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Title: Image processing and nonparametric regression

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Image processing and nonparametric regression

Rencontres R BoRdeaux 2012

B. Thieurmel

Collaborators : P.A. Cornillon, N. Hengartner,
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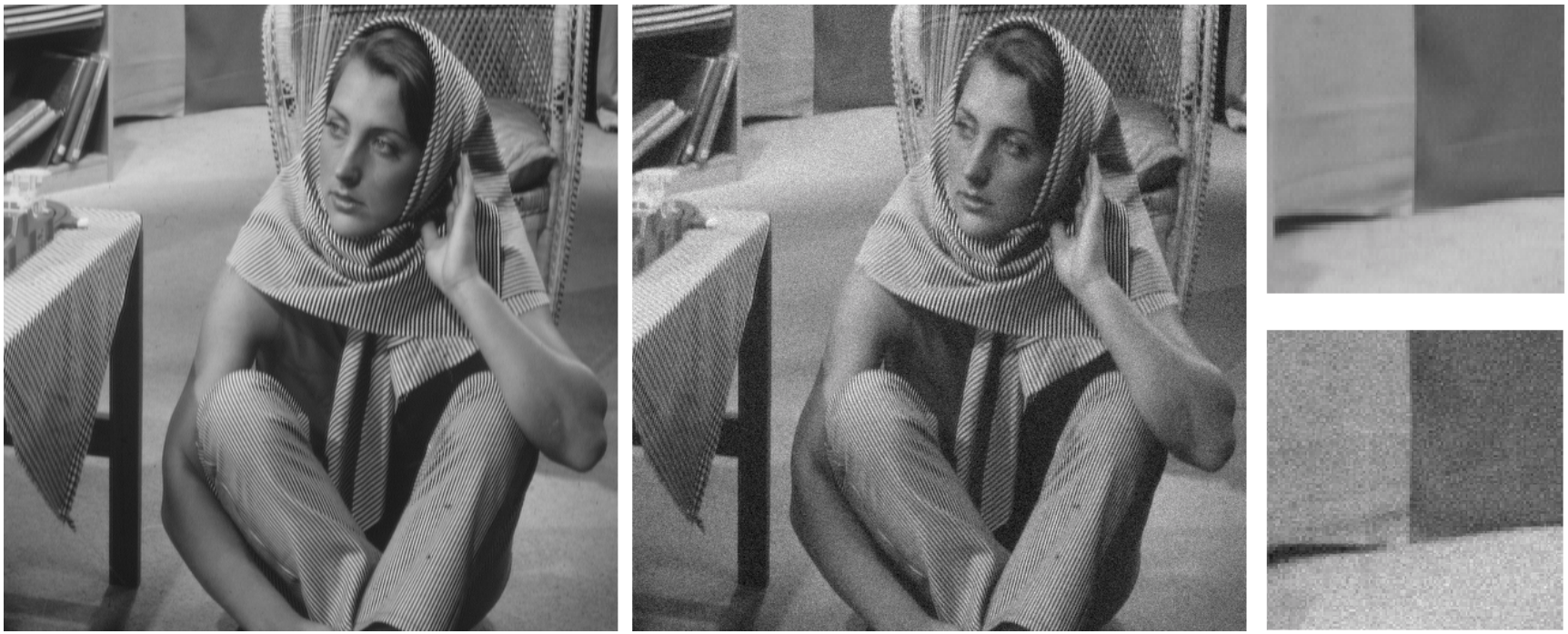
2 Juillet 2012



