M2RI, Parcours Images et Données
Module Acquisition et Représentation des Données
Extraction de caractéristiques

Features Extraction - 3

Bertrand Coüasnon
Irisa/Insa
Imadoc
Bureau C314
http://www.irisa.fr/imadoc
couasnon@irisa.fr

IFSIC INSTITUT DE FORMATION SUPÉRIEURE EN INFORMATIQUE ET COMMUNICATION
INSA RENNES
IRISA

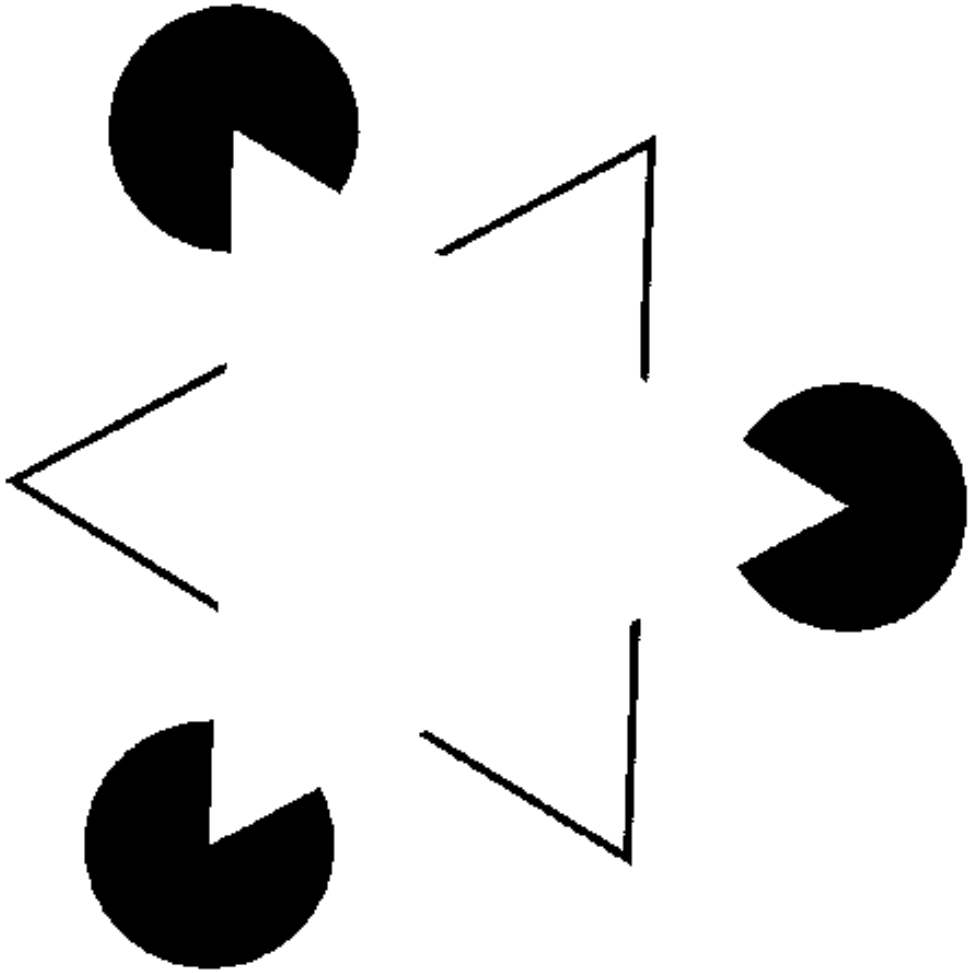
Features: Object Localization / Extraction

- Difficulties of Feature Extraction
- Feature Extraction/Detection on the whole Signal
- Feature Extraction/Detection on Objects
  - Object Localization / Extraction
    - Region Labeling
    - Edge Detection
    - Connected Components Labeling
    - Skeletonization
    - Handwriting extraction
    - Line-Segment Detection
  - Object Characterization
- Interest of Multi-Resolution
- Using Features

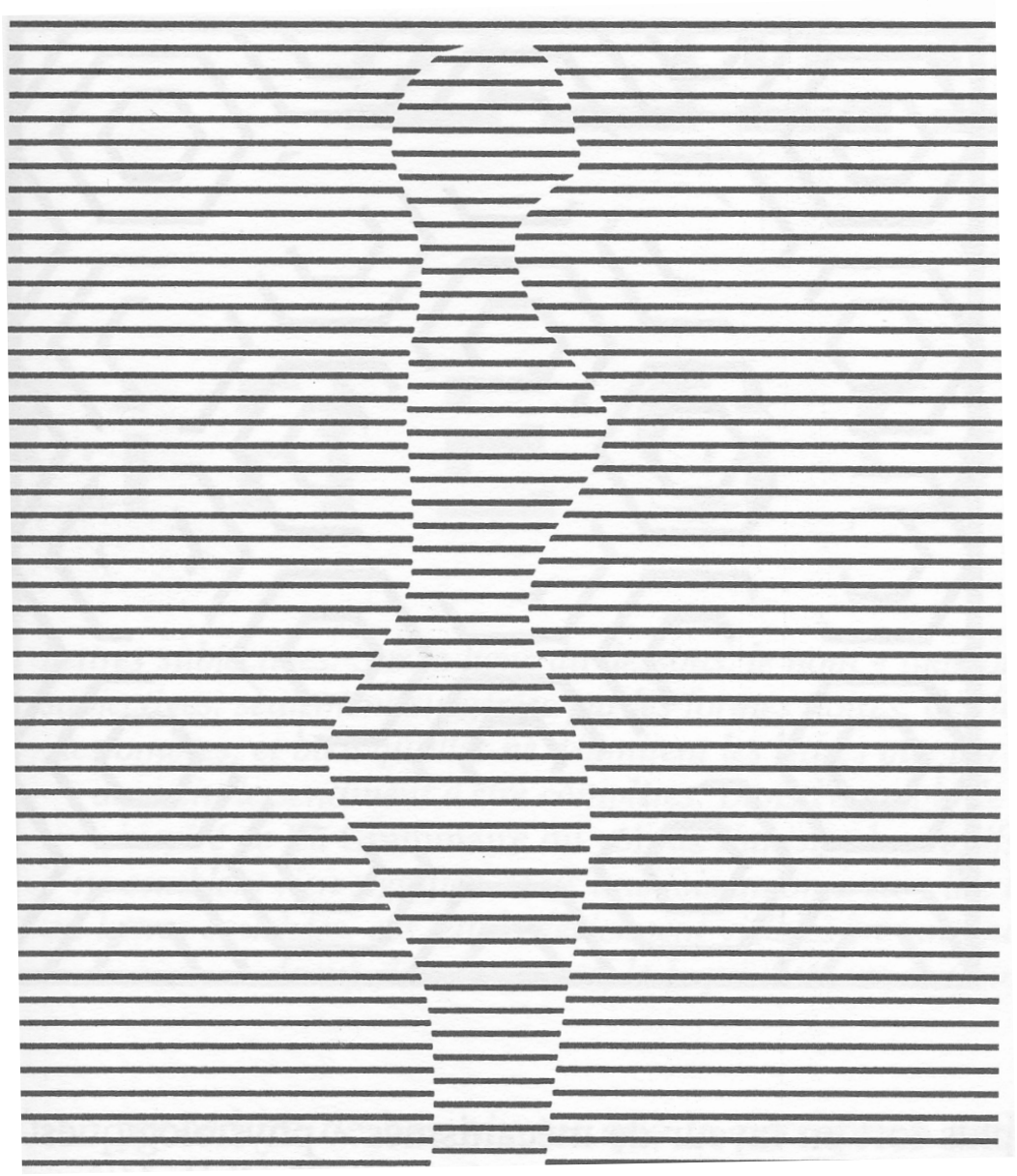
Object Extraction: Edge Detection

- 1) Notion of Edge
- 2) Derivative Filters
- 3) Edge Point Selection
- 4) Laplacian Filter

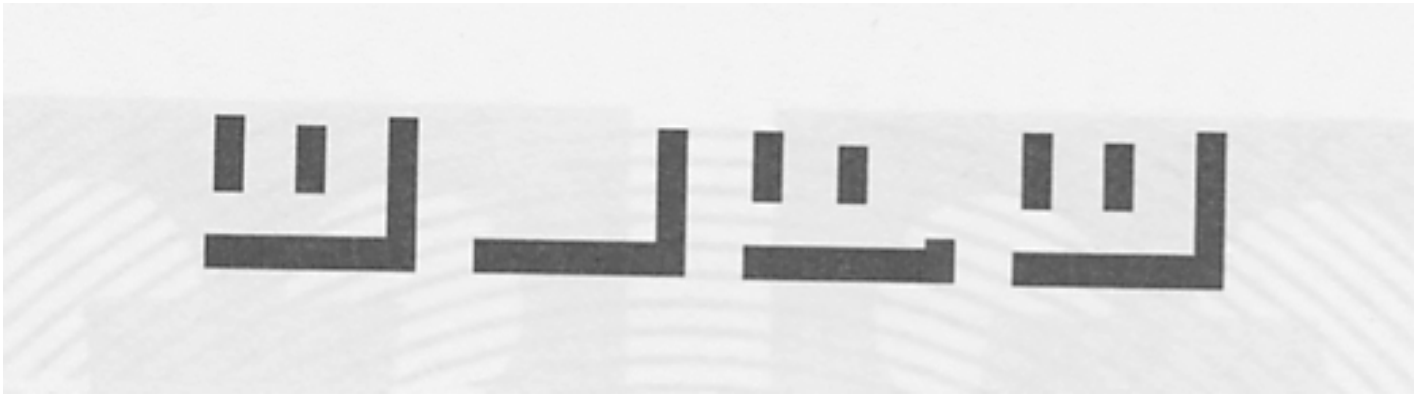
1) Notion of Edge: Subjective Edges



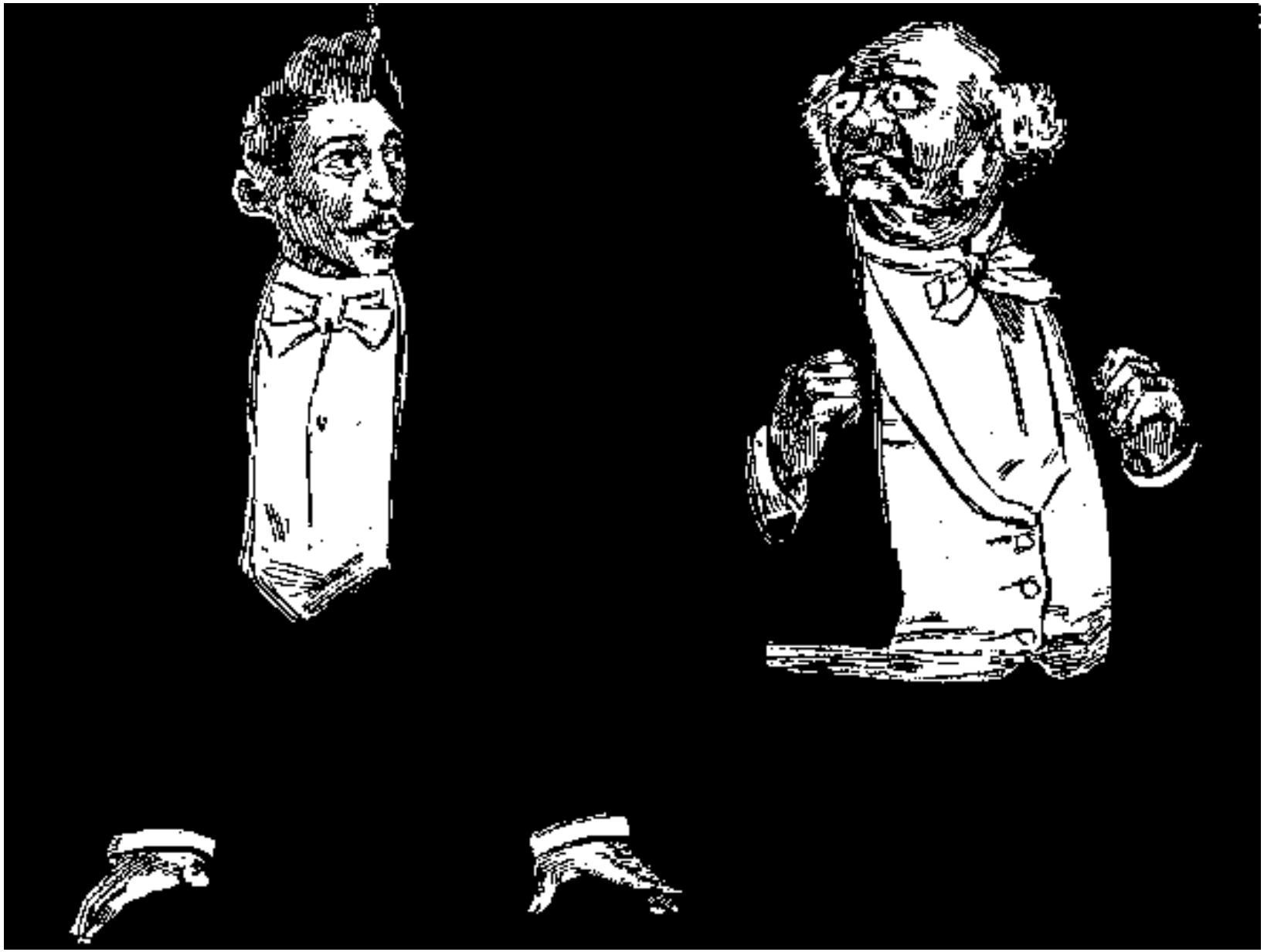
1) Notion of Edge: Subjective Edges



1) Notion of Edge: Cultural Edges



1) Notion of Edge: Cultural Edges



1) Notion of Edge: Cultural Edges

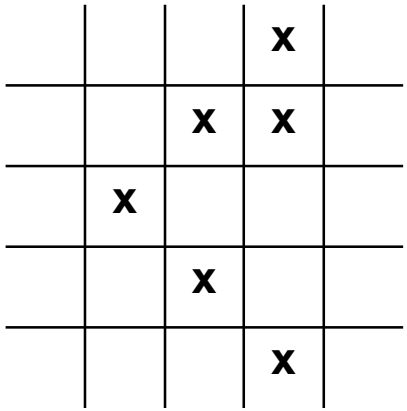
1) Notion of Edge: Contours photométriques

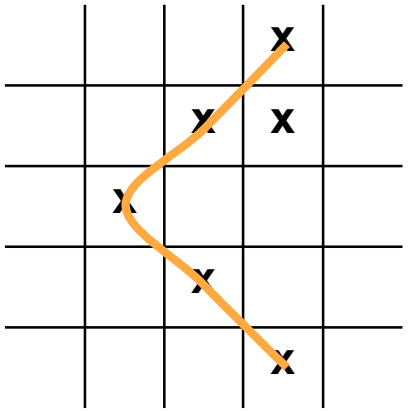
- **Variation importante de luminosité**

