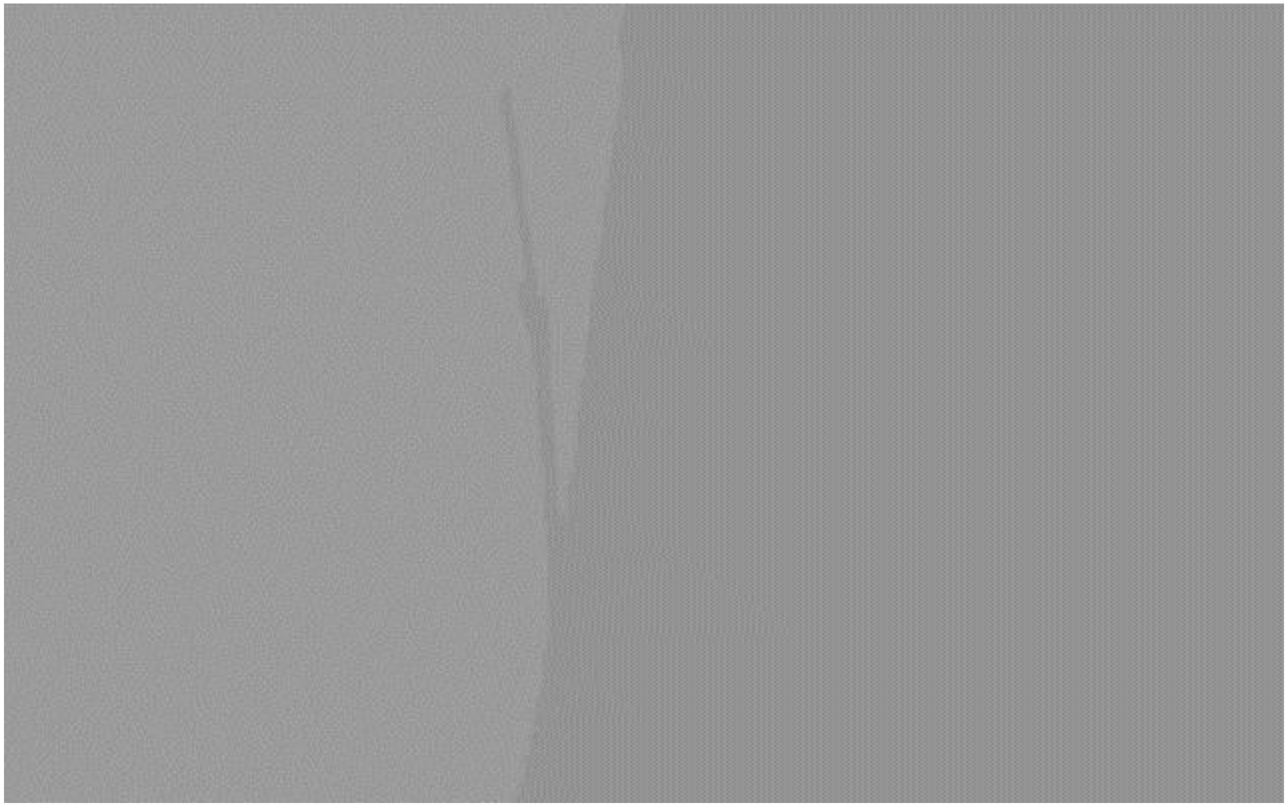
Energy or Cost associated with each partial partition