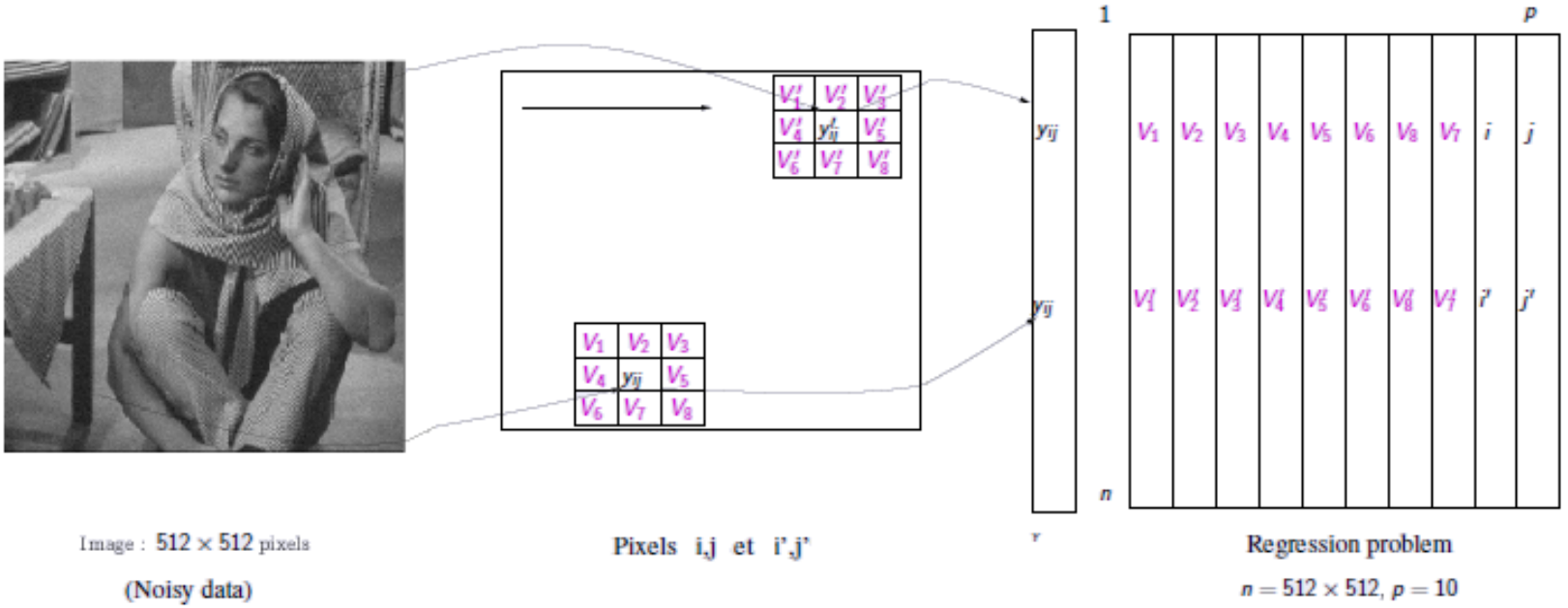
Definition :

- noisy image = original image + noise
- Our study : gaussian noise

- **image :** matrix pixel
- **one pixel**
  - represent a value of grey level or color level
  - is spatially defined by its coordinates (i, j)
  - is surrounded with 8 neighbors (vertical, horizontal and diagonal)
- **numerical measure :** Peak Signal to Noise Ratio (**PSNR**)

$$PSNR = 10 \times log10(\frac{d^2}{MSE})$$

  - d maximum possible pixel value of the image
  - MSE mean squared error between the original image and the treated image
  - quality of reconstruction, in decibel (**dB**)
  - well reconstructed image $\rightarrow 30 \leq \text{PSNR} \leq 40$



Notations :

- y_{ij} the grey level at pixel (i, j)
- Y the grey level of the pixel to be denoised
- $X \in \mathbb{R}^{10}$ (or more) the vector of explanatory variables

Non parametric regression model :

- $(X_i, Y_i) \in \mathbb{R}^d \times \mathbb{R}$ pairs of observations

$$\begin{aligned} Y &= m(X) + \varepsilon \\ \hat{Y} &= S_\lambda Y \end{aligned}$$

Using method Iterative Bias Reduction (**IBR**) :

- developed by Cornillon, Hengartner et Matzner-Løber
- competes with classic techniques (MARS, GAM)
- estimation without constraints of the regression function m
- **R** package **ibr** available on cran

Problem :

$n = 262144 \rightarrow$ smoothing matrix very big

Resolution :

Image partitioning in small-sized regions

Our proposal :

- free itself from the choice of the size of regions
- have a certain freedom of shape
- data dependent regions
- use of **CART**(Breiman *et al.*, 1984) and more exactly regression trees
- explain grey level Y by coordinates (i, j)

Modifications of package **rpart** (T.M. Therneau *et al.*, 2002) :