  - **Sélection des pixels**

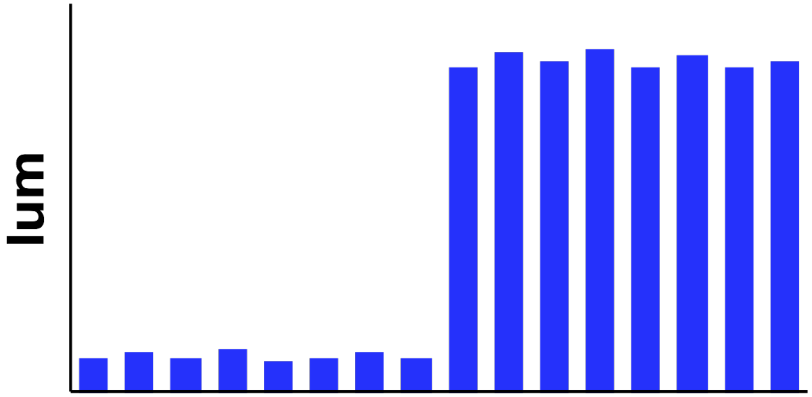
  - **Suivi de contour**

  - **Affinage des contours**

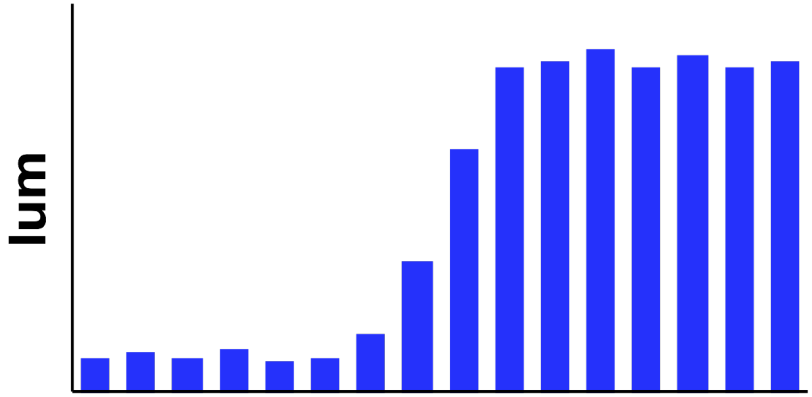




1) Notion of Edge: Approche continue



Contour idéal



Contour réel

- **Gradient de la luminosité**

$$\nabla lum(x,y) = \left(\frac{\partial}{\partial x} lum, \frac{\partial}{\partial y} lum \right)$$

2) Derivative Filters

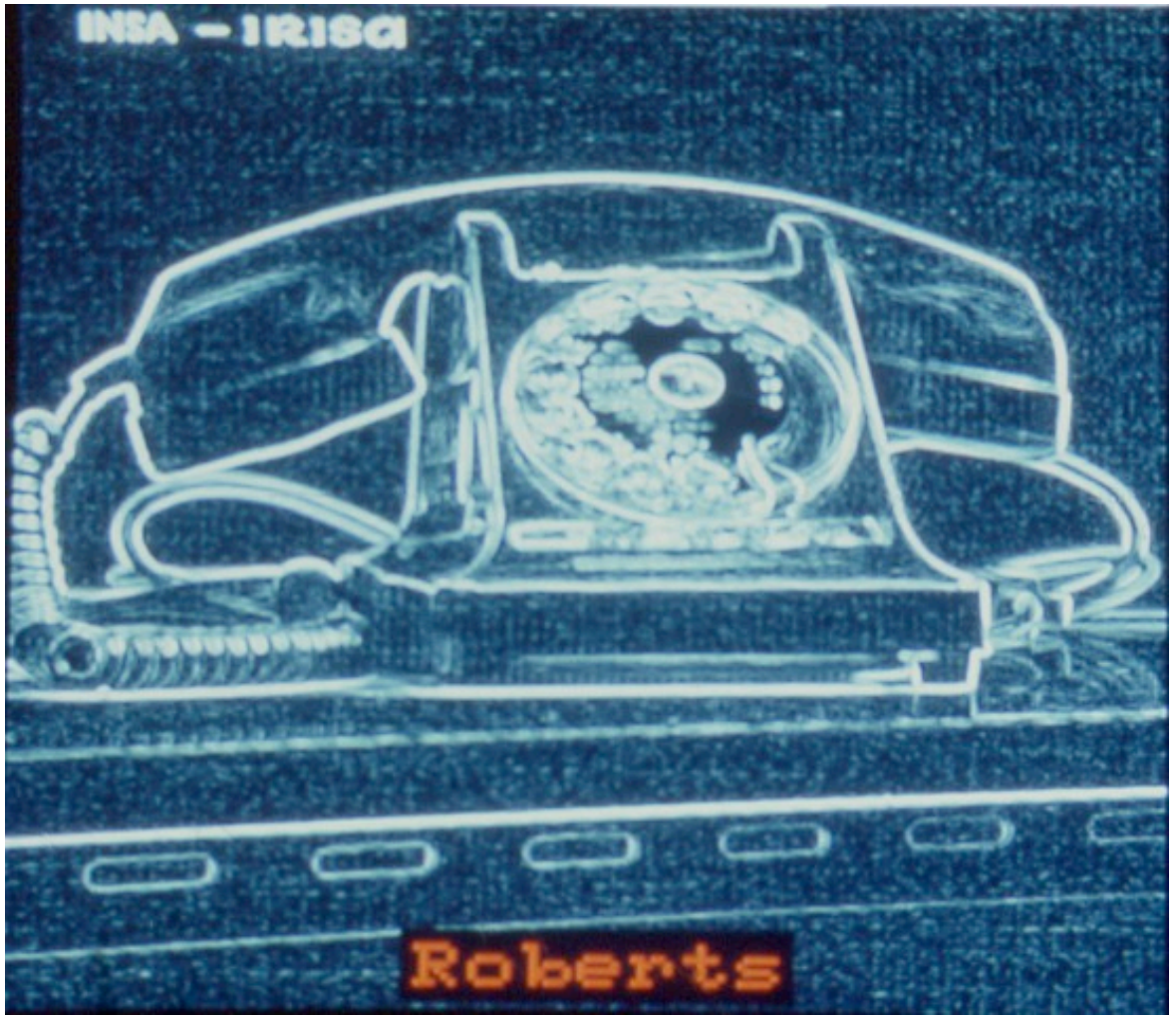
- Roberts
- Prewitt
- Sobel
- Filtre dérivateur (-1, 0, 1)
- Filtre récursif de Shen et Castan

2) Derivative Filters: Détecteur de Roberts

- **Décomposition suivant les diagonales**
  - 1ère diagonale $= \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$
  - 2nde diagonale $= \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$
  - calcul du module sur 4 points

$$\begin{matrix} a & b \\ c & d \end{matrix} \Rightarrow |a-d| + |b-c|$$

2) Derivative Filters: Roberts : module



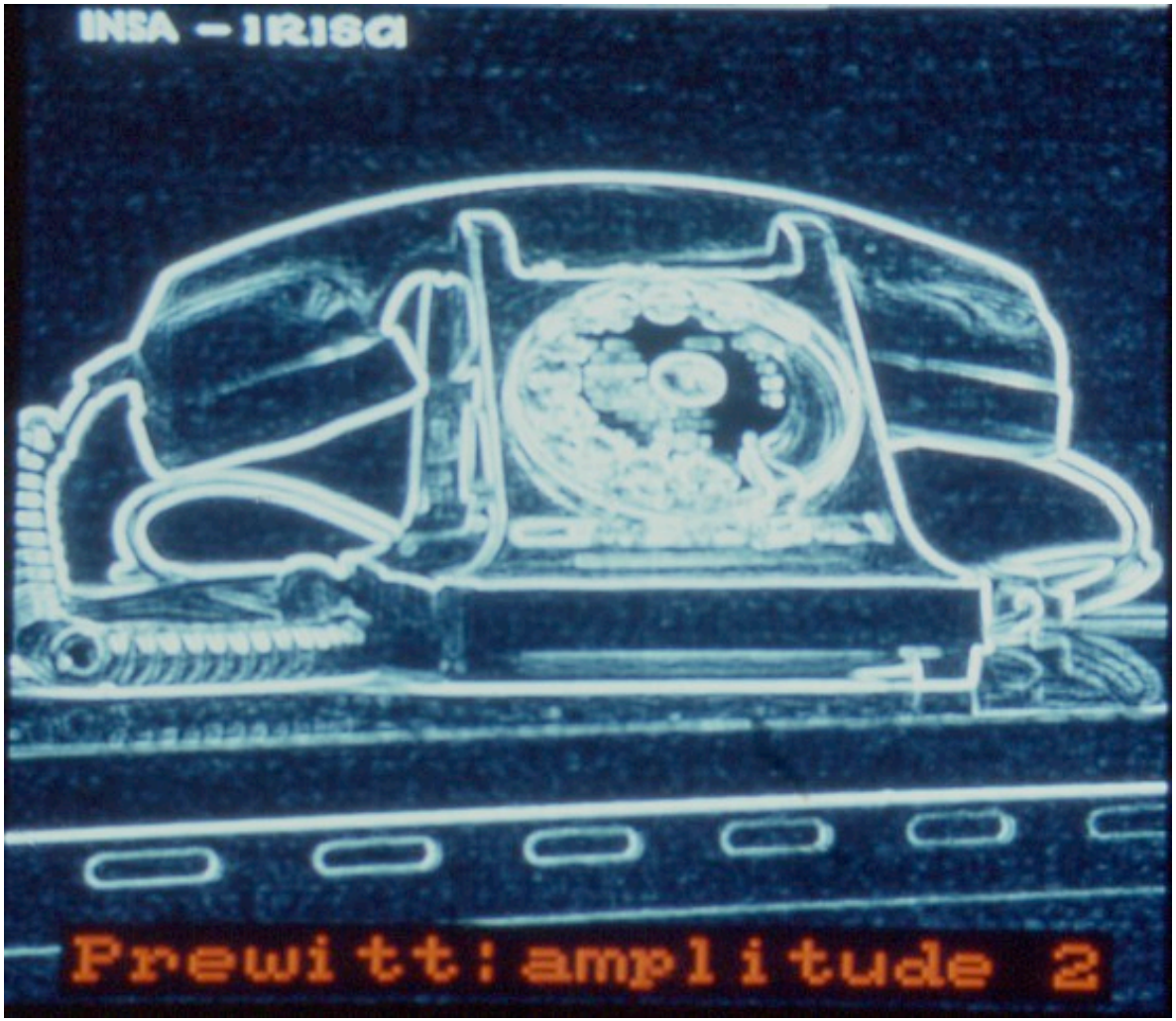
2) Derivative Filters: Détecteur de Prewitt

- **Prewitt**

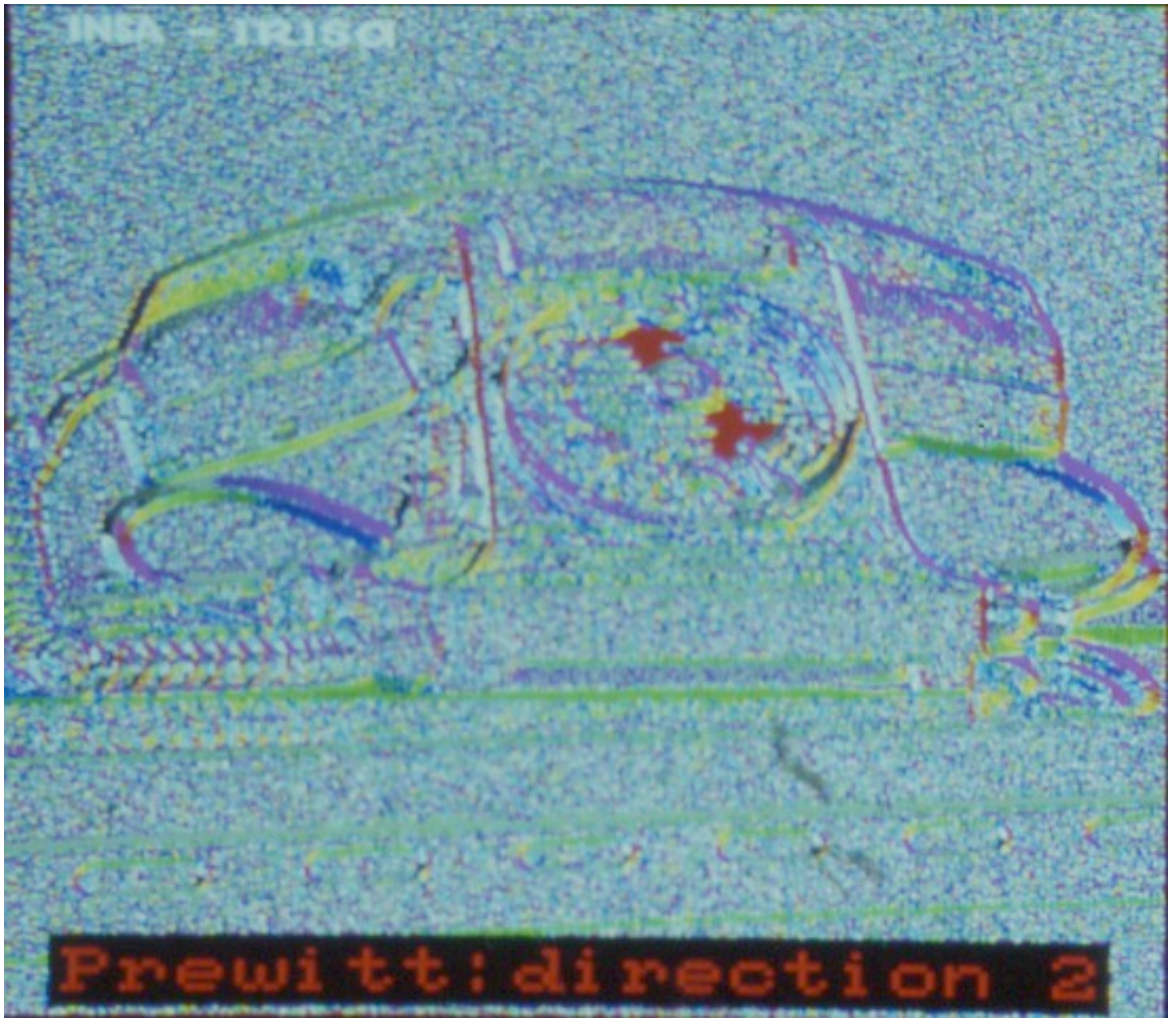
$$g_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad g_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

- **Décomposition de g_x :**
  - Filtre **dérivateur** en ligne $\begin{pmatrix} -1 & 0 & 1 \end{pmatrix}$
  - Filtre **passe-bas** en colonne $\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$

2) Derivative Filters: Prewitt : module



2) Derivative Filters: Prewitt : direction



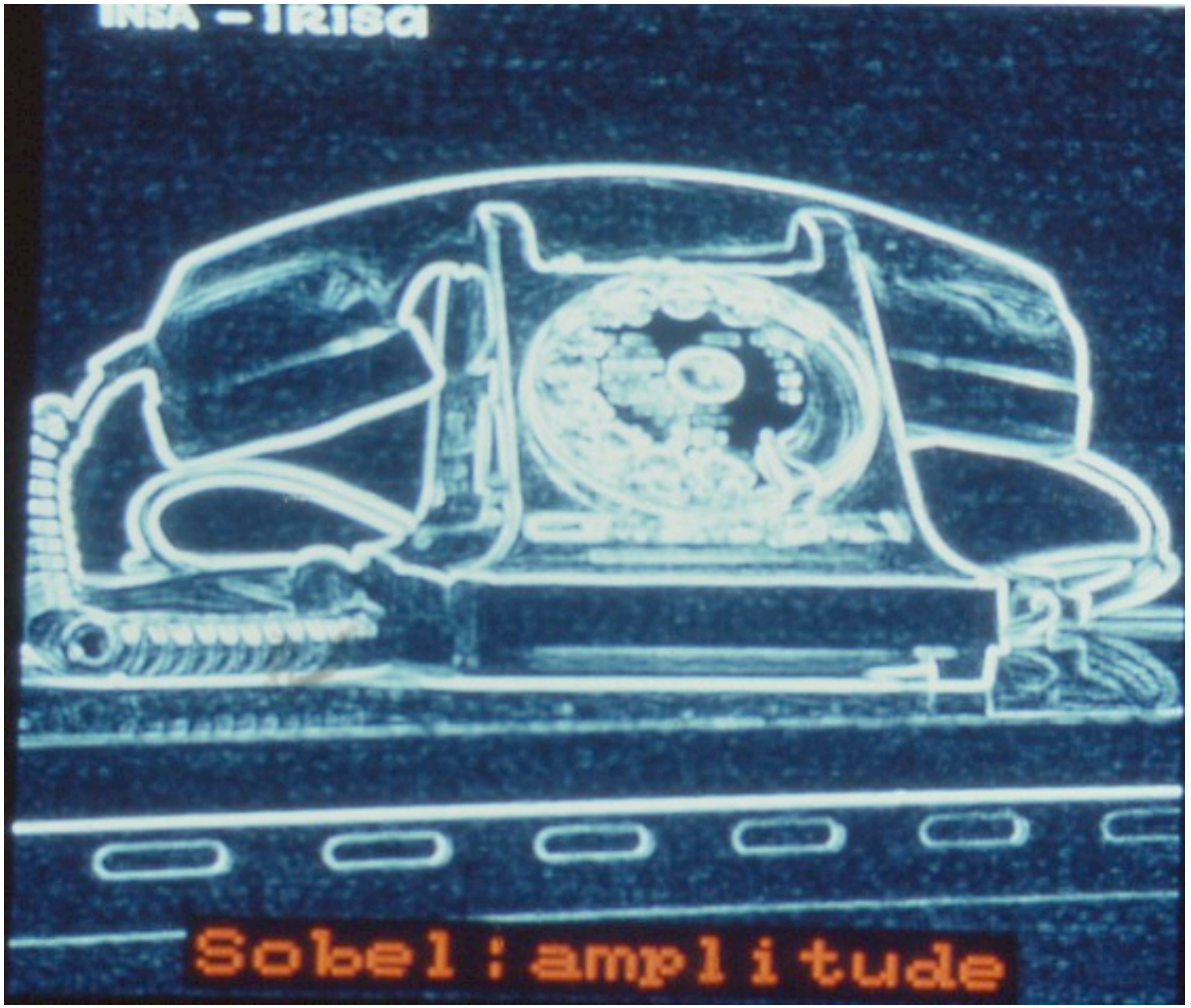
2) Derivative Filters: Détecteur de Sobel

