Adaptive spatio-colorimetric classification

Michèle Gouiffès
IEF Institut d'Electronique Fondamentale UMR 8622
Université de Paris XI ORSAY, France

Color classification methods :

- Clusters of colors in the color space
- Modes in color histograms

Spatio-colorimetric classification : introduction of spatial information in the attributes to classify

Classical classification methods using extended attributes: vector of neighbors pixels **[Ferri 92]** , Neural network **[Campadelli 97]**, Fuzzy classification **[Noordam 00]**, Homogram **[Cheng 03]**: fuzzy homogeneity vectors.

Pyramid of connectedness degrees **[Fontaine 01]**, Spatial color compactness degree **[Macaire 06]**.

Our approach:

Use of the **connectedness degree** in a more time-effective classification method.

I. The connectedness degree

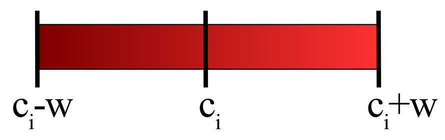
First order probability of a color interval

Trichromatic components $c_i=(c_1,c_2,c_3)$

Monochromatic color intervals of size $2w+1$: $I(c_i,w)=[c_i-w,c_i+w]$

First order probability of a color interval :

$$P_1(I(c_i,w))=\sum_{a\in I(c_i,w)} P_i(a)$$



An interval I on the R component

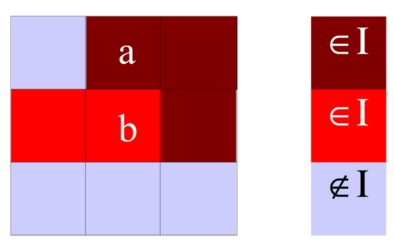
Second order probability of a color interval

Occurrence probability $P_{oc}(a,b)$: probability that colors a and b are neighbors (8-connectedness)

Co-occurence probability $P_{cc}(a,b)=\frac{1}{8}\sum_{a\in N(b)} P_{oc}(a,b)$

Second order probability of a color interval:

$$P_2(I(c_i,w))=\sum_{a\in I(c_i,w)}\sum_{b\in I(c_i,w)} P_{cc}(a,b)$$



$P_2=0,5$

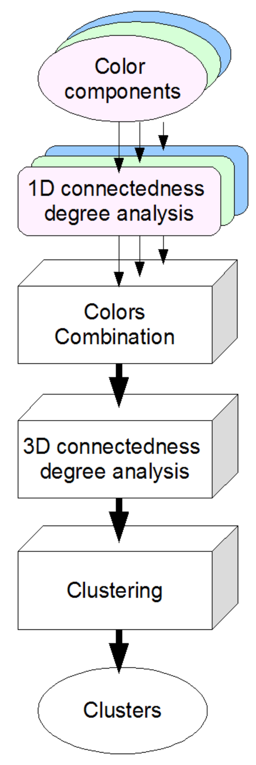
Connectedness degree

$$\mathcal{D}(I(c_i,w))=\frac{P_2(I(c_i,w))}{P_1(I(c_i,w))}$$

- **Property: maximun** when the interval $I(c_i, w)$ corresponds to one or several connected components in the image, *i.e* to a **meaningful color interval** in terms of connectedness.
- **Previous works on the connectedness degree :**
  - **[Fontaine00]:** gray images, multi-level 2D data structure.
    By analyzing various sizes of intensity interval, the relevant intensity classes are computed by extracting some *signatures* in this representation.
  - **[Fontaine01]:** extension to color.
    - Multi-level pyramid of connectedness for each bichromatic histogram.
    - 3 pyramids are required to extract each meaningful color interval : not time-effective.