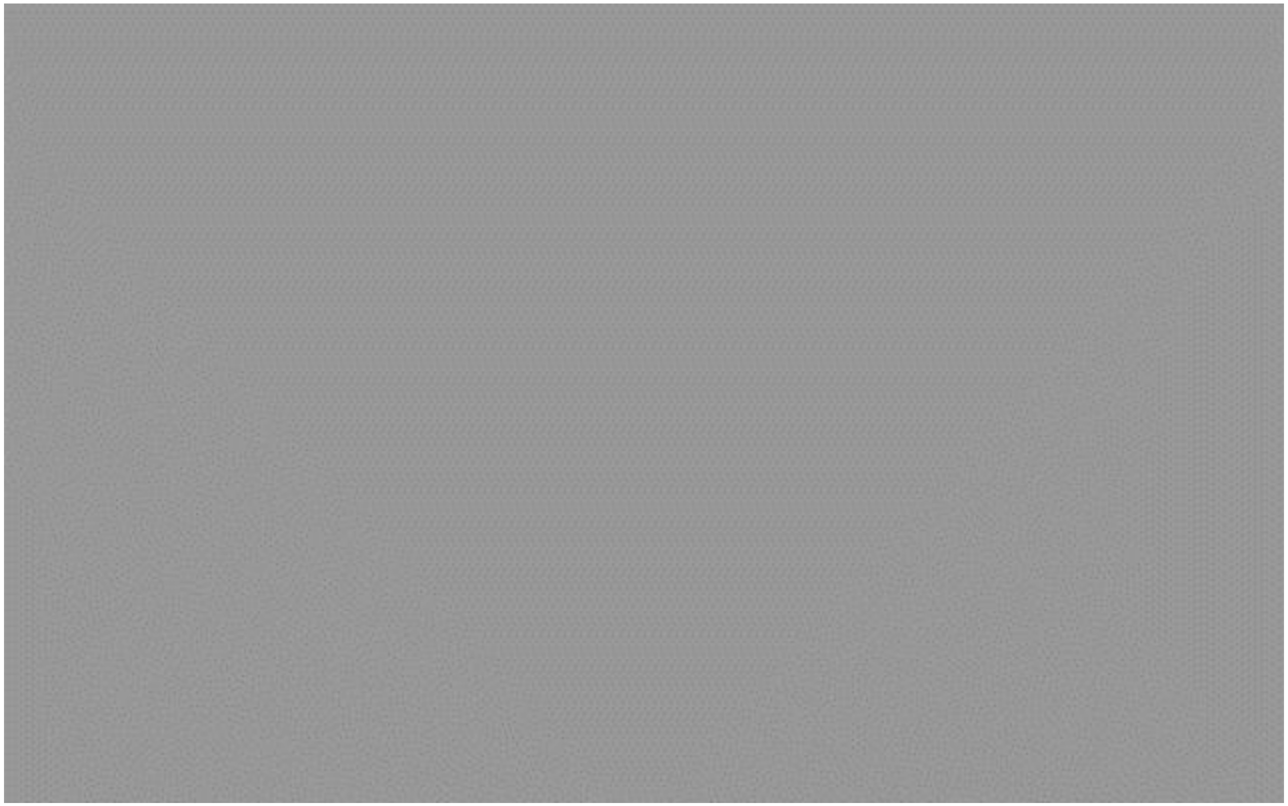


Hierarchy of segmentations generated by connected area closings of increasing area parameter