- **Sobel**

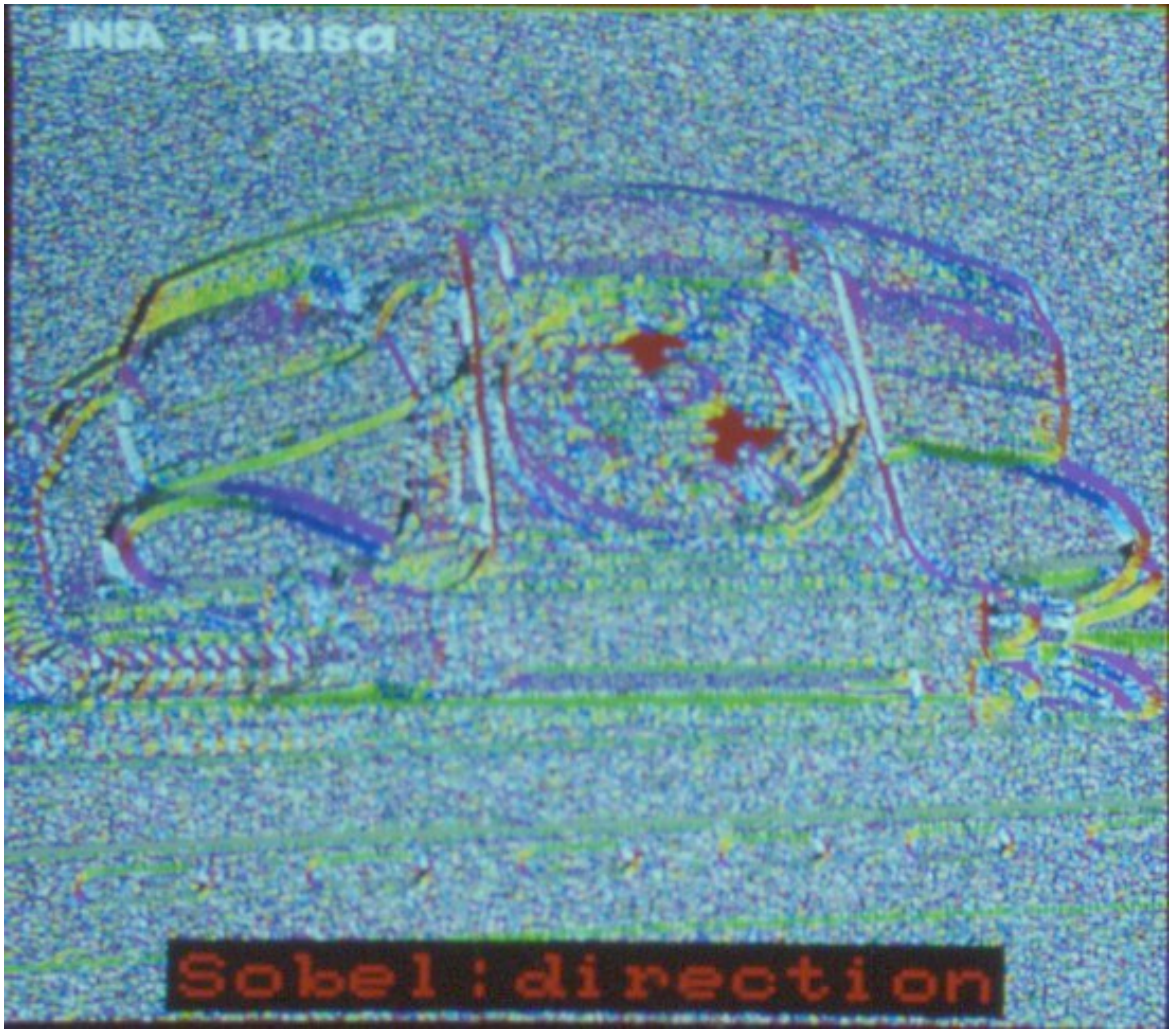
$$g_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad g_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

- **Décomposition de g_x :**
  - Filtre dérivateur en ligne $\begin{pmatrix} -1 & 0 & 1 \end{pmatrix}$
  - Filtre passe-bas en colonne $\begin{pmatrix} 1 & 2 & 1 \end{pmatrix}$

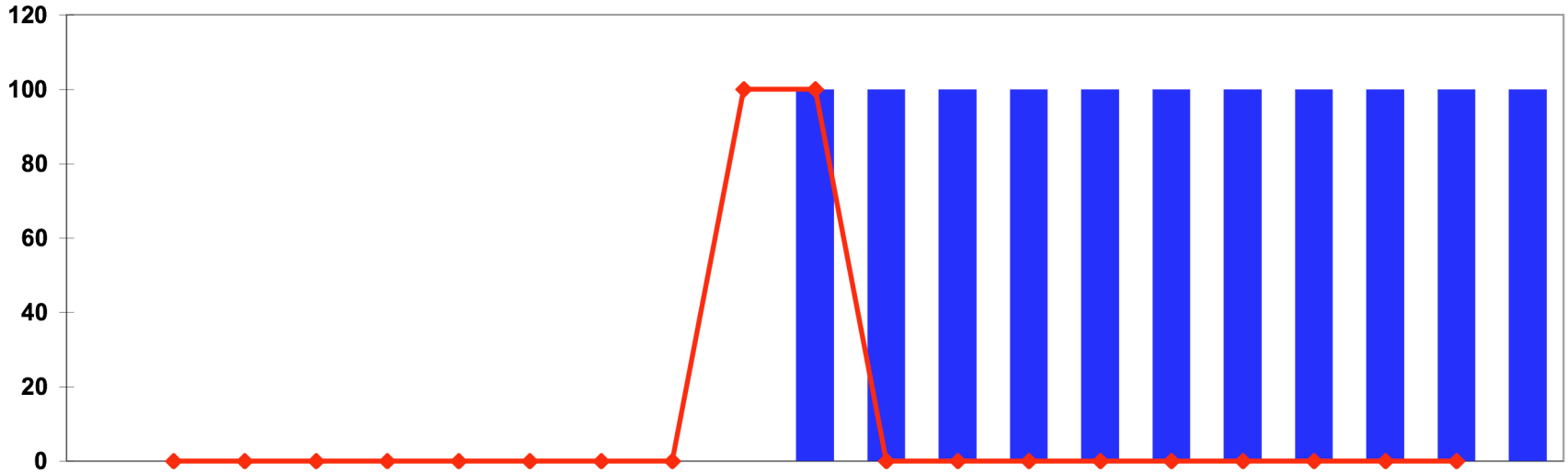
2) Derivative Filters: Sobel : module



2) Derivative Filters: Sobel : direction

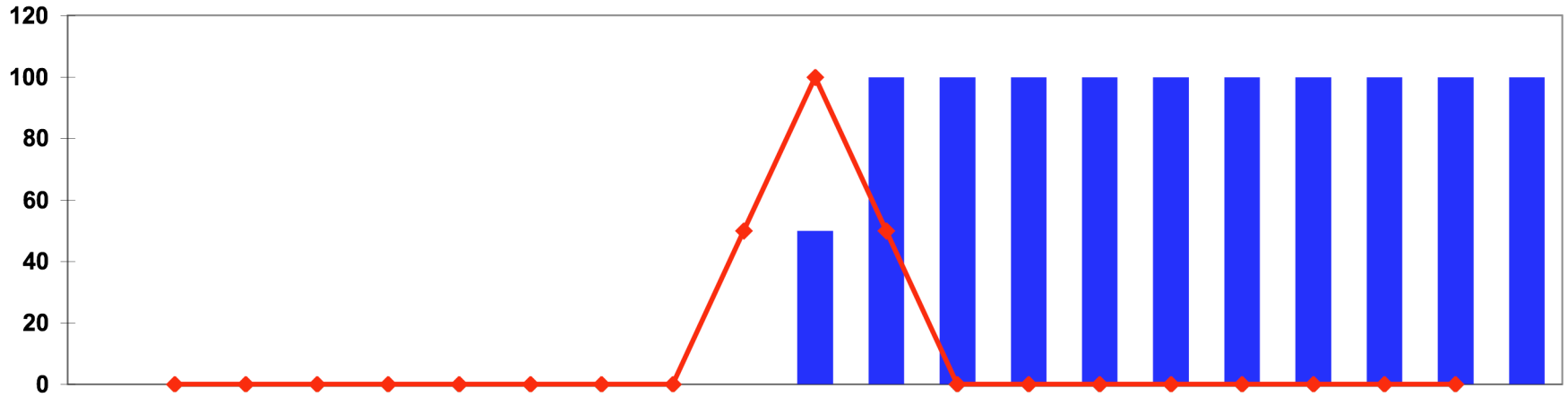


2) Derivative Filters: (-1, 0, 1)



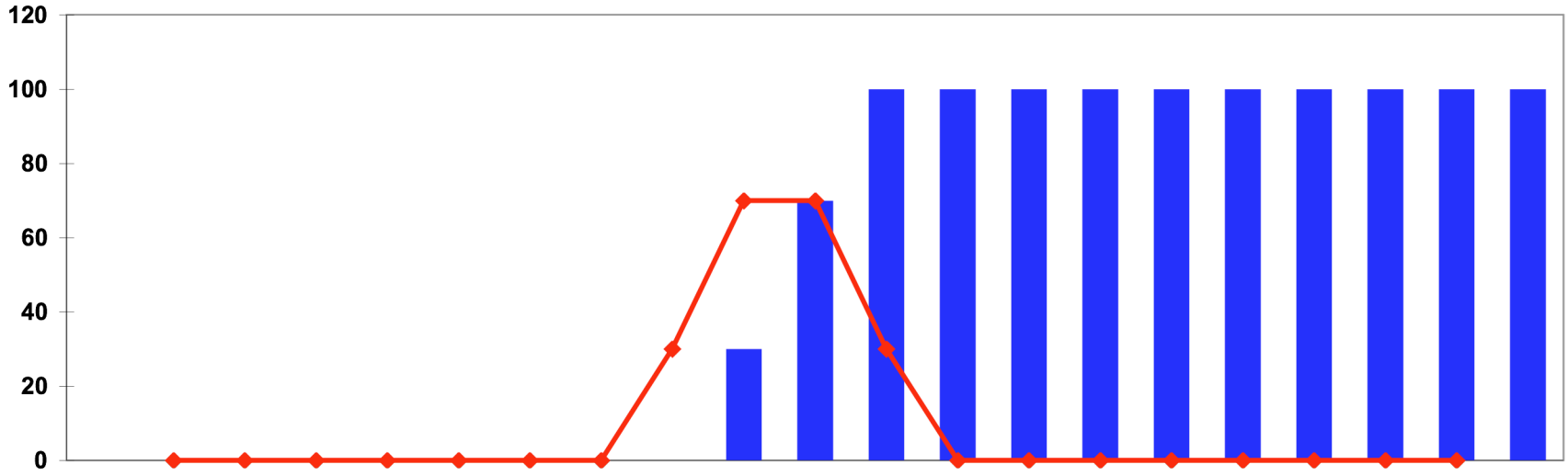
- **Saut de luminosité**
- **Réponse non nulle sur 2 points**

2) Derivative Filters:(-1, 0, 1)



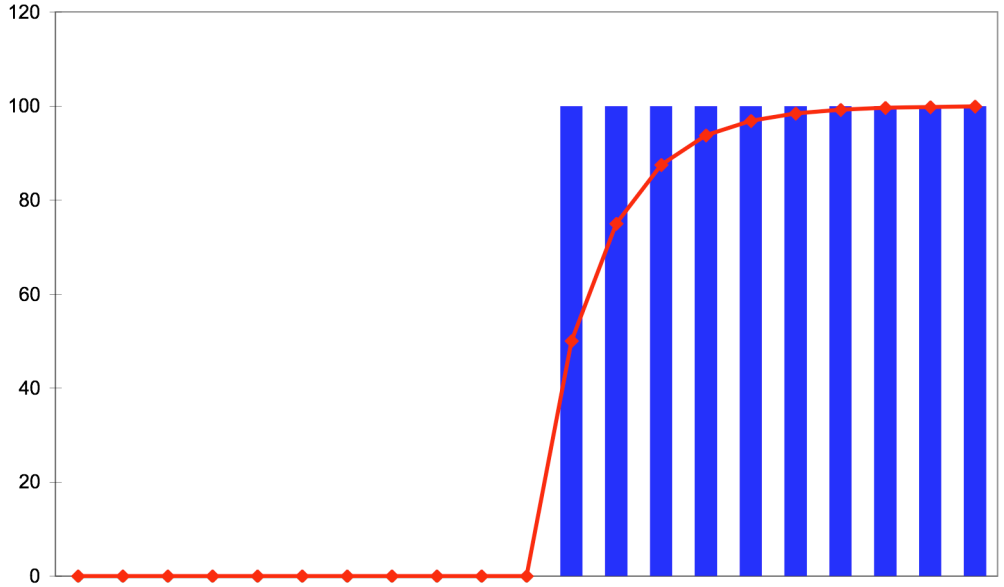
- **Rampe de luminosité : 1 intermédiaire**
- **Réponse non nulle sur 3 points**

2) Derivative Filters:(-1, 0, 1)