- application for high-dimension data
- control maximal and minimal region size

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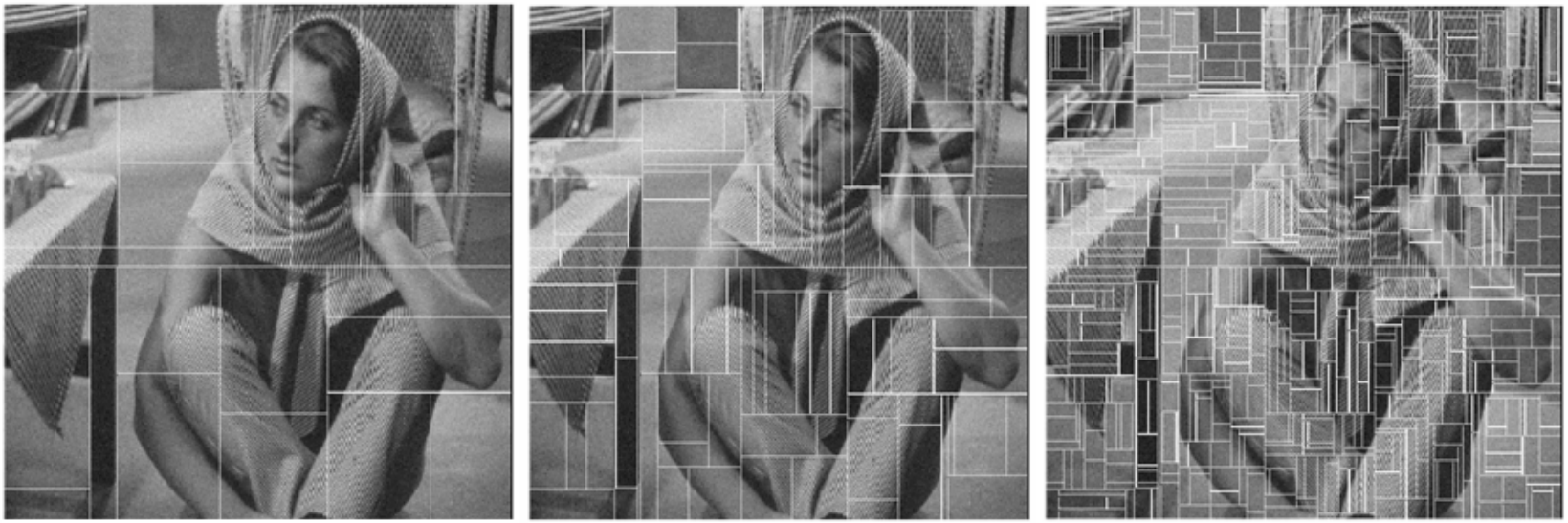
- Evolution of partitioning via **rpart** :



Characteristics :

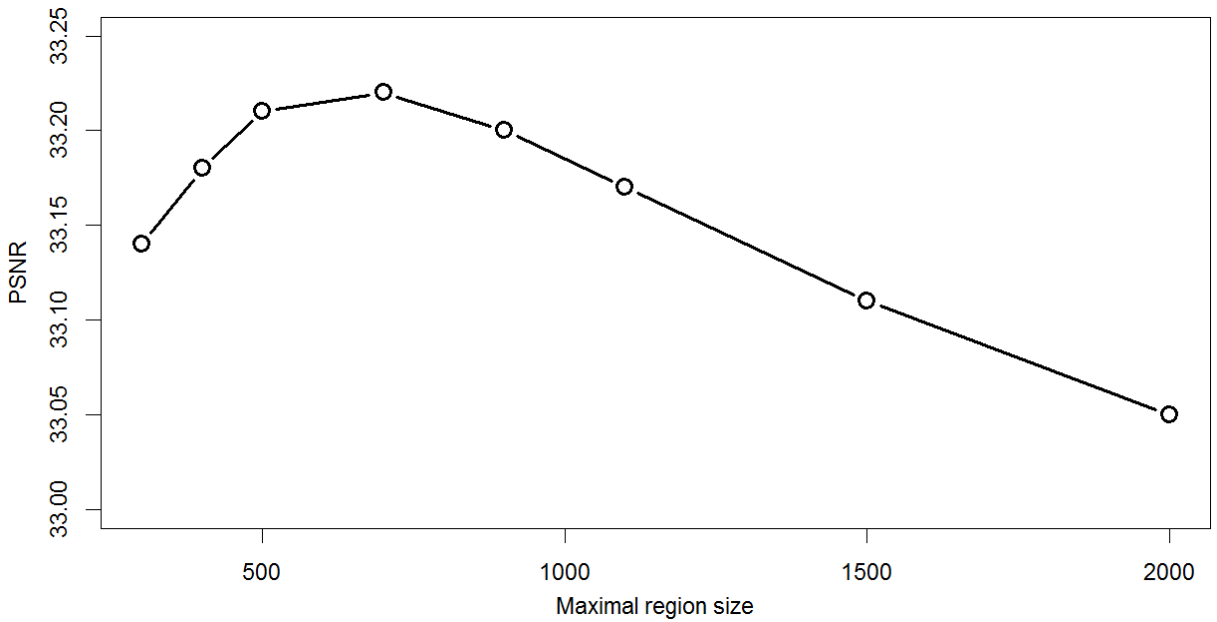
- rectangular regions
- detection of the horizontal and/or vertical structures of the image