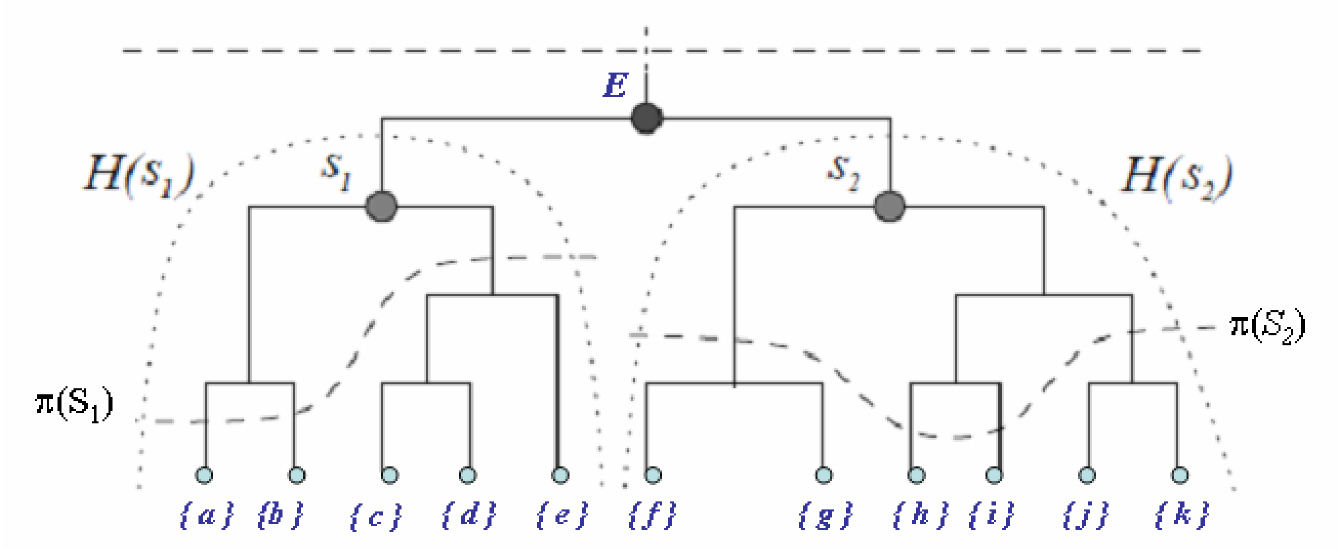






Cuts

- Given an initial hierarchy *H*, a number of partitions of *E* whose classes are in *H* can be obtained.



- These undulating sections are called ***cuts*** and denoted by π

Energy and pyramid

There are a combinatorially high number of cuts. To choose among them, we « Climb the pyramid in an principled way ».

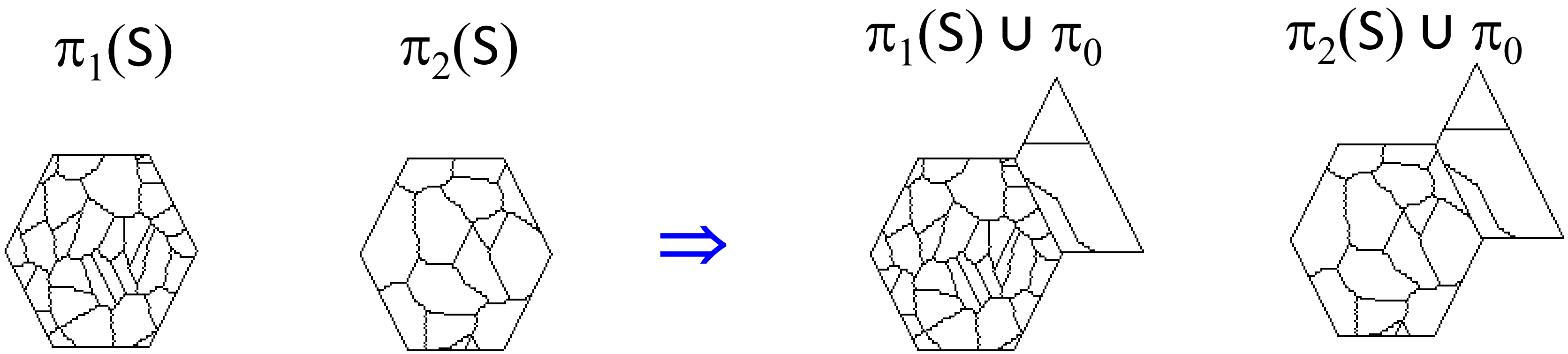
This rests on three independent data

- A ***pyramid*** *H* of partitions of *E*,
- A ***function*** *f* on E

  f may be the initial image, or another
- An ***energy*** i.e. a non-negative function ω on the set of all partial partitions.