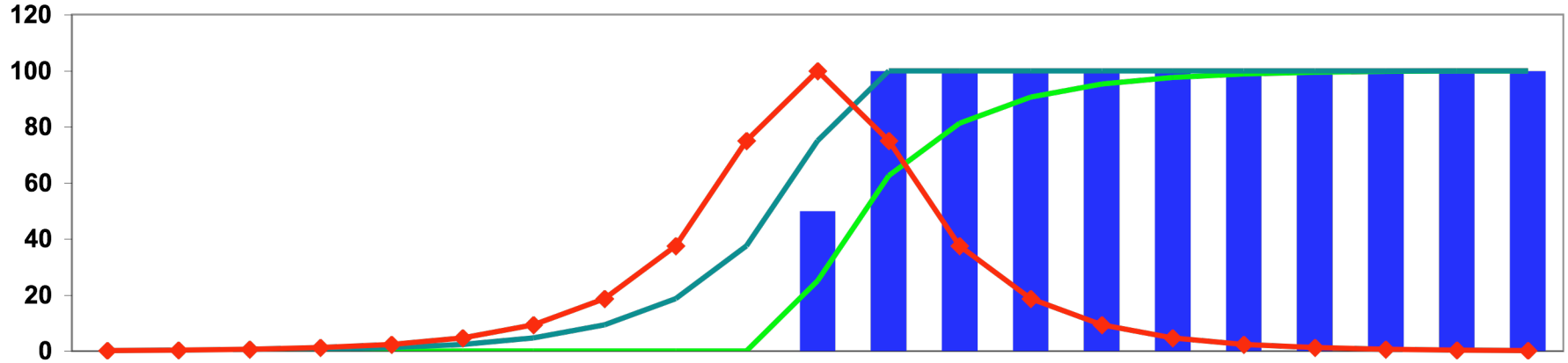
- **Rampe de luminosité : 2 intermédiaires**
- **Réponse non nulle sur 4 points**
- **Affaiblissement de la dérivée**

2) Deriv. Filters: Shen & Castan Recursive Filter



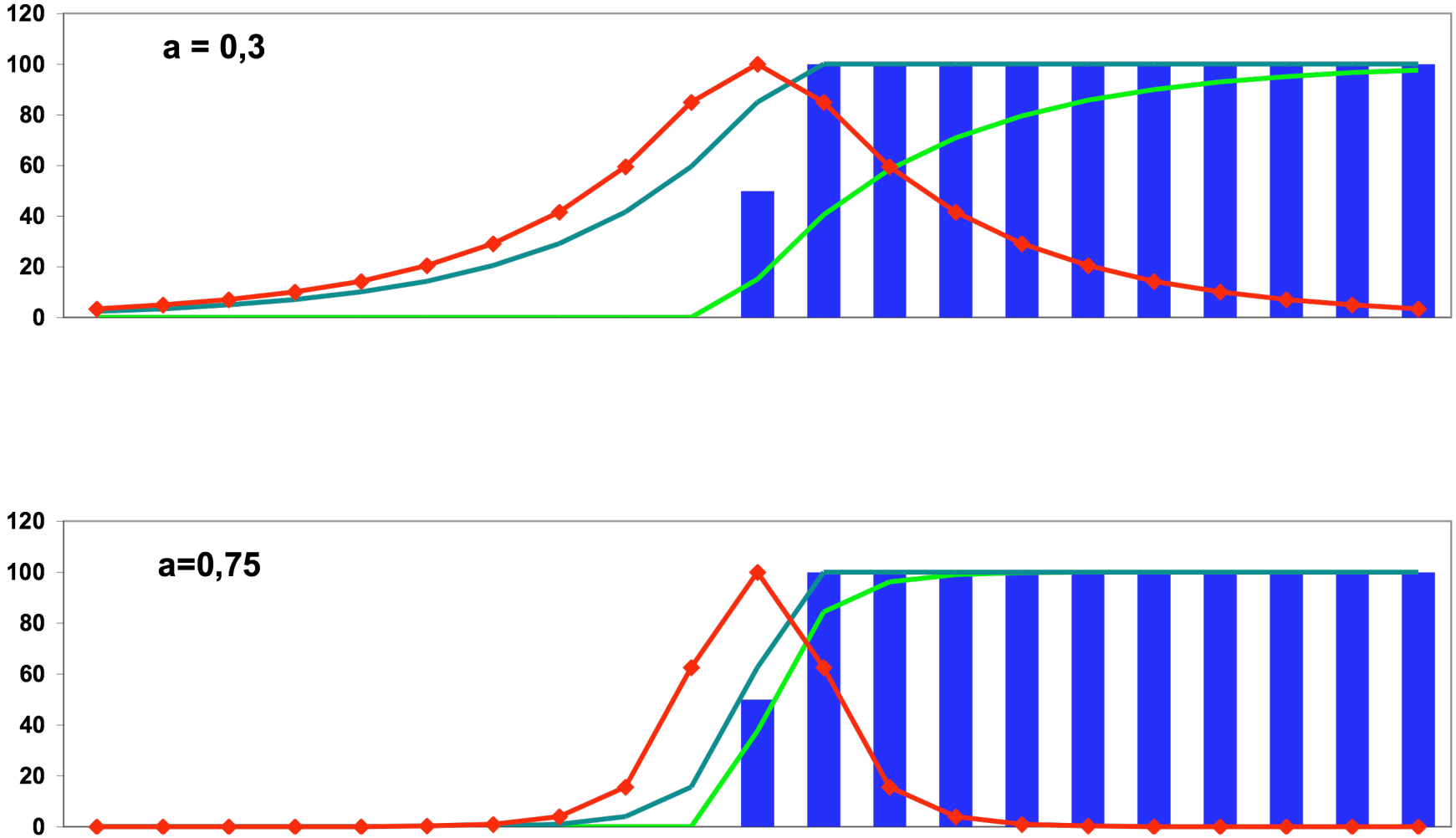
- **Balayage de gauche à droite** $s_n = a.e_n + b.s_{n-1}$
- **Passe-bas** $s_n = s_{n-1} + a(e_n - s_{n-1})$
- **Exemple avec a = 0,5**

2) Deriv. Filters: Shen & Castan Recursive Filter



- **De gauche à droite** $g_n = g_{n-1} + a(e_n - g_{n-1})$
- **De droite à gauche** $d_n = d_{n+1} + a(e_n - d_{n+1})$
- **Différence** $s_n = norm * (d_n - g_n)$

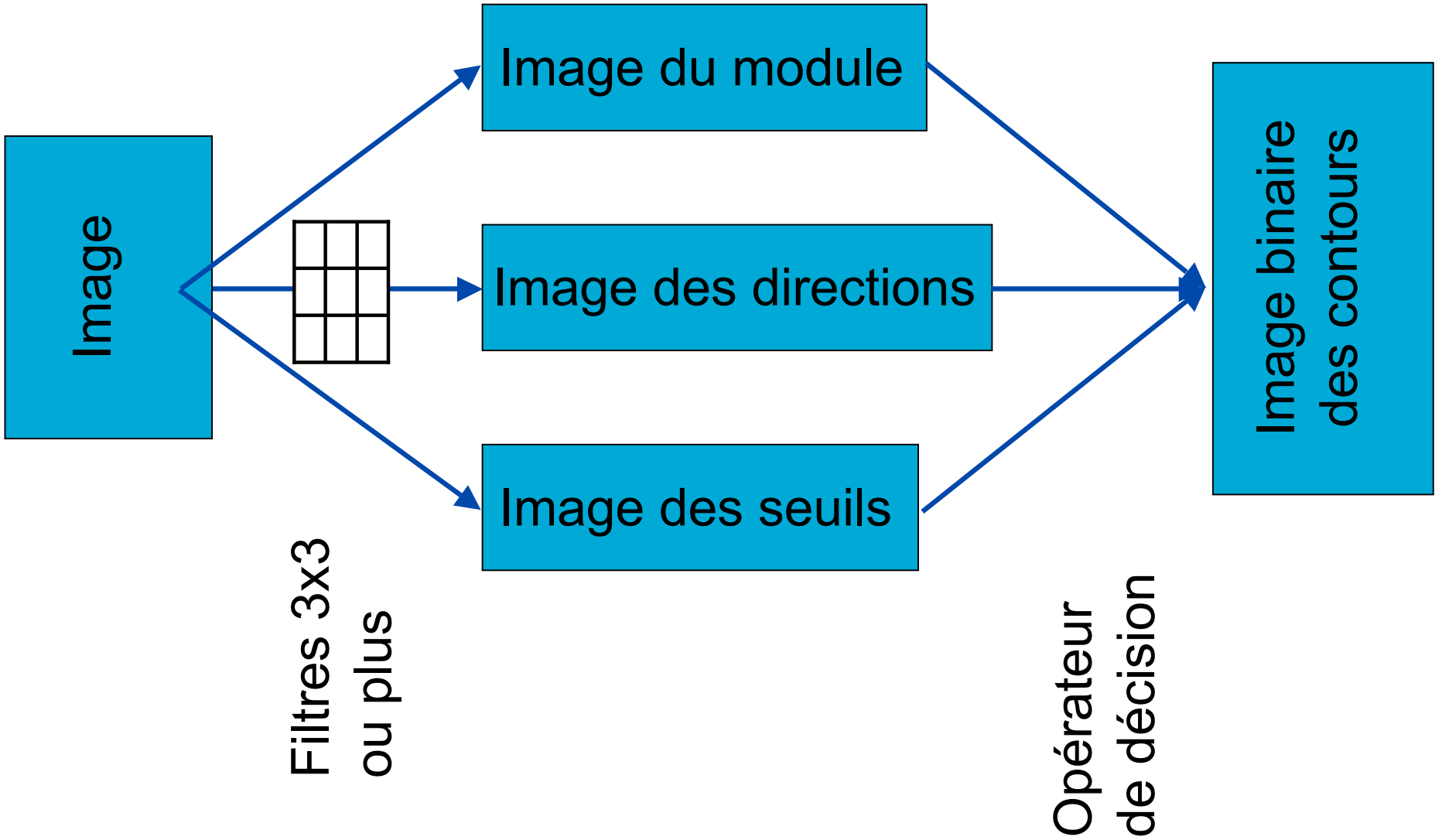
2) Deriv. Filters: Shen & Castan Recursive Filter



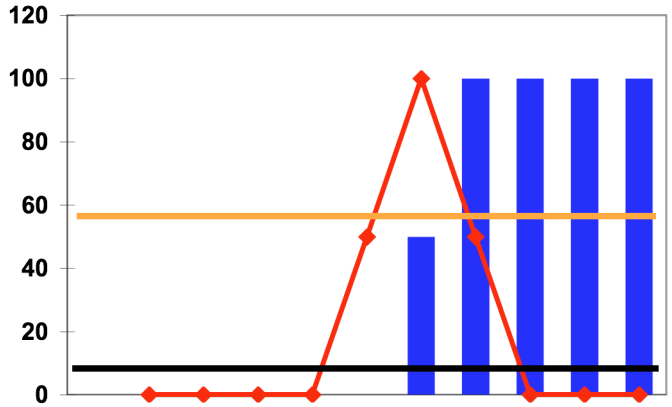
3) Edge Point Selection

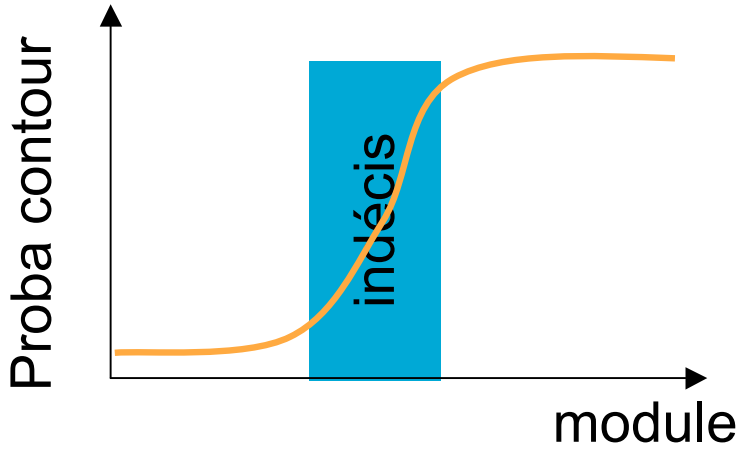
- **Image binaire de points contours**
  - Schéma général
  - Ajustement de masques
  - Binarisation
- **Propriétés :**
  - Lignes fines
  - Fermeture des contours
- **Connexion des points du contour**

3) Edge Point Selection



3) Edge Point Selection: Binarization





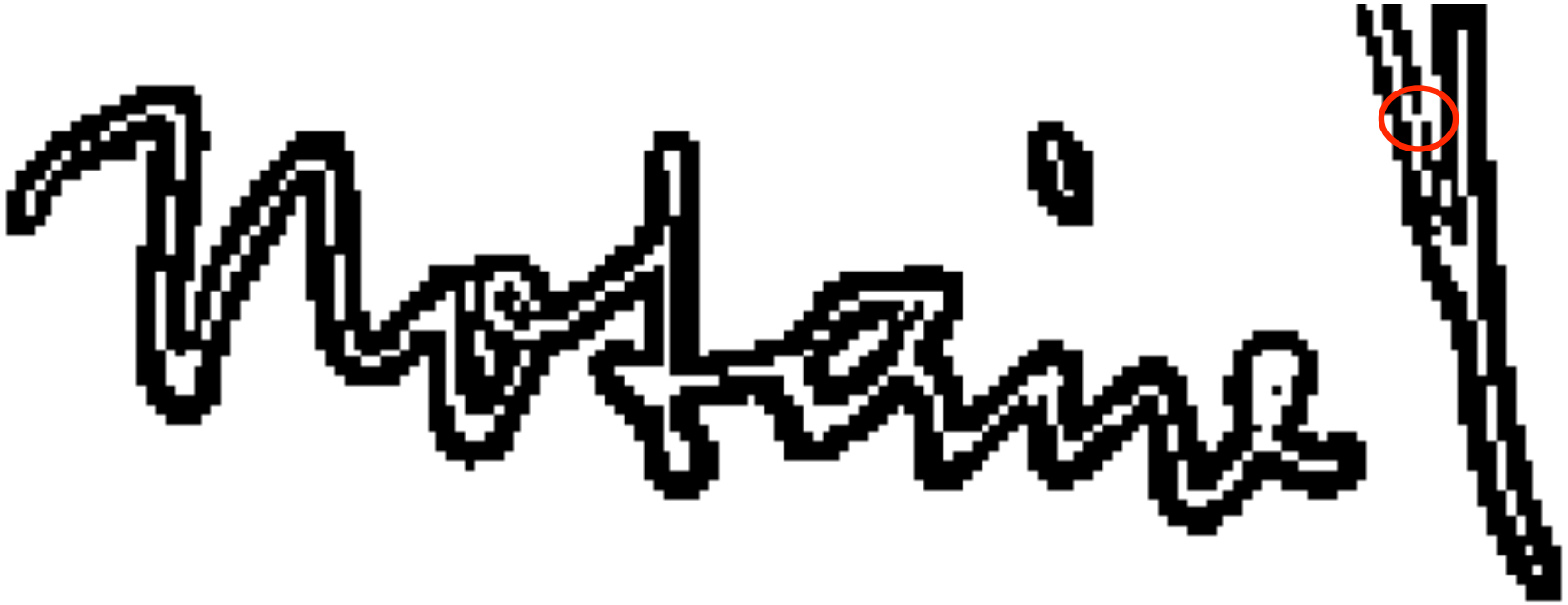
- **Comparaison du module à un seuil**
  - Local ou global ?
- **Valeur du seuil**
  - Trop bas = épaississement
  - Trop haut = mitage