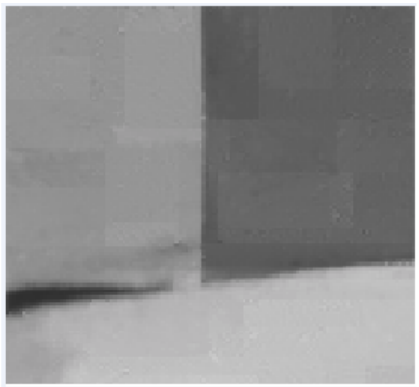
Regression model for each region :

$$Y_i = m(X_i) + \varepsilon_i, \quad i = 1, \ldots, n,$$

with $X \in \mathbb{R}^{10}$ the vector of explanatory variables, and n the size of the region

- Question : Influence of the size of regions ?



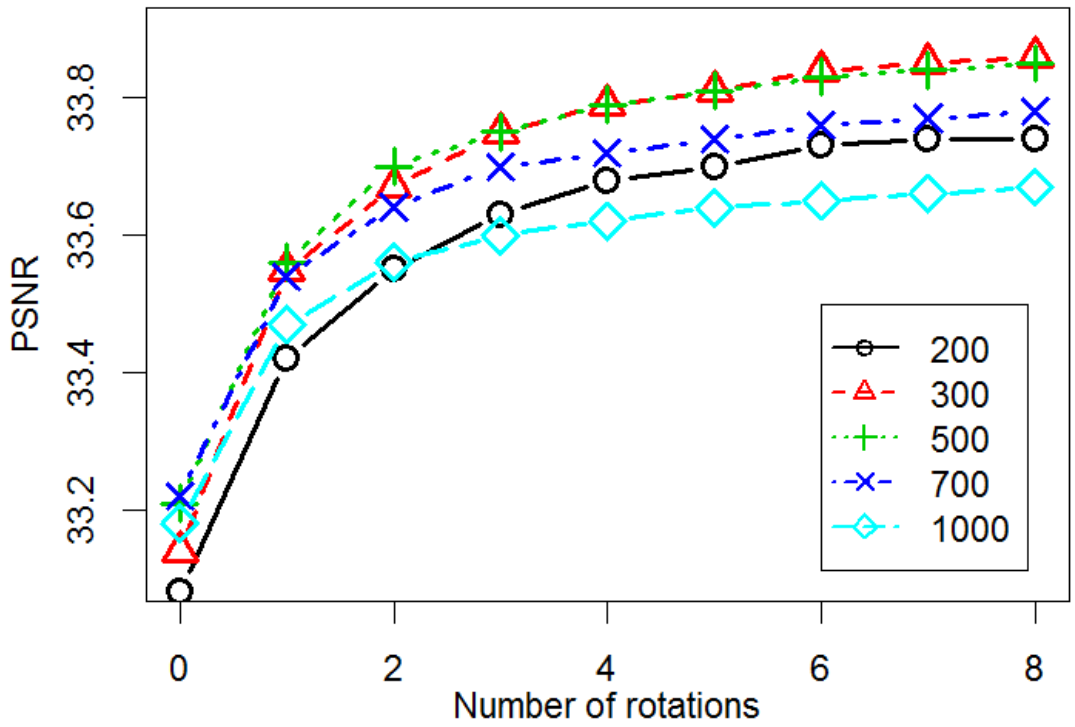


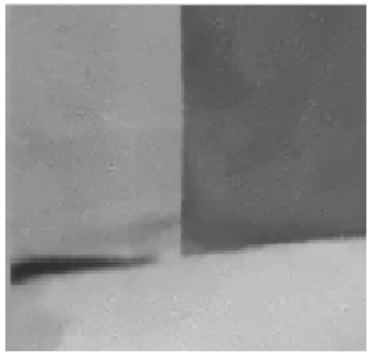
- maximale size of regions : 700 pixels
- number of regions : 686
- region no overlapping $\rightarrow$ visibility of the outlines of regions
- PSNR = 33.22 dB

Rotation :

- iteration of image partitioning and image denoising via **IBR**
- rotation of plan IJ between every iteration
- prediction of a same pixel with different regions
- unique prediction : mean of predicted values