Hierarchically Increasing Energies

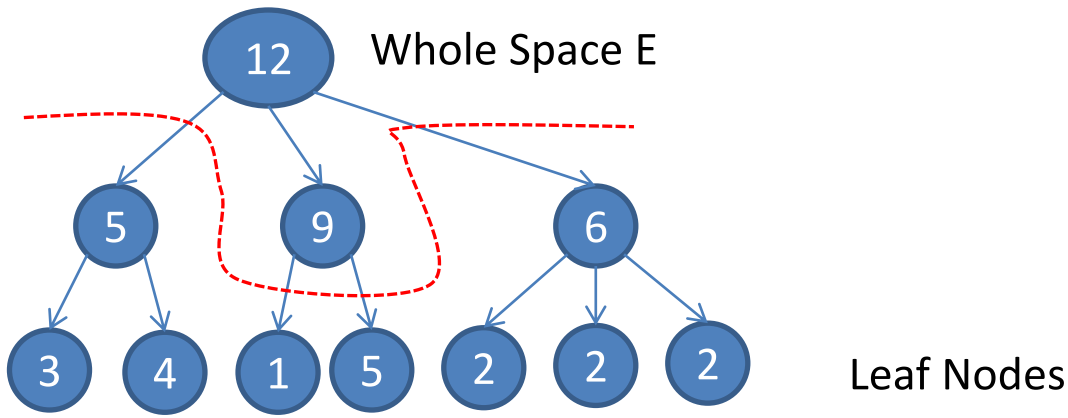
- Is there a cut of ***minimum energy*** ?
- Answer is Yes in case of ***hierarchical increasingness***



$$\omega\,[\pi_1(S)] \le \omega\,[\pi_2(S)] \quad \Rightarrow \quad \omega\,[\,\pi_1(S) \cup \pi_0] \le \omega\,[\pi_2(S) \cup \pi_0]$$

At any sub hierarchy the optimal either consists of the summit itself or union of the optimal cut of the sons – **IFF** the energy is H-increasing .

Optimizing on the hierarchy



$$\omega\big(\pi(S)\big) = \sum_{1 \le u \le q} \int_{x \in T^u} ||(f(x) - m(T^u)||^2 + \lambda \sum_{1 \le u \le q} \left(\frac{k}{2} dT^u + 24 \right)$$

Fidelity Term + (Scale Parameter) Compression Cost

Objective function

Lagrange Parameter

Constraint

EXAMPLES

Optimal Cut

Lambda = 60

Using Average of RGB channels for from the original image to calculate the mean values of classes

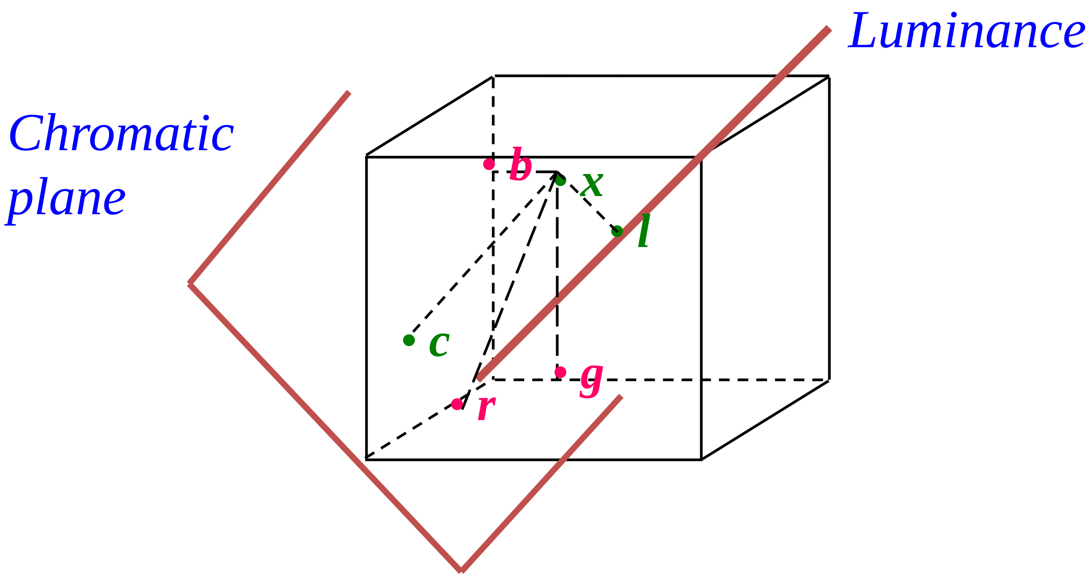
$$\omega(\pi(S)) = \sum_{1 \le u \le q} \int_{x \in T^u} ||(f(x) - m(T^u)||^2 + \lambda \sum_{1 \le u \le q} \left(\frac{k}{2} dT^u + 24\right)$$