3) Edge Point Selection: Binarization

- **Seuil à 20**
  - **Epaississement**

    => Affinage des contours

3) Edge Point Selection: Binarization



- **Seuil à 40**
  - **Mitage**

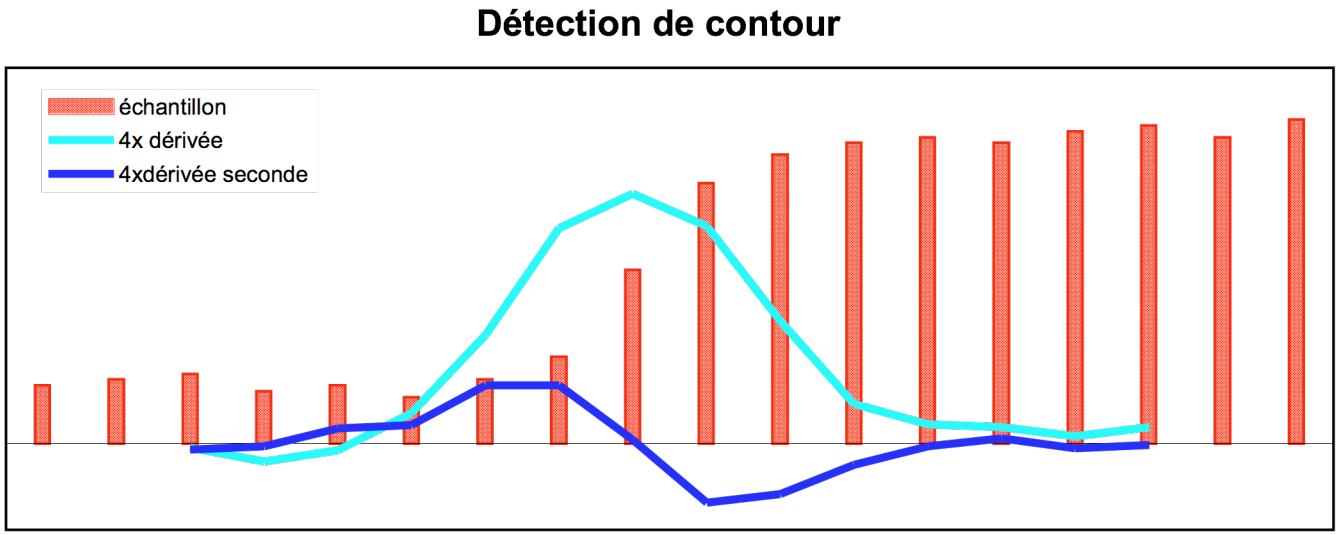
    => Fermeture des contours

4) Laplacian Filter

- Introduction à une dimension
- Utilisation de filtres 2D
- Dérivation du gradient
- Coopération gradient laplacien

4) Laplacian Filter: Introduction à une dimension

- Contour = valeur importante de la dérivée
- Seuillage = épaississement des contours
- Recherche du maximum de la dérivée
- Passage par 0 de la dérivée seconde, bruit



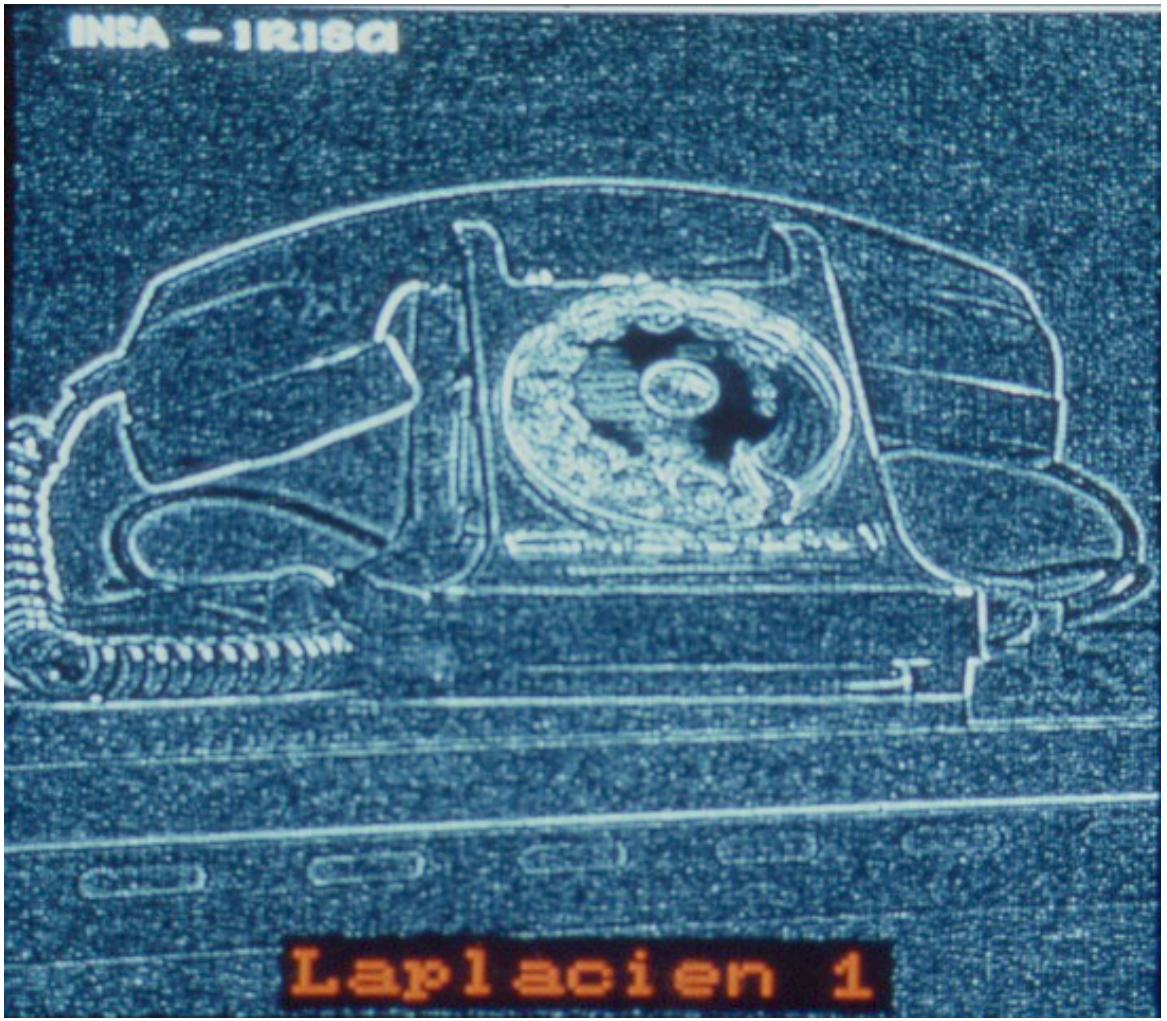
4) Laplacian Filter: Filtres à 2 dimensions

- **Laplacien :** $= \frac{\partial^2}{\partial x^2} lum + \frac{\partial^2}{\partial y^2} lum$

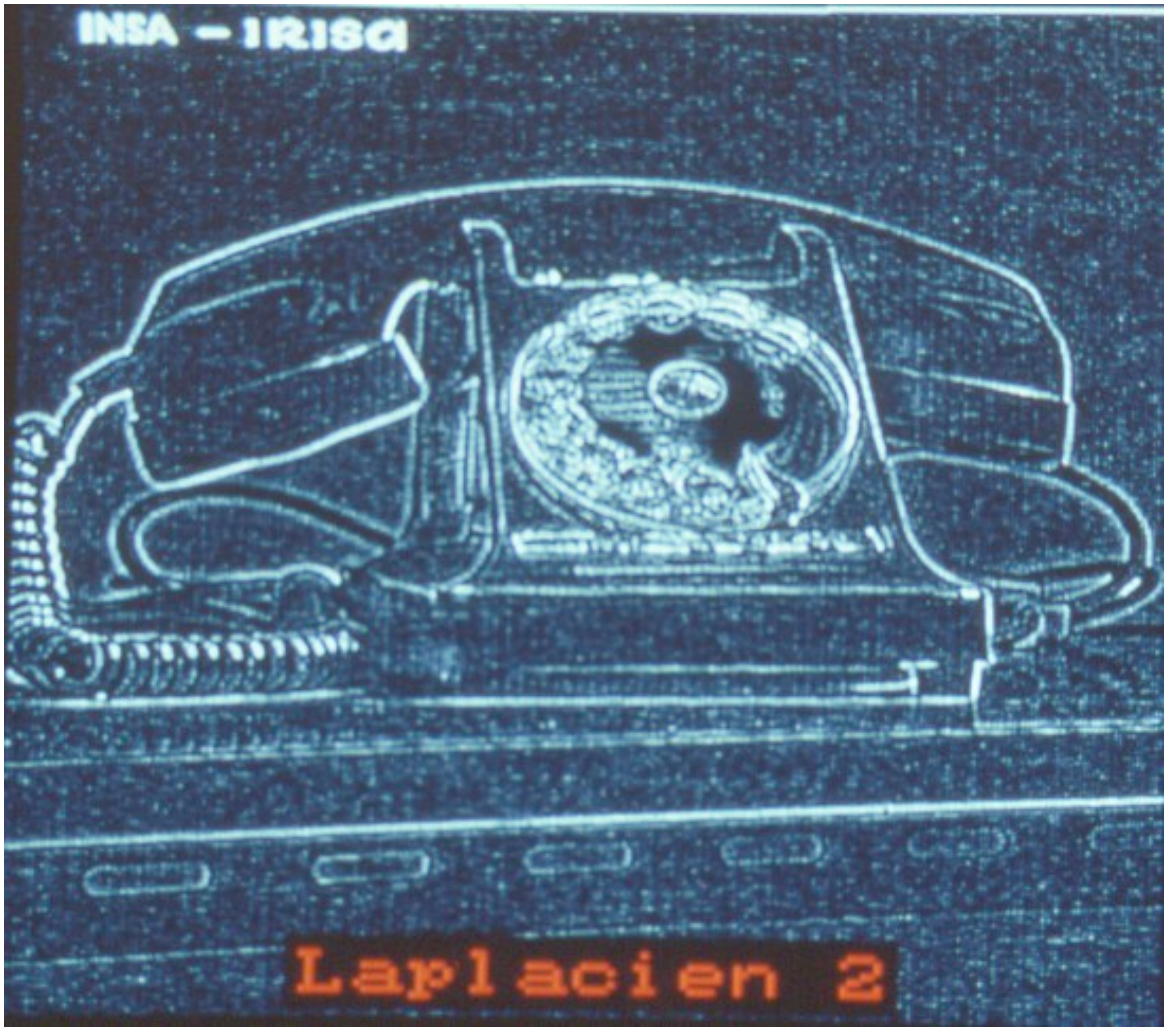
- **Approximations** $\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$

- **Propriétés**
  - **Somme des coefs = 0**
  - **Décomposition ?**

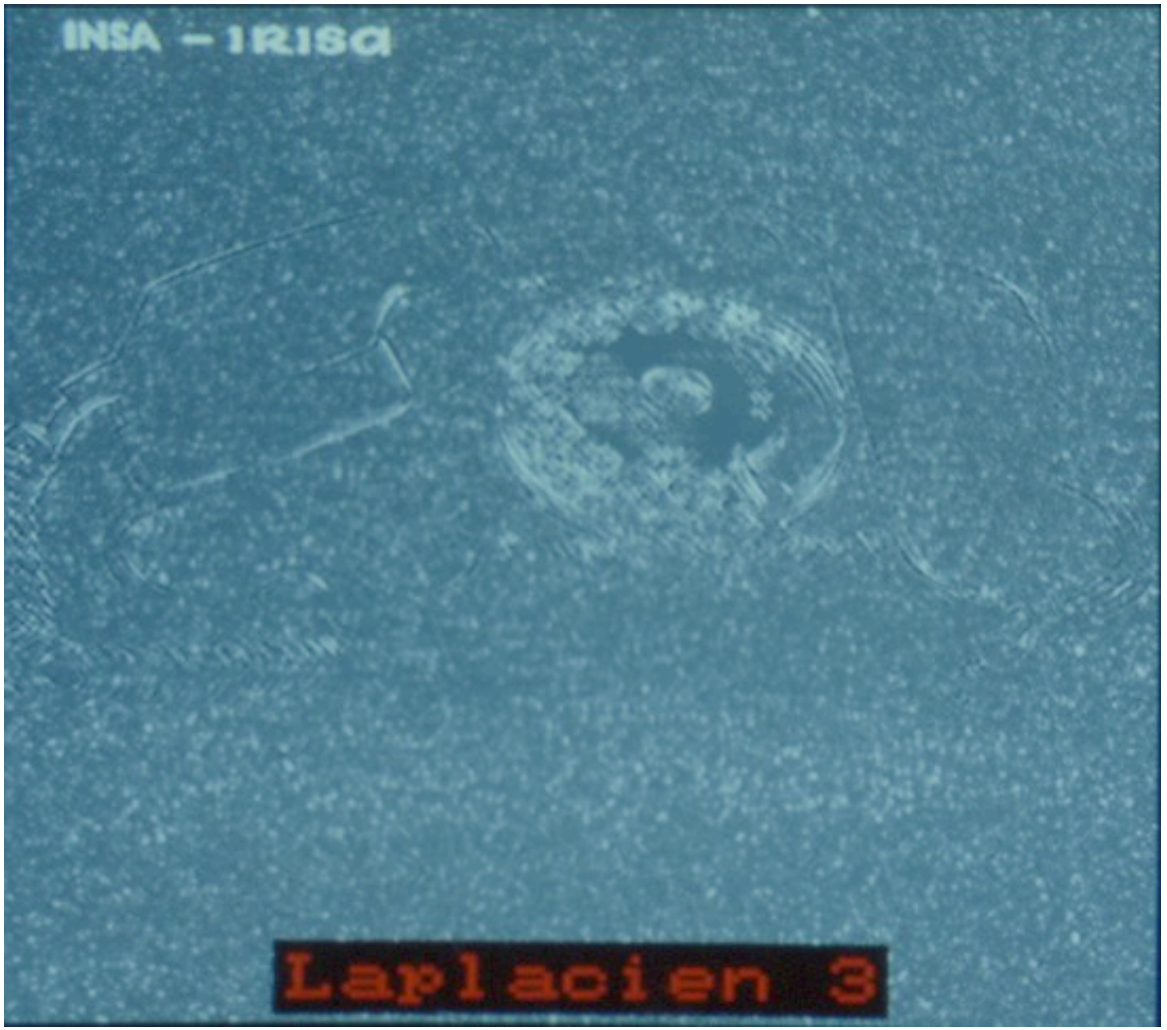
4) Laplacian Filter: Laplacien 1



4) Laplacian Filter: Laplacien 2



4) Laplacian Filter: Laplacien 3



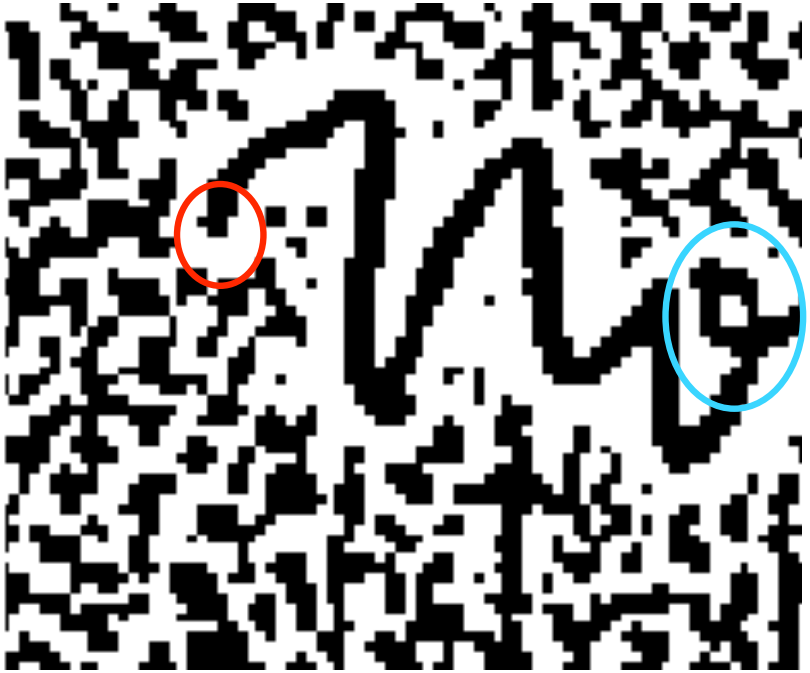
4) Laplacian Filter: Dérivation du gradient