- Question : Influence of the number of rotations ?





- maximale size of regions : 300 pixels
- number of rotations : 3
- PSNR $= 33.75$ dB $\rightarrow +$ 0.5 dB

Presentation :

- developed by Dabov *et al.*, 2007
- state of art
- **algorithm :** standard deviation of the noise in parameter
  $\rightarrow$ strong influence on the result
  $\rightarrow$ unknown noise, default standard deviation = 25
- source **Matlab** code available

Comparison BM3D / IBR :

- several images with various noise
- 3 results :
  1. BM3D with good standard deviation of the noise
  2. BM3D with default standard deviation of the noise
  3. IBR, 3 rotations, maximale size = 700

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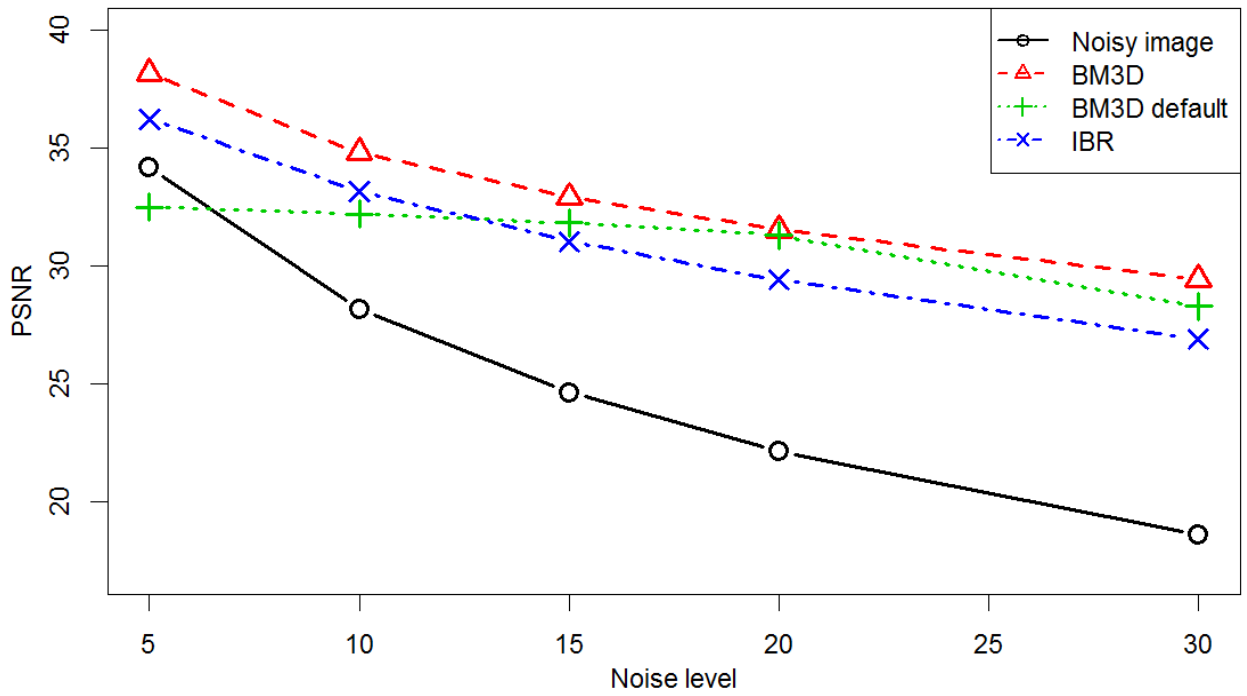