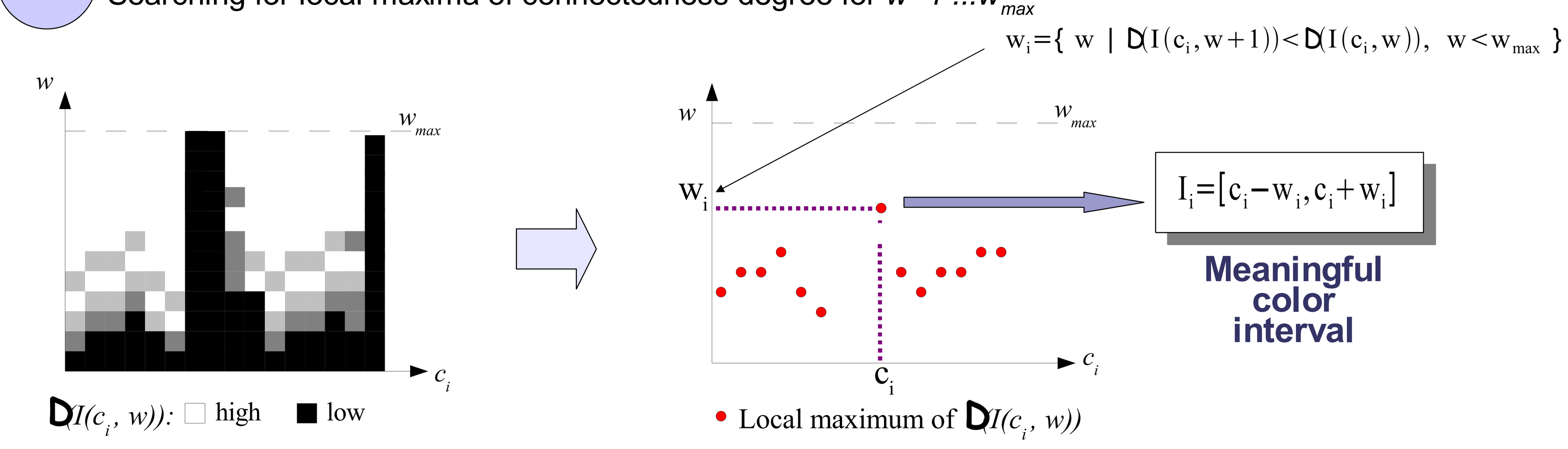
II. The procedure, in 3 stages

1. **Marginal analysis** of color connectedness degree on each color component independently.
   - Extraction of the most meaningful color intervals on each color component (local maxima of degree)
   - Reduction of the number of monochromatic colors
2. **Combination of colors**
3. **Vectorial analysis:** analysis of the trichromatic connectedness degrees.