- Gradient de Shen et Castan avec a=0,5
- g_x(x+1, y) - g_x(x-1, y) + g_y(x, y+1) - g_y(x, y-1)

4) Laplacian Filter: Dérivation du gradient

- **Gradient de Shen et Castan avec a=0,25**
- **g_x(x+1, y) - g_x(x-1, y) + g_y(x, y+1) - g_y(x, y-1)**

4) Laplacian Filter: Influence de a

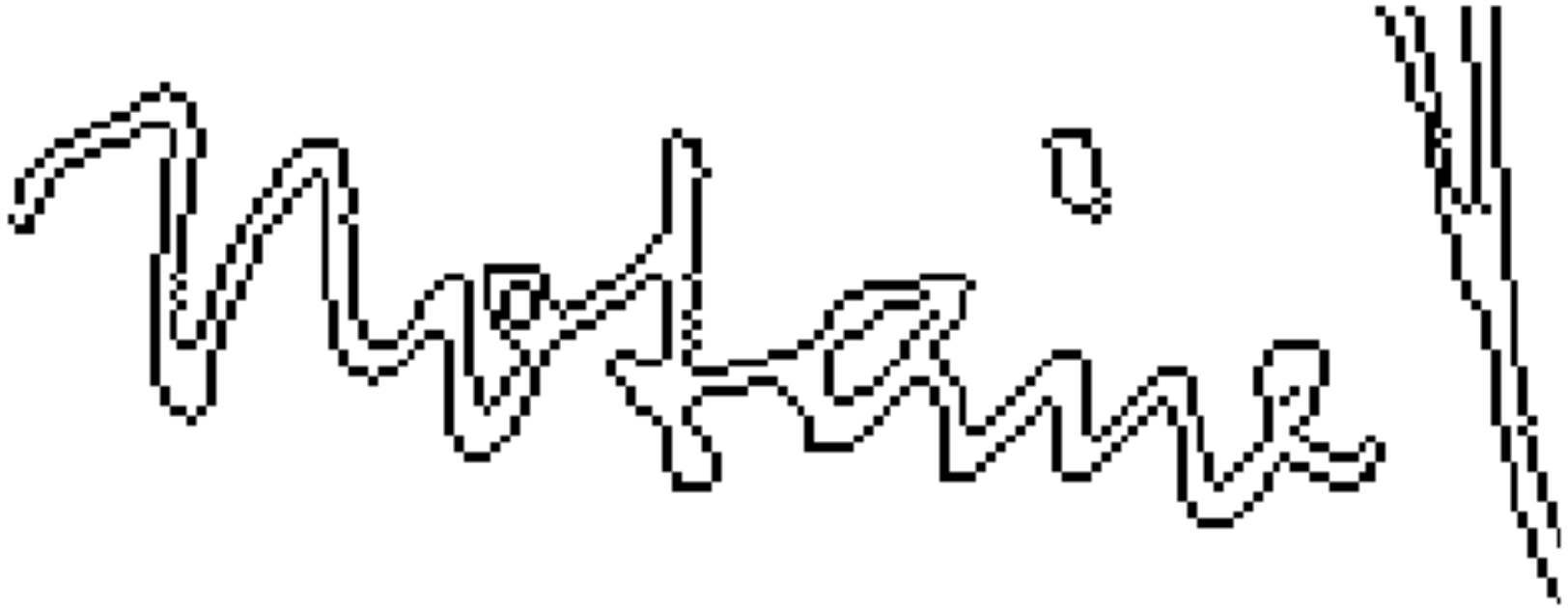


- Taille de la région autour du tracé
- Petite boucle
- Instabilité de la séparation

4) Laplacian: Coopération gradient-laplacien

- **Fort gradient**
- **Passage par zéro**
  - **Points clairs**

4) Laplacian: Coopération gradient laplacien

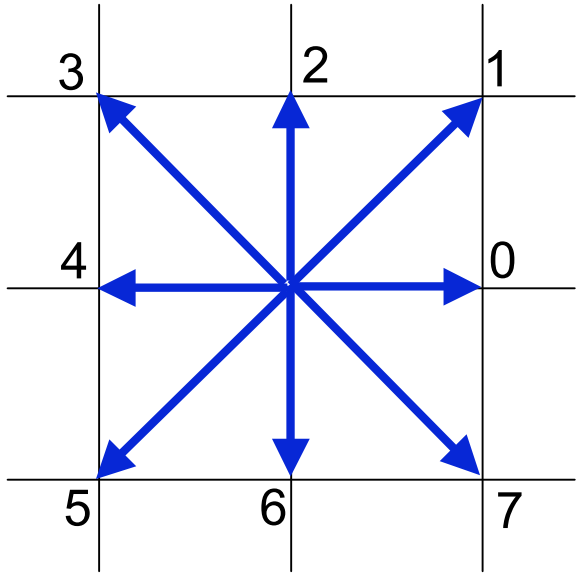


- **Fort gradient**
- **Passage par zéro**
  - **Points sombres**

Edge Representation: Freeman Code

- **Courbe = liste des directions**
  invariance/origine

- **Codage de Freeman**



- **Calcul de propriétés de la courbe à partir du codage :**
  surface, barycentre, …

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- Difficulties of Feature Extraction
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    - Region Labeling
    - Edge Detection
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    - Line-Segment Detection
  - Object Characterization
- Interest of Multi-Resolution
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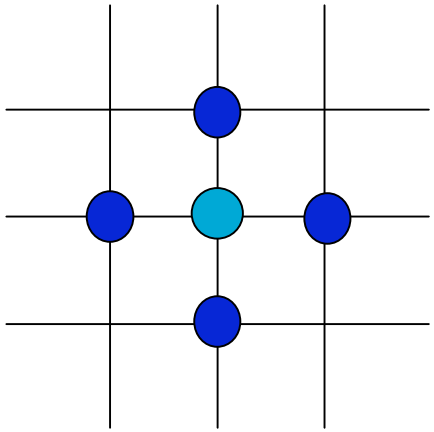
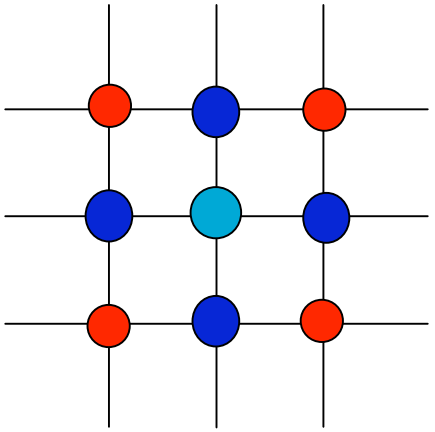
Connected Components Labeling

- **Neighborhood**

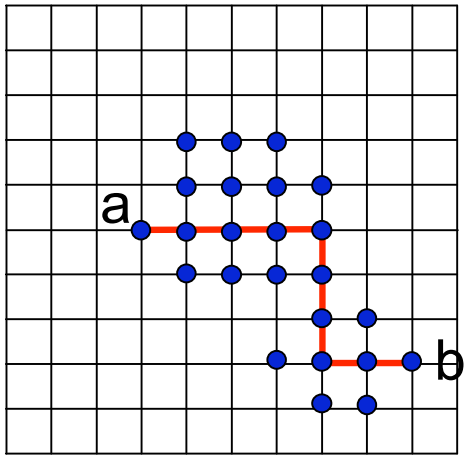


- **4 neighbors**

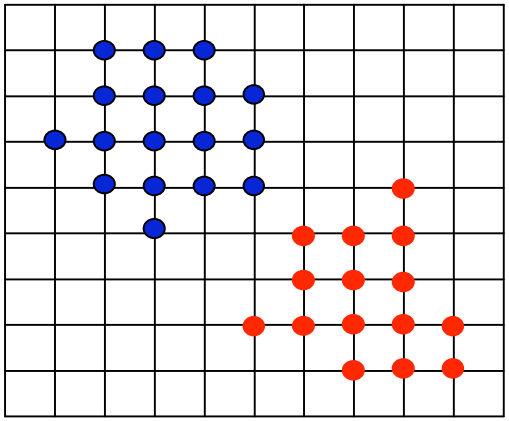


- **8 neighbors**

- **Path**
  - 4|8 path from a to b
    - Series of 4|8 adjacent points a,…,b



Connected Components Labeling



- Two points a and b are 4|8 connected in S
  - There is a 4|8 path from a to b in S
  - are 4|8 connected is a biconditional relation
- Biconditional Classes =

  Connected Components
- Connected Component Represents
  - Objects
  - Part of Objects
  - Several Objects

Connected Components Labeling

- **Example of Algorithm (4-connectedness)**
  - Raster Scan: left to right, top to bottom
  - Define the label of the current pixel (p) if p=1
    - Depends of the up (u) and left (l) pixels

	u	
l	*p*	

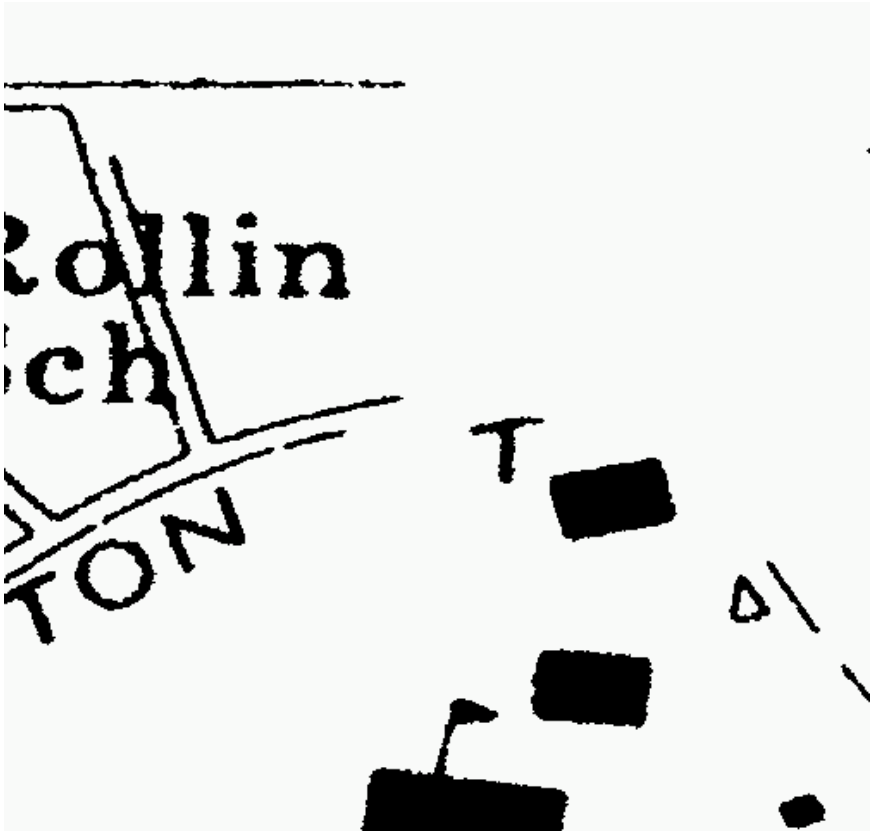
Label(p)=

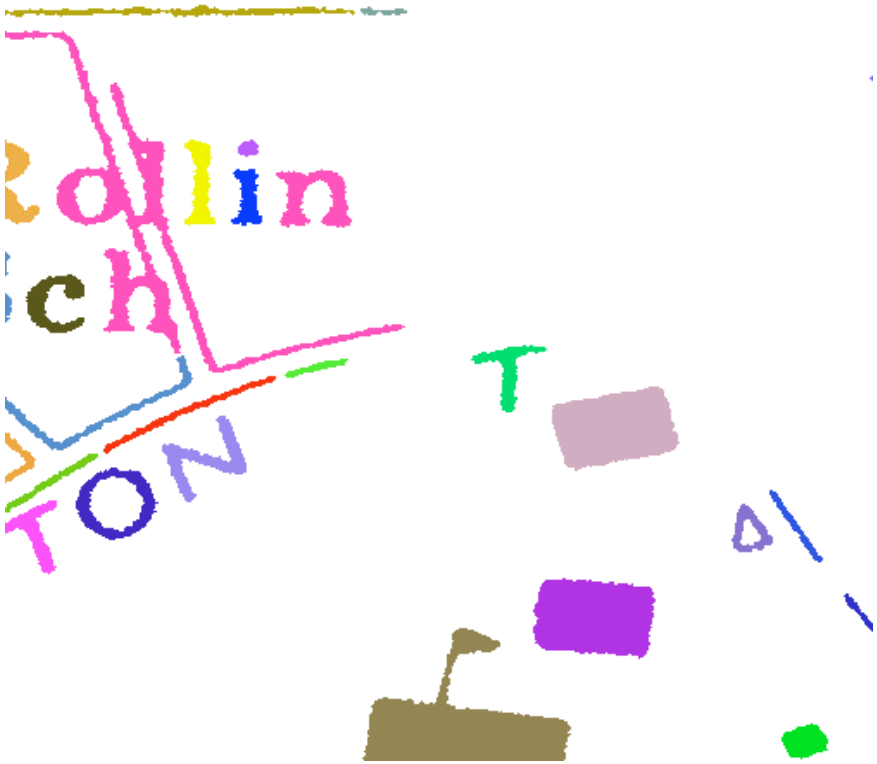
	u=0	u=1
l=0	New label	Label(u)
l=1	Label(l)	Label(u) Equivalence Table: Label(l) equiv. to Label(u)

  - Find the lowest label for each equivalence set in the equivalence table.
  - Scan the picture. Replace each label by the lowest label in its equivalence set.