- BM3D with good standard deviation of the noise (red) :
  $\rightarrow$ IBR (blue) less successful of more or less 2 dB
  $\rightarrow$ the differences increase with the level of noise
- BM3D with default standard deviation of the noise (green) :
  $\rightarrow$ IBR better for a low level of noise

Performance :

Image denoising by means of the method **IBR** already gives satisfactory results for its entrance to the vast field of image processing

Current research :

- more freedom of shape in the creation of regions
- implementation of connections between similar regions

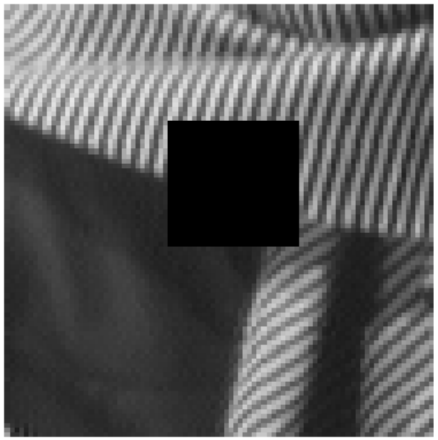
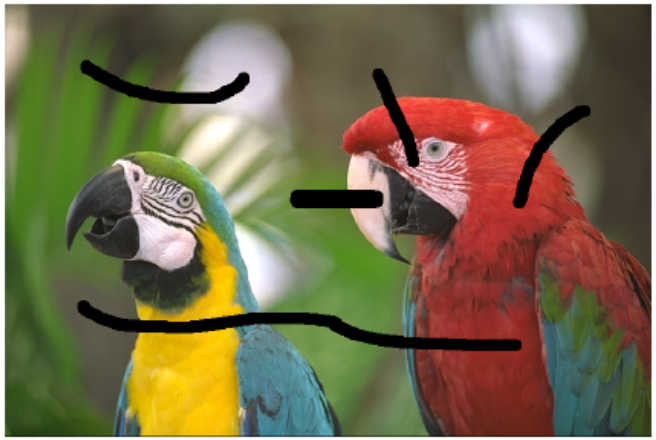
Others applications :

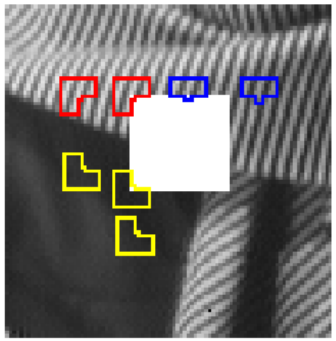
- use of the **rpart** partitioning for high-dimension data in regression
- application in chronological series

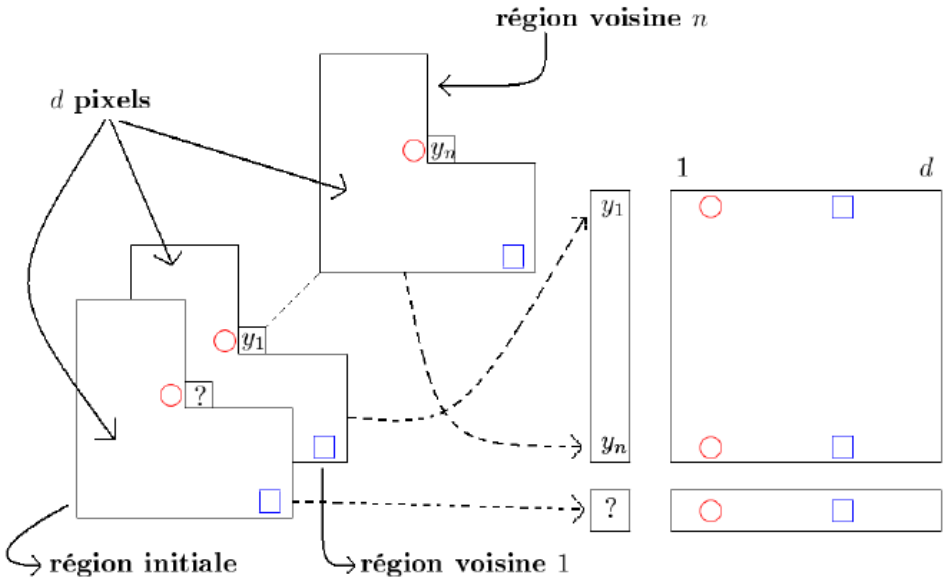
- **Objective :** reconstruct the missing parts of an image by means of the iterative bias reduction