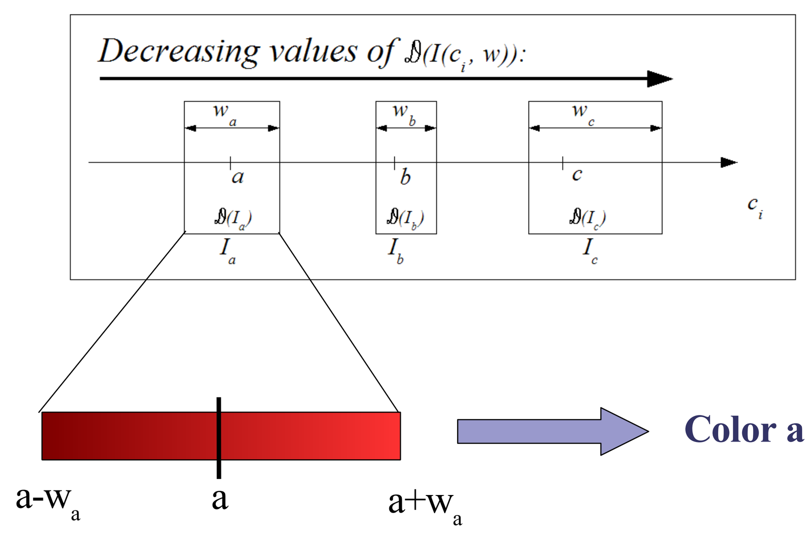
1 First stage : marginal analysis

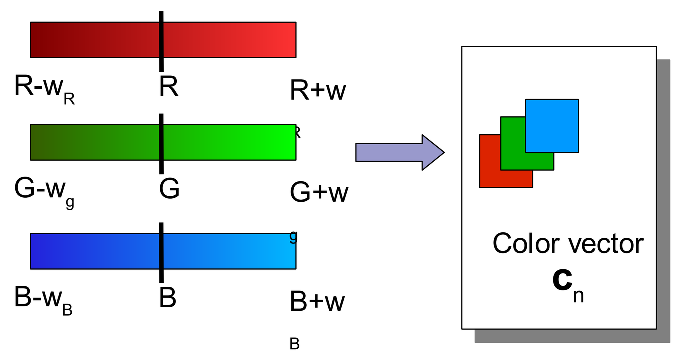
Searching for local maxima of connectedness degree for $w=1 \ldots w_{max}$



2 Color combination

- Color are sorted in decreasing order of degree
- Pixels are classified in that order
- Reduction of the number of colors: each color of the interval inherits the centroid color and will not be treated anymore by a less relevant interval.





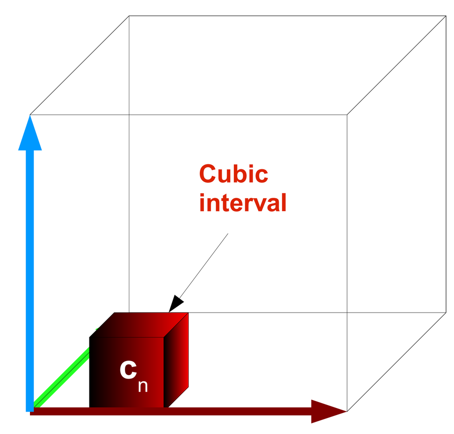
Color combination $\mathbf{c}_n$ for $n=1\ldots N$ gets: the color vector $\mathbf{c}(n)=(c_1(n),c_2(n),c_3(n))$

3 Vectorial analysis: similar analysis as the stage 1 but 3D intervals are considered.

Cubic color interval $\mathbf{I}(\mathbf{c}_n,d)$ in the color space, centered around the color $\mathbf{c}(n)$ and of size $(2d+1,2d+1,2d+1)$:

For $n=1..N$ and $d<d_{max}$:

$$\mathbf{I}(\mathbf{c}_n,d)=\begin{vmatrix}[c_1(n)-d,c_1(n)+d]\\ [c_2(n)-d,c_2(n)+d]\\ [c_3(n)-d,c_3(n)+d]\end{vmatrix}$$

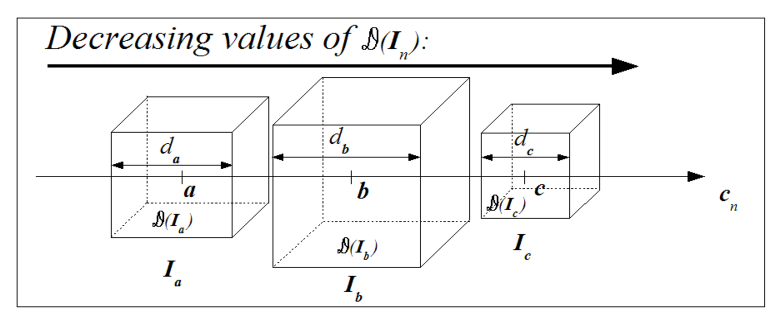


1st order probability of the 3D interval:

First order probabilities $P_1(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))$ of the colors intervals $\mathbf{I}(\mathbf{c}_n,\mathbf{d})$:
$P_1(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))=\sum_{\mathbf{a}\in\mathbf{I}(\mathbf{c}_n,\mathbf{d})} P_1(\mathbf{a})$
where $P_1(\mathbf{a})$ is the occurrence probability of the color $\mathbf{a}$.