Connected Components Labeling

- **Example of Result**





Connected Components Labeling

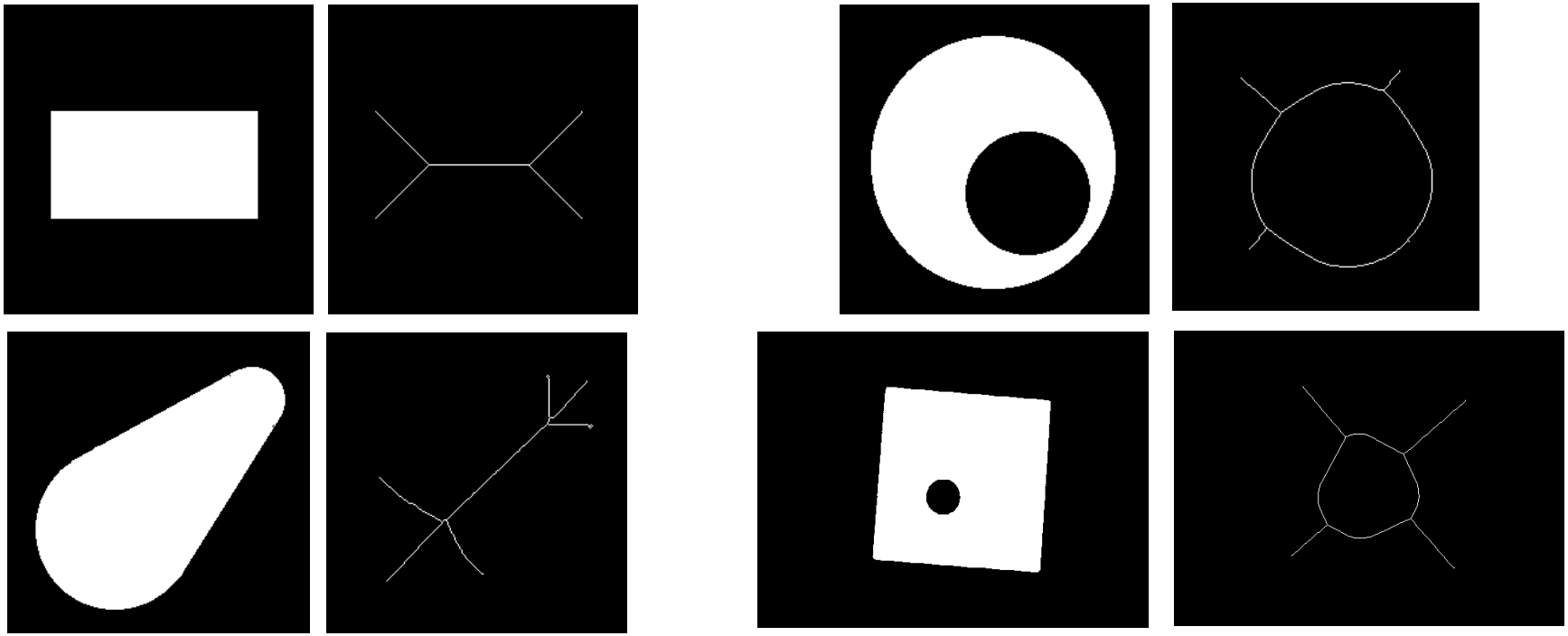
- Features can be computed during labeling
- Each feature is associated to a label in the Equivalence Table
  - Current pixel is labeled
  - Features associated are modified
- Example of features
  - Bounding box (min(x), min(y), max(x), max(y))
  - Number of Black Pixels
    - Zeroth-order moment of the object
  - Center of Gravity
    - First-order moment of the object
  - Object Orientation (orientation of its greatest elongation)
    - Axis of the second-order moment of the object
  - …
- Feature Standardization

Features: Object Localization / Extraction

- Difficulties of Feature Extraction
- Feature Extraction/Detection on the whole Signal
- Feature Extraction/Detection on Objects
  - Object Localization / Extraction
    - Region Labeling
    - Edge Detection
    - Connected Components Labeling
    - Skeletonization
    - Handwriting extraction
    - Line-Segment Detection
  - Object Characterization
- Interest of Multi-Resolution
- Using Features

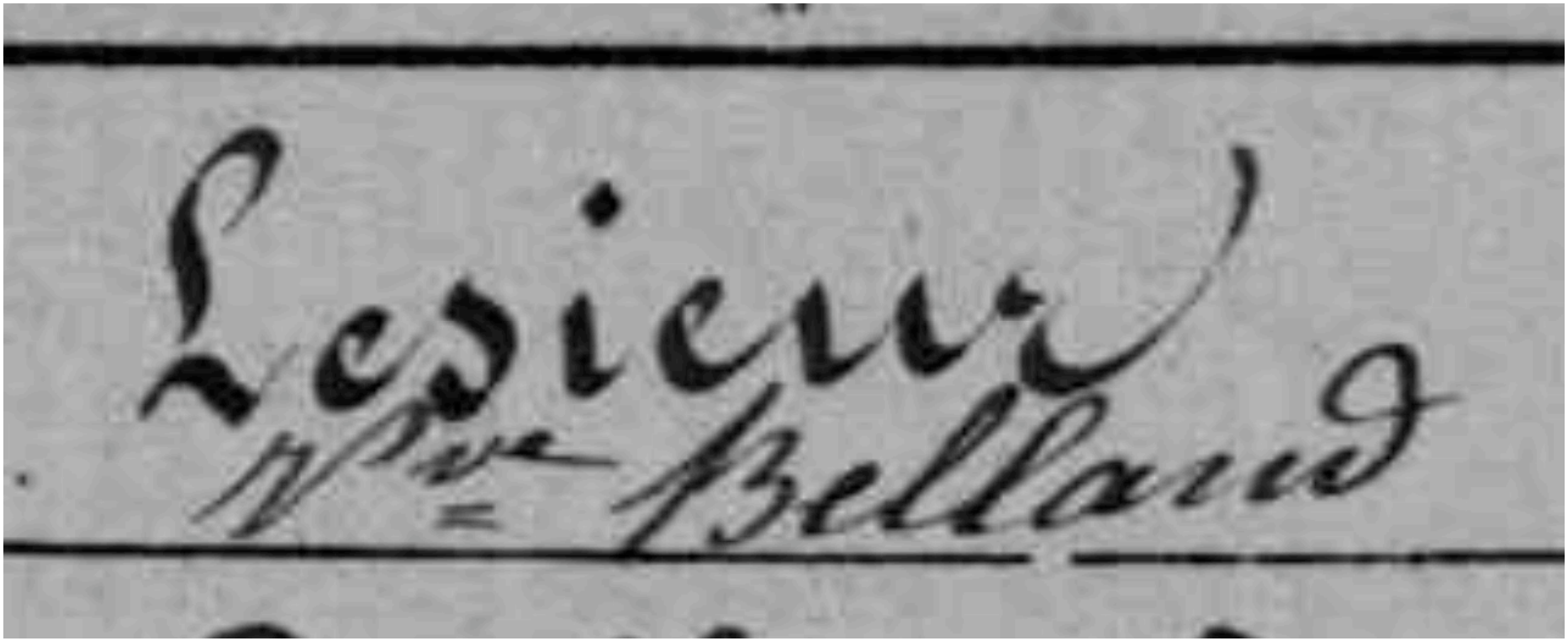
Skeletonization

- **Objective**
  - Reduce a shape as a one pixel thin shape
- **Principle**
  - Fire Front Propagation
  - Median Axis
- **Examples**



Skeletonization

- **Examples of different methods**



Skeletonization

- **Discrete Distance to the border**
  - [Rozenfeld & Pfaltz 1966]

Skeletonization

- Thinning by Erosion
  - [Pavlidis 1980]

Skeletonization

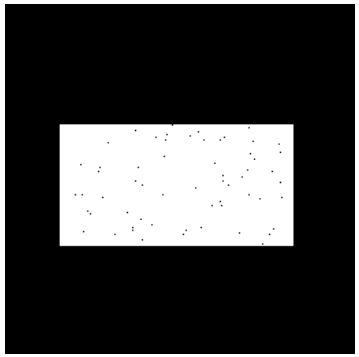
- Thinning by Erosion
  - [Zhang & Suen 1984]

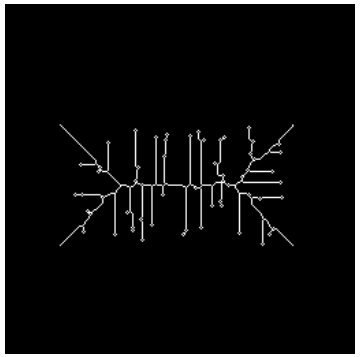
Skeletonization

- **Thinning by Erosion**
  - **Mathematical Morphology: [Chermant 1985] 8-connectedness**

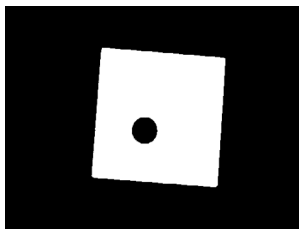
Skeletonization

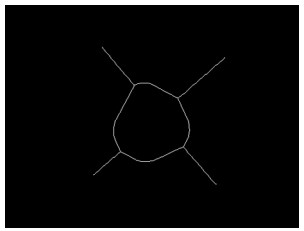
- 300 different methods in 1990
- Very sensible to noise





- Non stable representation (rotation…)
- Skeleton
  - Meaningful on linear objects
  - Non-linear Objects?





Features: Object Localization / Extraction

- Difficulties of Feature Extraction
- Feature Extraction/Detection on the whole Signal
- Feature Extraction/Detection on Objects
  - Object Localization / Extraction
    - Region Labeling
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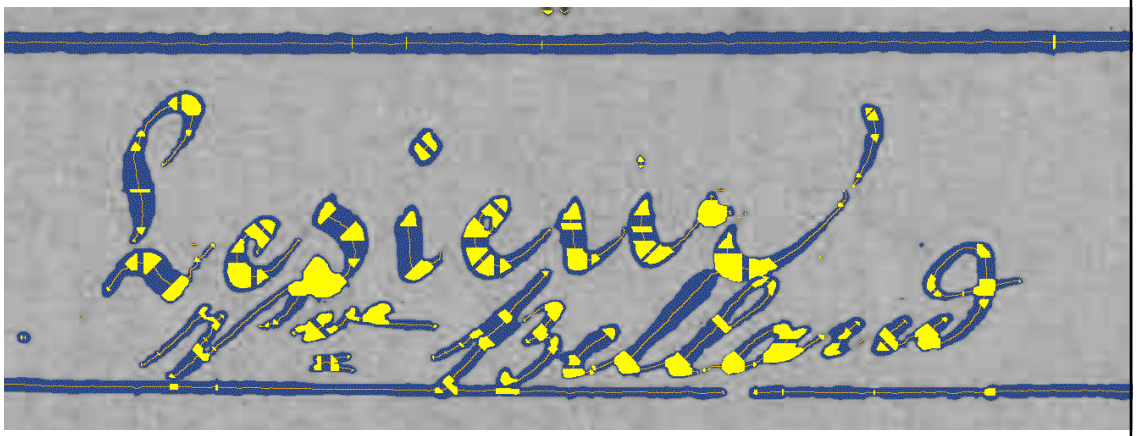
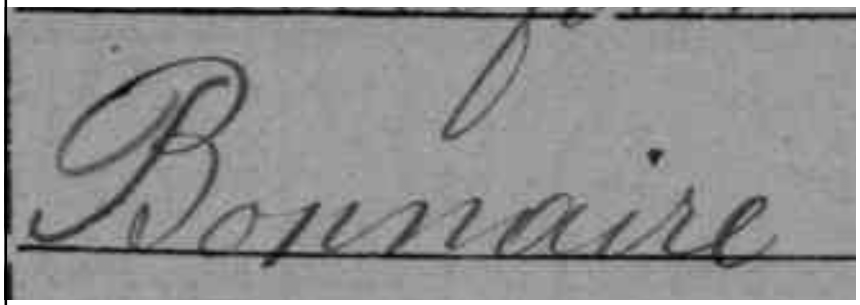
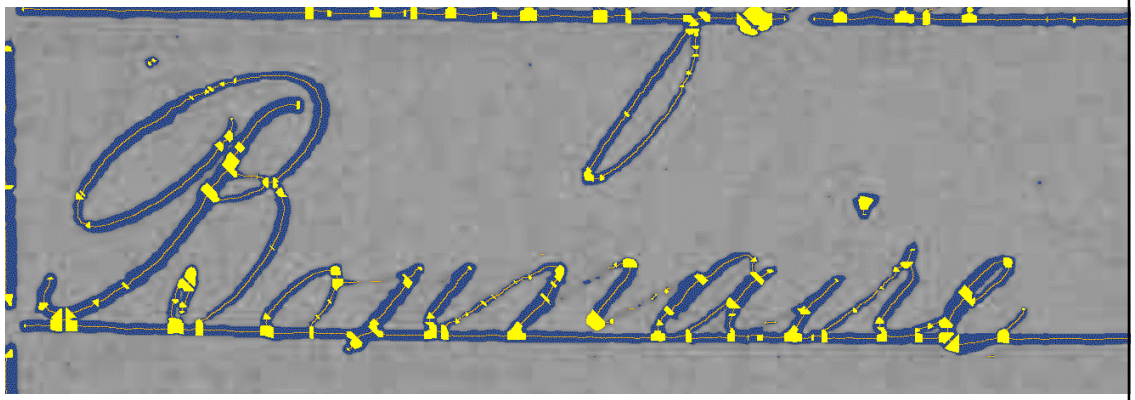
Handwriting extraction

- Off-line handwriting
- Skeleton
  - Not well adapted to handwriting
- Idea
  - Using median axis for linear elements
  - No decision on non-linear elements
- Two areas for handwriting extraction
  - Regular areas
  - Singular areas

Handwriting Extraction: Off-Line

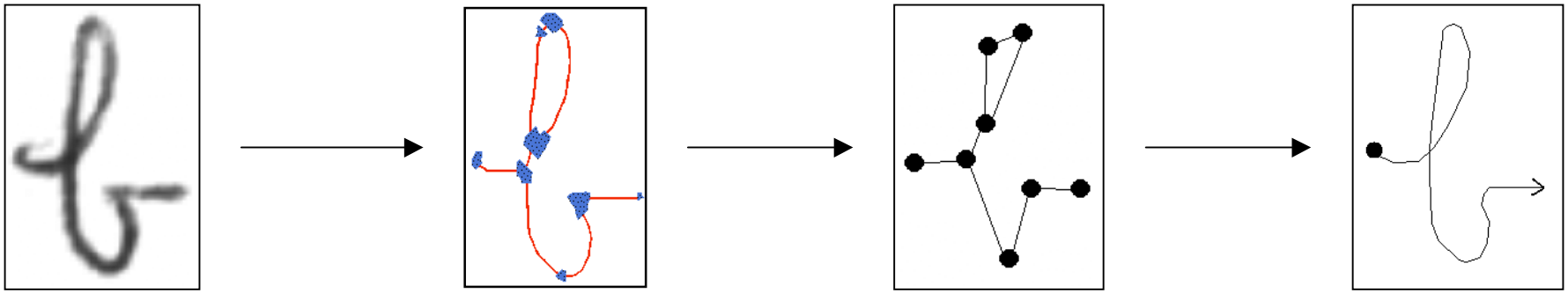


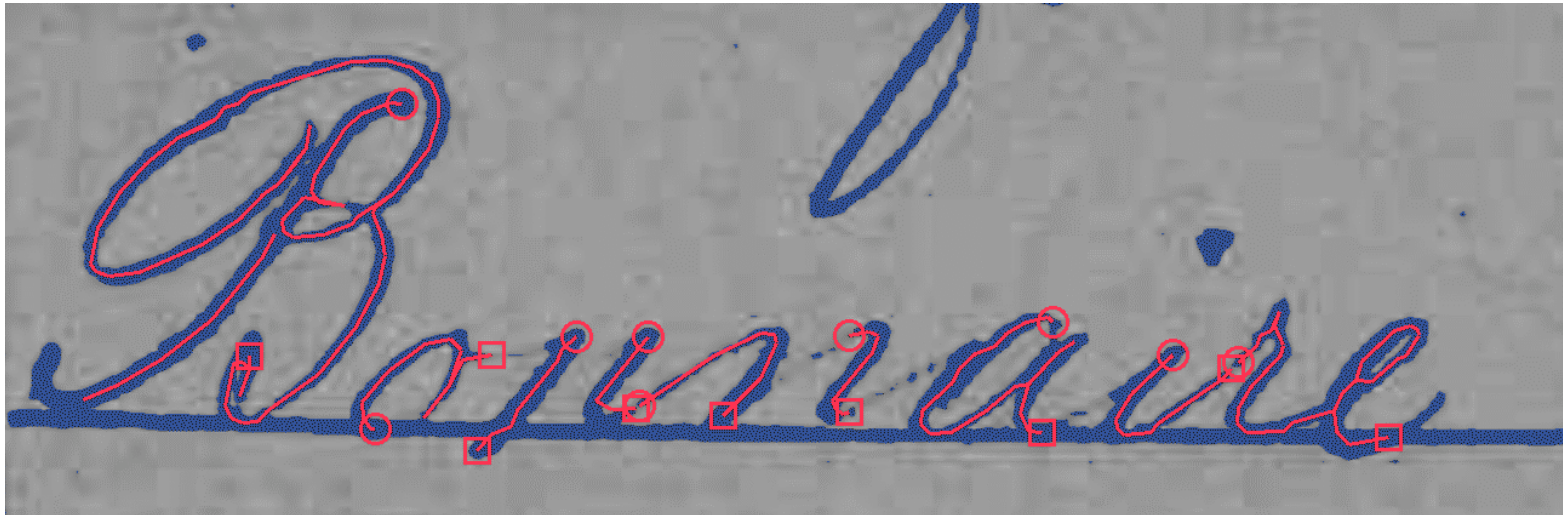




Handwriting Extraction: Off-Line

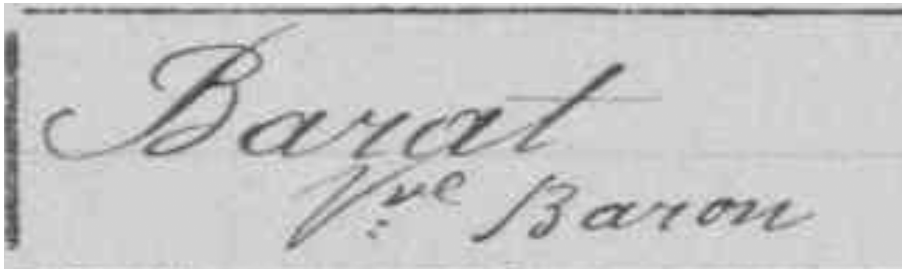
- **Recovering writing order**
  - **Graph Representation**