Chrominance

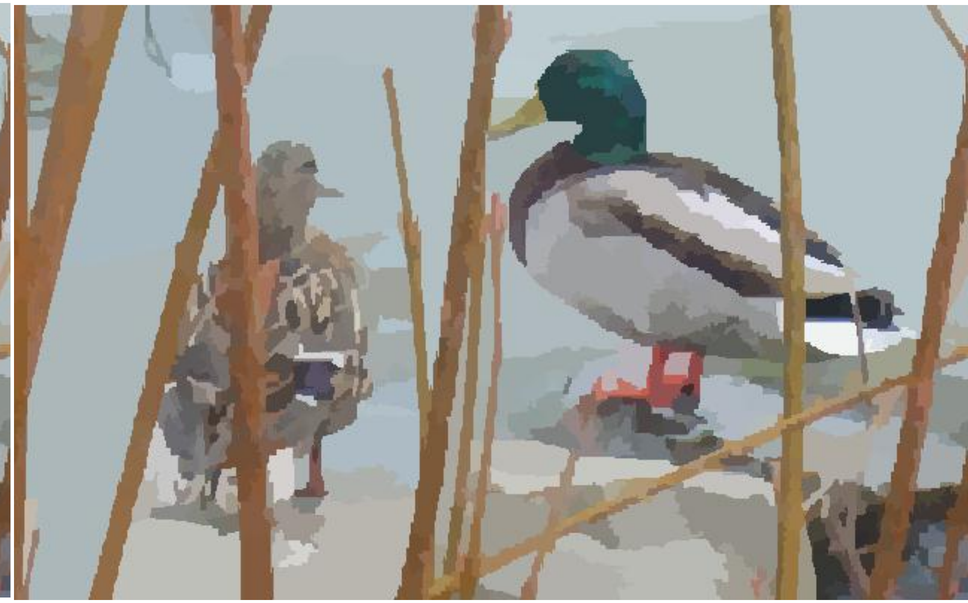
Passing to *polar coordinates*, one finds