2nd order probability of the 3D interval:

Second order probabilities $P_2(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))$ of the colors intervals $\mathbf{I}(\mathbf{c}_n,\mathbf{d})$
$P_2(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))=\sum_{\mathbf{a}\in\mathbf{I}(\mathbf{c}_n,\mathbf{d})}\sum_{\mathbf{b}\in\mathbf{I}(\mathbf{c}_n,\mathbf{d})} P_{cc}(\mathbf{a},\mathbf{b})$
where the co-occurence probabilities $P_{cc}(\mathbf{a},\mathbf{b})$ of two colors $\mathbf{a}$ and $\mathbf{b}$ are computed as:
$P_{cc}(\mathbf{a},\mathbf{b})=\frac{1}{8}\sum_{\mathbf{a}\in N(\mathbf{b})} P_{oc}(\mathbf{a},\mathbf{b})$
considering the 8-connexity and a neighborhood N around $\mathbf{b}$.



- Trichromatic color intervals are sorted in decreasing order of connectedness degree.
- The colors in I_a inherit the color **a**, then the colors in I_b inherit the color **b** and so on...

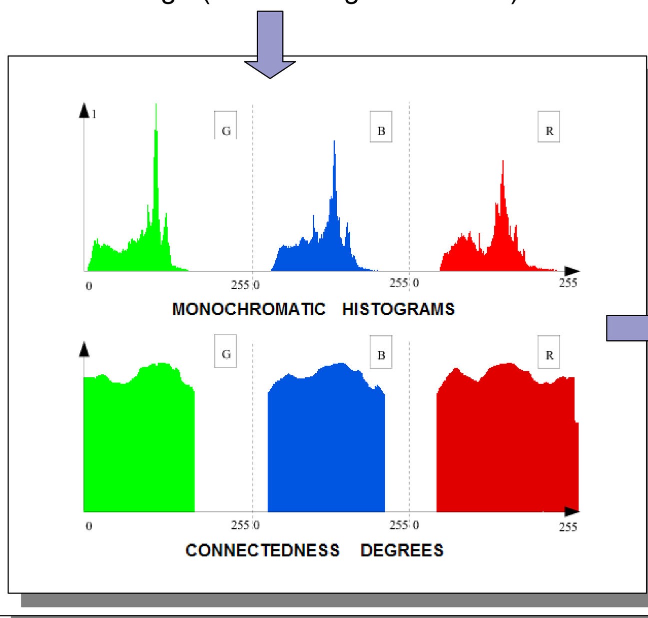
Connectedness degree of the 3D interval:

Connectedness degree $\mathcal{D}(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))$ of the interval $\mathbf{I}(\mathbf{c}_n,\mathbf{d})$ $\quad \mathcal{D}(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))=\frac{P_2(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))}{P_1(\mathbf{I}(\mathbf{c}_n,\mathbf{d}))}$

Example of result with :
$d_{max}=w_{max}$=10% of image range

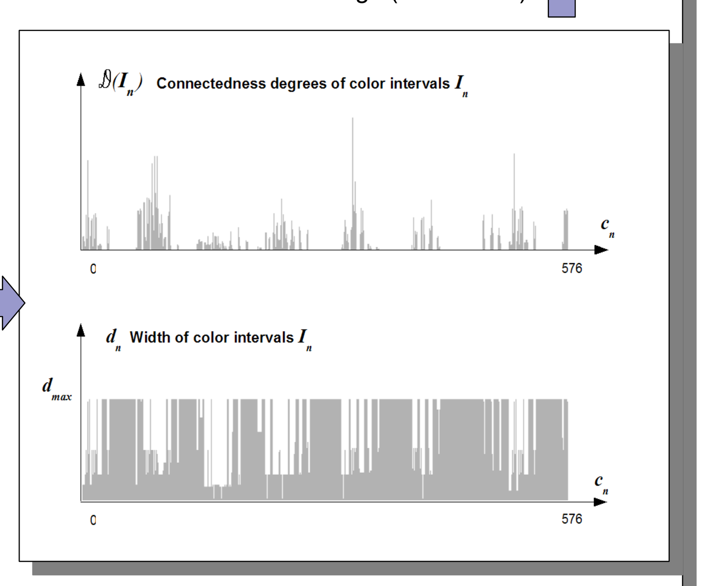
Initial image (Kodak image data base)