Picture data base :

- black and white images and color images
- accent put on the structural reconstruction

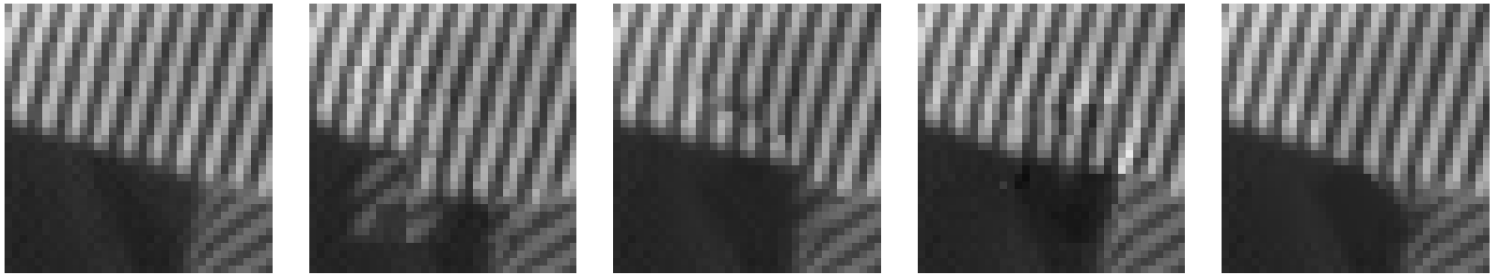



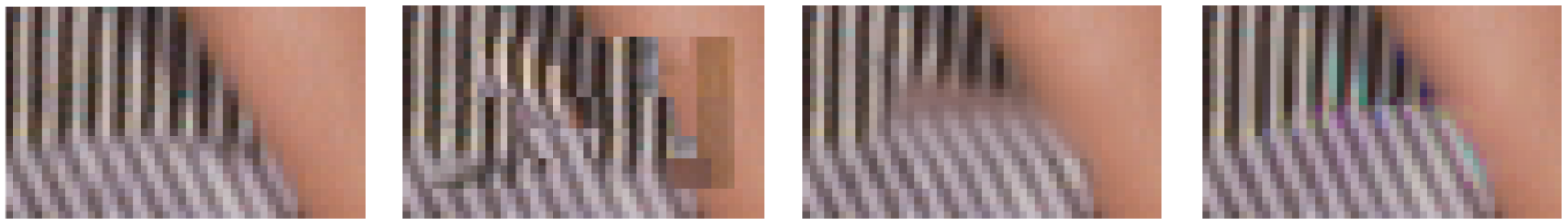


Process :

1. pixels treated one by one, from extremities to the center
2. definition of a region formed by the d available neighbors in a neighborhood of 4 pixels
3. **data base : K** nearest neighbors $\rightarrow$ n most similar regions



(a) Reference	(b)Criminisi *et al.*	(c)Wexler *et al.*	(d)Xu and Sun	(d)Proposed
PSNR :	18.85 dB	20.10 dB	23.07 dB	25.84 dB
SSIM :	0.66	0.76	0.86	0.94



(a) Reference	(b)Criminisi *et al.*	(c)Wexler *et al.*	(d)Proposed
PSNR :	16.5 dB	21 dB	22 dB
SSIM :	0.47	0.74	0.81

- color images :
  → formed by three different images (Red, Green, Blue)
  → treatment separated by image

Conclusion :

- Good structural reconstruction
- No impression of blur
- **Current research** : use of the structural information of the image in the choice of the filling order
- **Others applications** : treatment of missing data, tested at the moment for chronological series

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