$$1.5\, c\sqrt{2} = (\, 2r - g - b\ ;\ \ 2g - b - r\ ;\ \ 2b - r - g\,)$$

$$3l = (\, r + g + b\ ;\ r + g + b\ ;\ r + g + b\,)$$



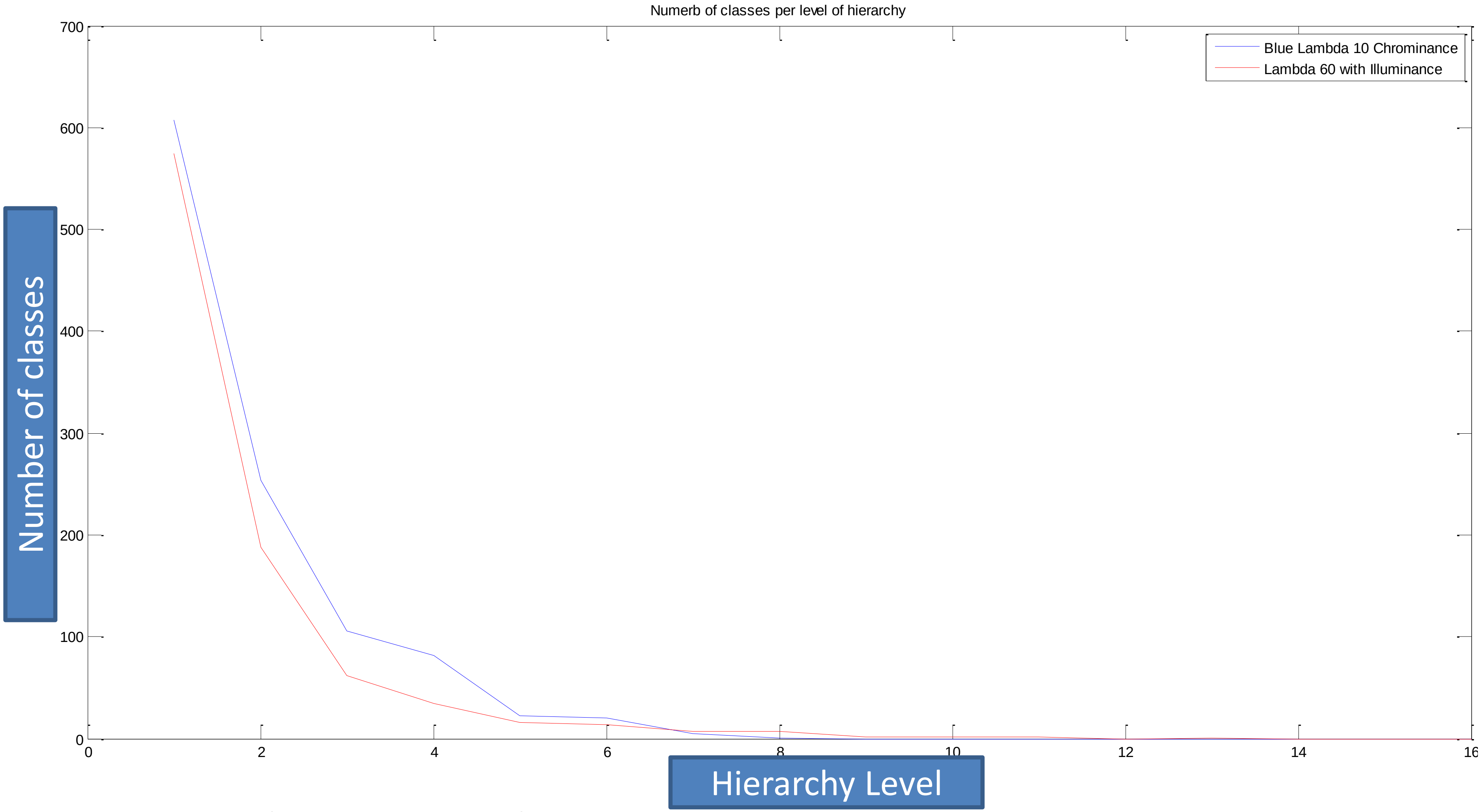
Optimal Cuts
Luminance Vs Chrominance



Optimal cut
Lambda = 60
Compression = 21
Number of Classes = 1097
Energy: variance(Luminance) + perimeter/2 + coding cost

Optimal cut
Lambda = 10
Compression = 19
Number of Classes = 911
Energy: variance(Chrominance) + perimeter/2 + coding cost

Distribution of classes in optimal cuts



The number of classes in the of the best cut using chrominance is

Future Work

- Developing morphological tools for Geospatial data
- In particular for
  - Energy suitable to model Population
  - Multivariable Climbing
  - Modeling Time evolution of Population, Employment etc.

Publications and Reports

- Papers
  - Hierarchies and Climbing Energies – Jean Serra, B Ravi Kiran, Jean Cousty: Accepted CIARP 2012
  - Climbing: A unified approach for global constraints on hierarchical segmentation- B Ravi Kiran, Jean Serra, Jean Cousty Accepted ECCV 2012 workshop on Higher order Potentials
- Technical Reports
  - Climbing the pyramids Technical Report ESIEE, March 2012 – Serra, J., Kiran, B.R. - updated HAL.
  - GIS Datasets and methods of Hierarchical segmentation - Technical Report B Ravi Kiran March 2012
  - Climbing energies and hierarchical Image segmentation for colour and texture images– Technical Report June 2012

Questions ?