Classification result after 2nd stage (27 classes)



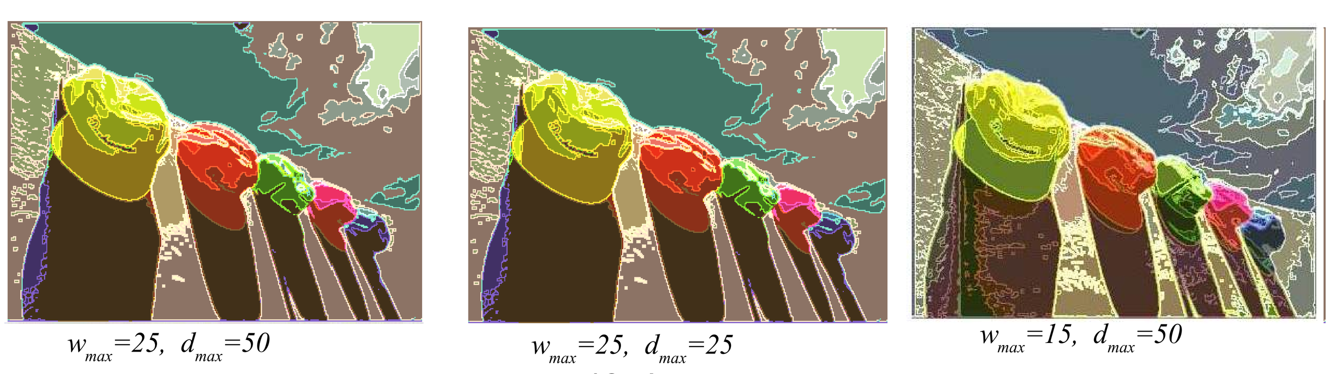
Classification result after 1st stage

⟹ 576 colors
(9 on R, 8 on G, 8 on B)



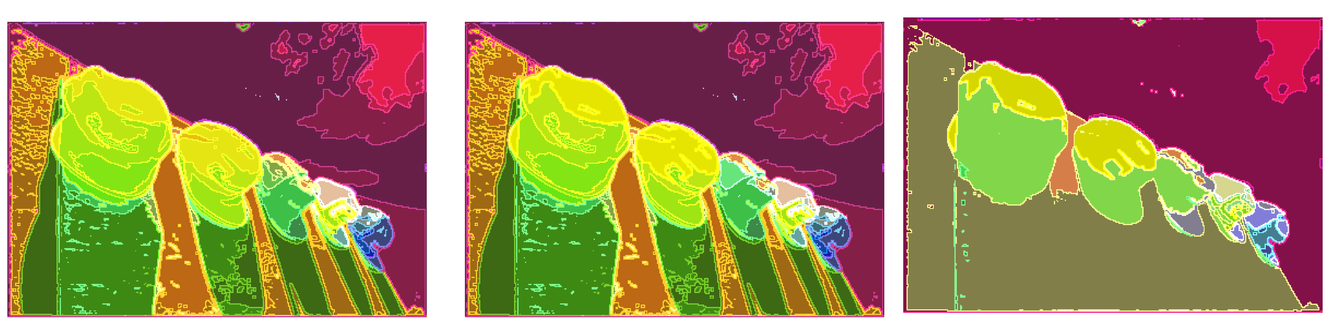
III. Results

RGB



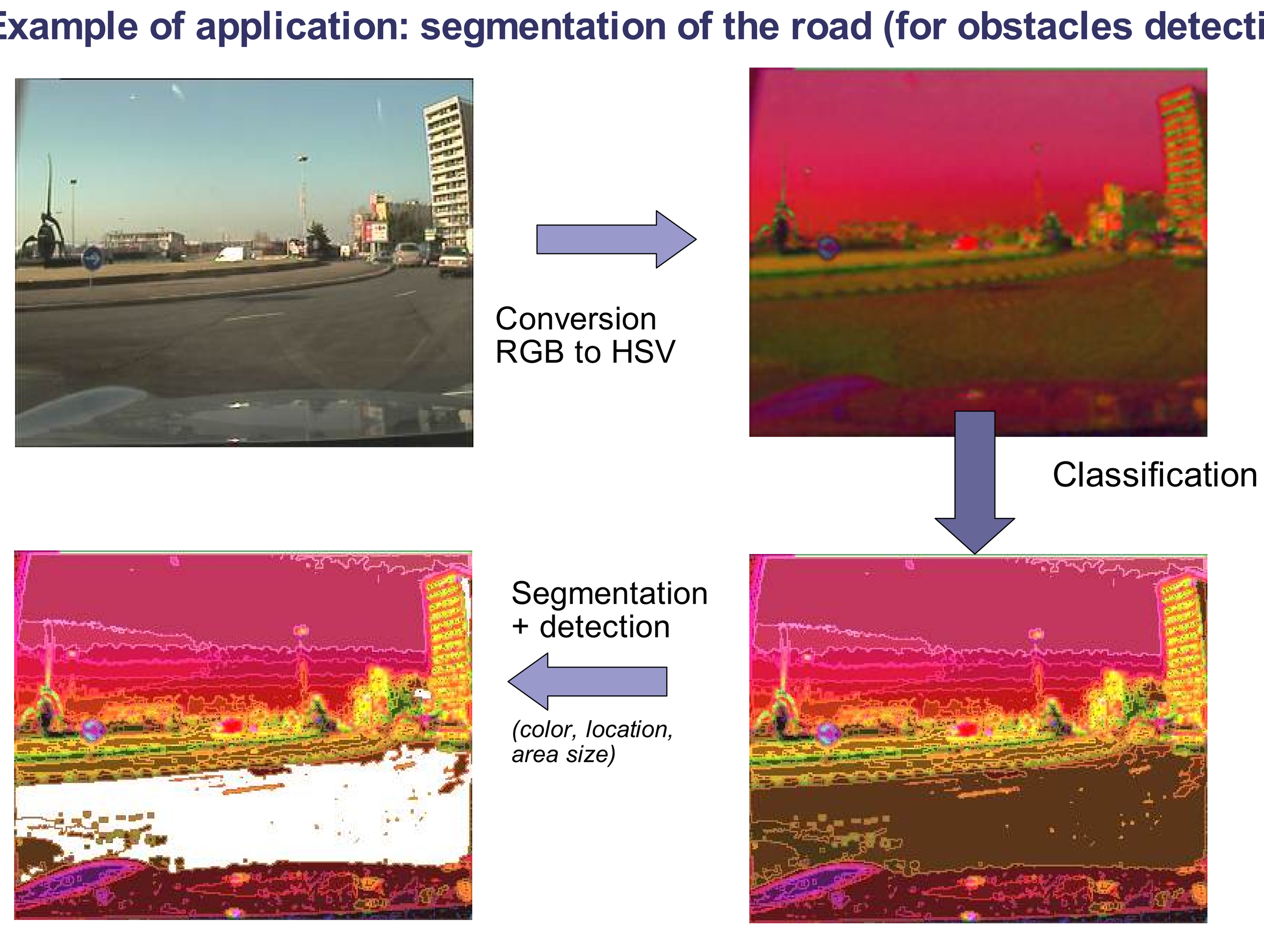
$w_{max}=25,\ d_{max}=50$ — 45 classes
$w_{max}=25,\ d_{max}=25$ — 46 classes
$w_{max}=15,\ d_{max}=50$ — 132 classes

HSV



$w_{max}=25,\ d_{max}=50$ — 58 classes
$w_{max}=25,\ d_{max}=25$ — 58 classes
$w_{max}=40,\ d_{max}=40$ — 24 classes

Example of application: segmentation of the road (for obstacles detection)



White pixels=road pixels