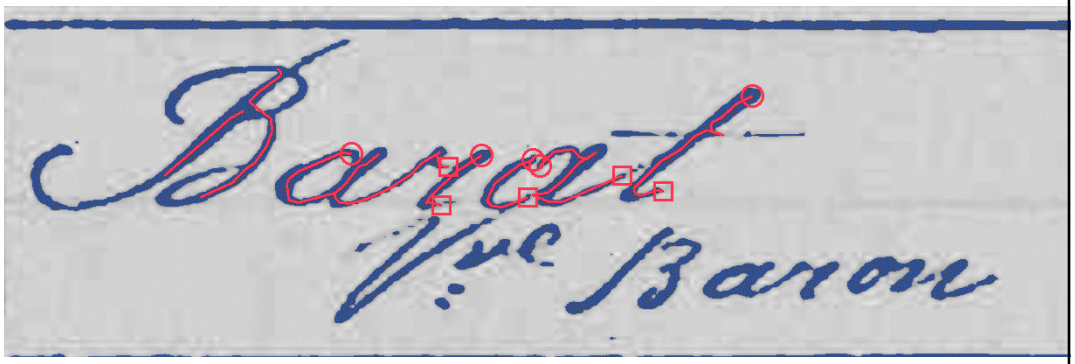


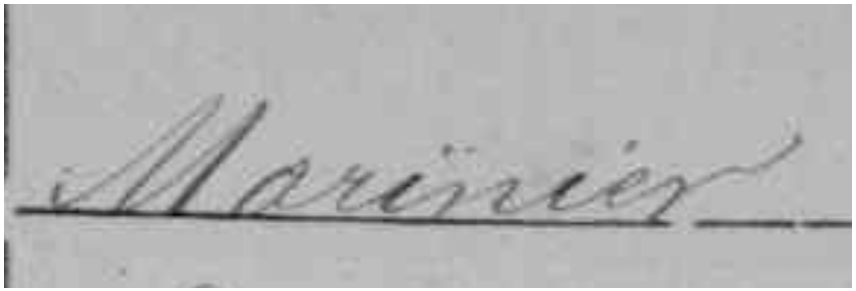


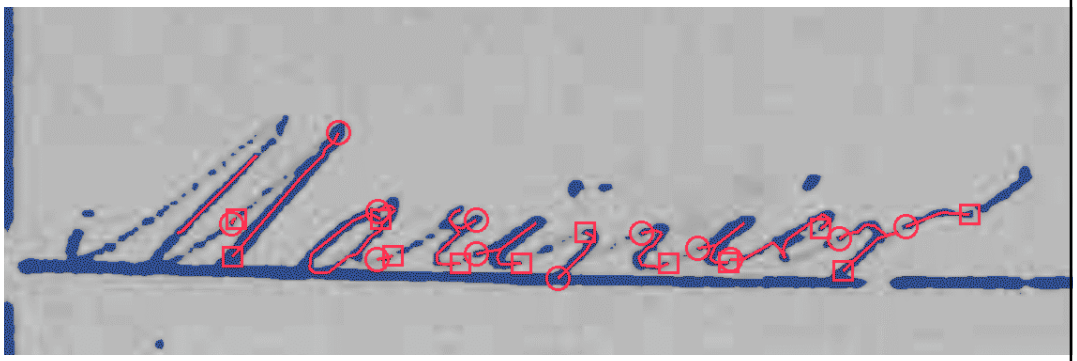
Handwriting Extraction: Off-Line

- **Recovering writing order - Difficulties**



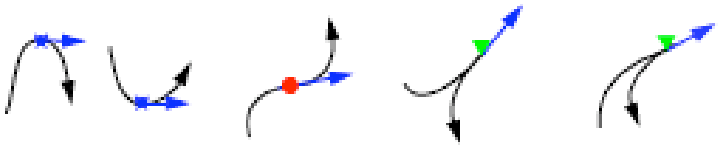




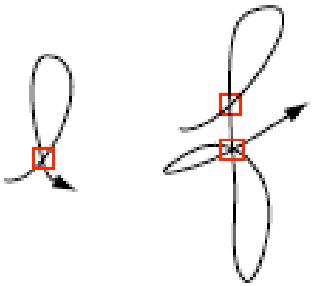


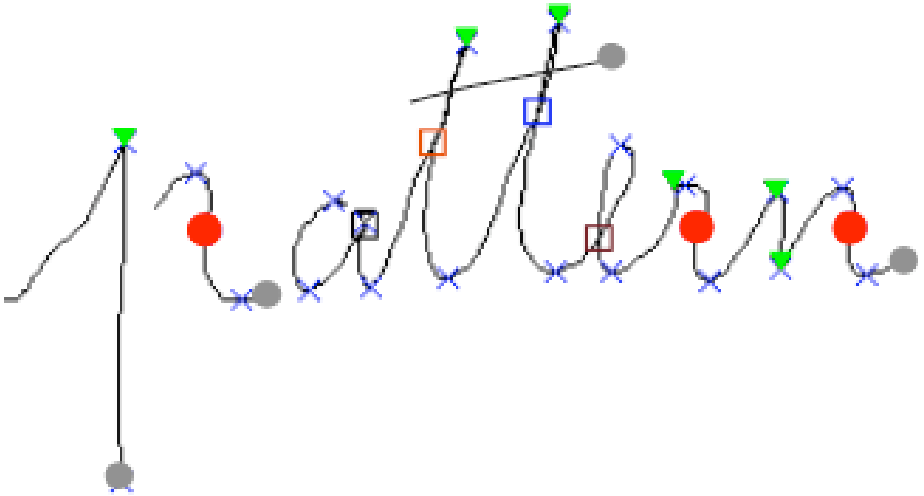
Handwriting Extraction: On-Line

- **Detection of specific feature points**
  - **Maxima, Inflexion, Turn back**



  - **Intersection**

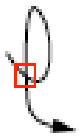




- **Non-stable Points**
  - **Use them for over-segmentation**

Handwriting Extraction: On-Line

- **Multiple Segmentation Hypothesis**

	Courbe	Hypothèses de segmentation
Point de rebroussement		
Point anguleux		
Point multiple, boucle simple de sens direct		
Point multiple, boucle simple de sens rétrograde		

- **On-Line Signal Segmentation**

Point	Regular stroke	Link
		invisibles

Features: Object Localization / Extraction

- Difficulties of Feature Extraction
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    - Region Labeling
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    - Thinning
    - Handwriting extraction
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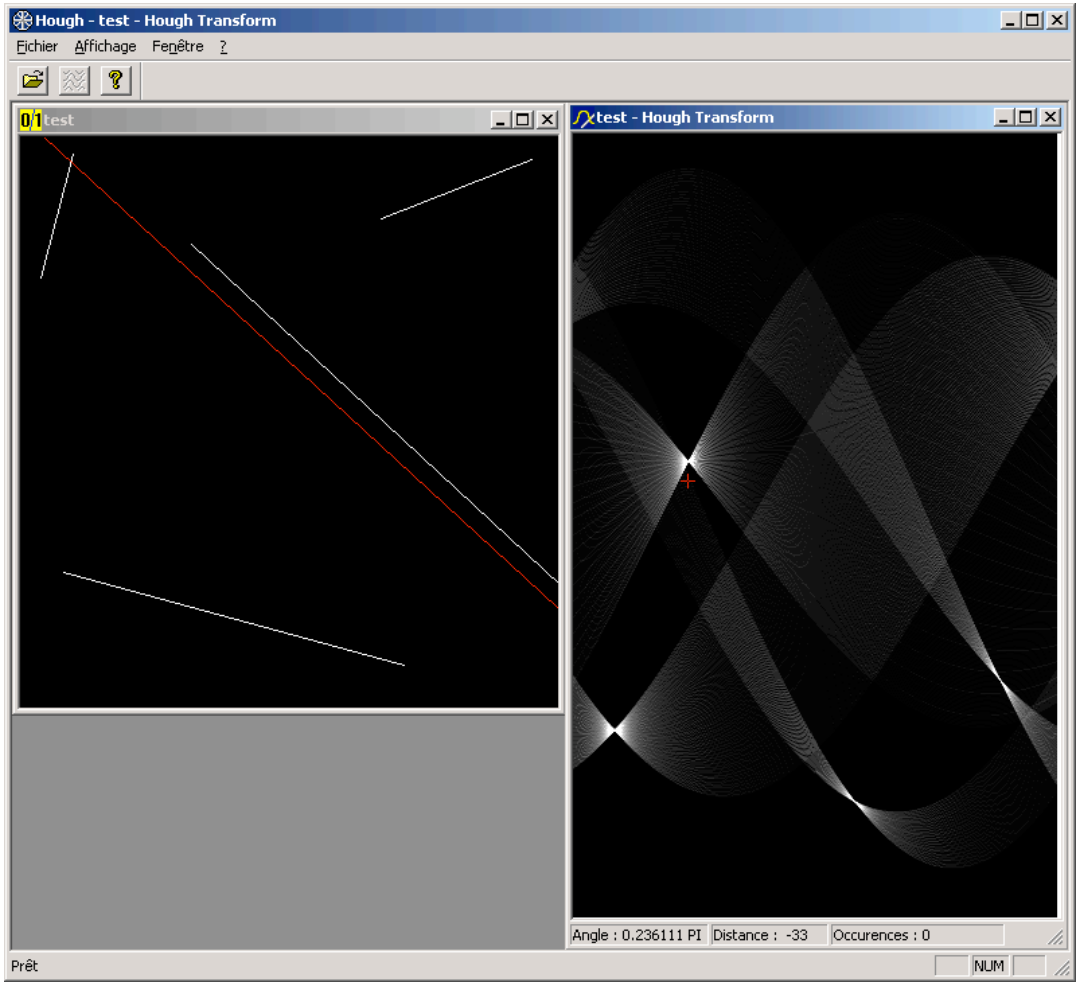
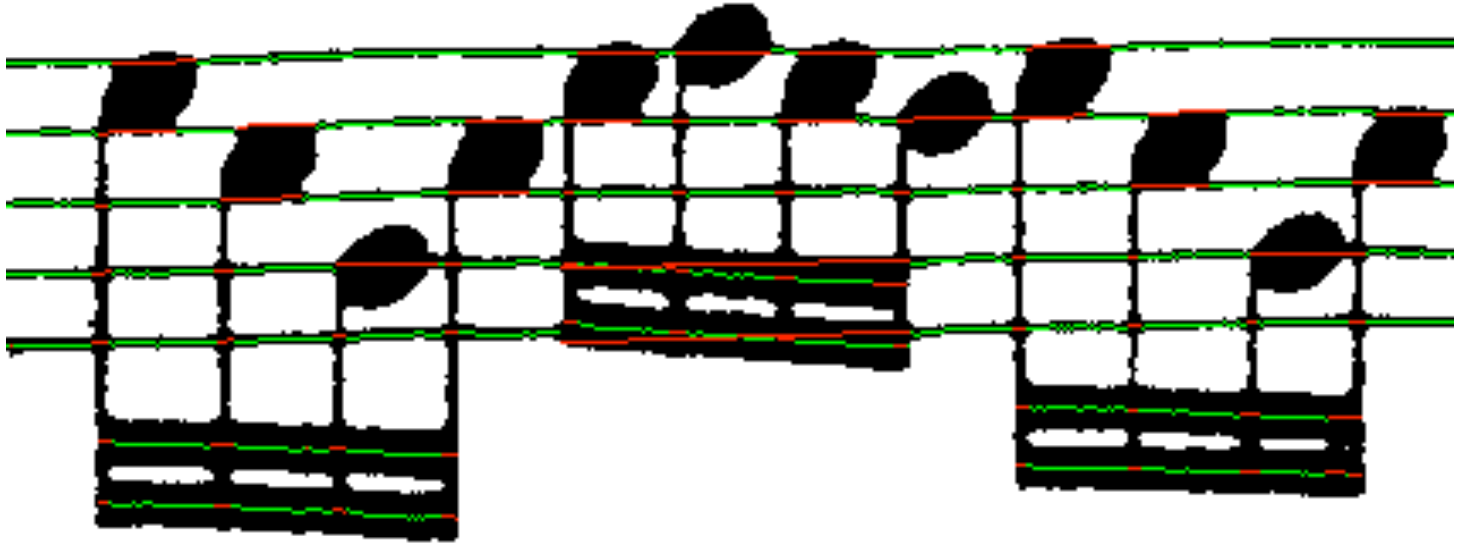
Line-Segment Detection

- **Hough Transform (1962)**
  - **Parametric Representation Space (ρ,θ) in each point correspond the number of pixels found on this line**
  - **Problems**
    - Non-straight line-segment
    - Strong gaps
    - Noise



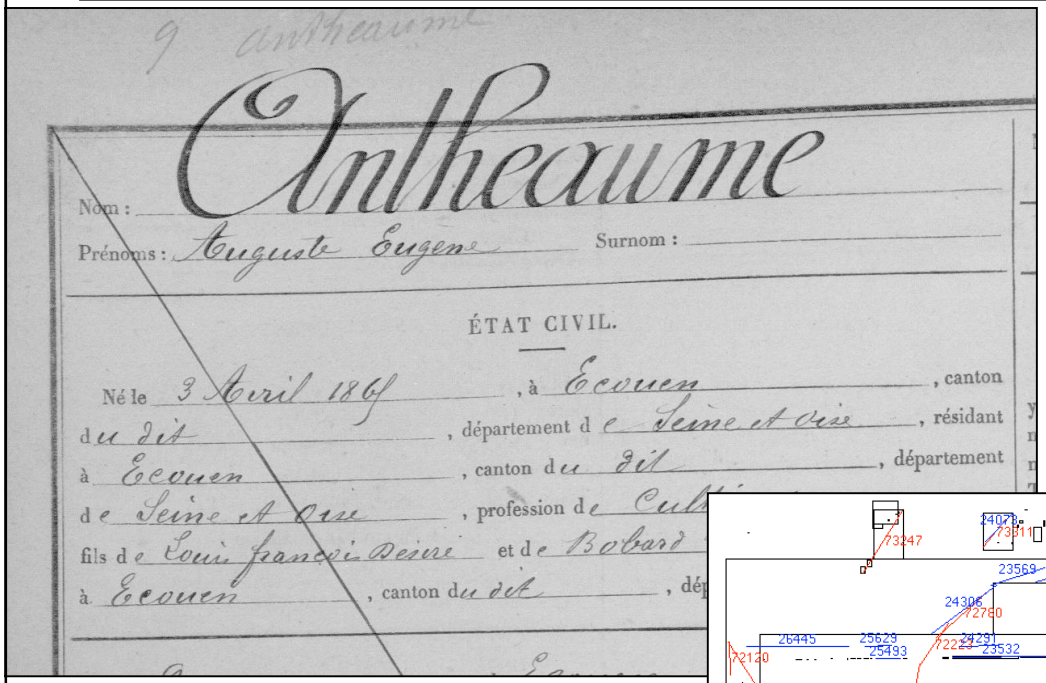
Line-Segment Detection

- Kalman Filtering Method



- Define a Line-Segment Model
  - Thickness
  - Slope
  - Position
  - Noise
- Prediction on a column
- Verification on the next column

Line-Segment Detection

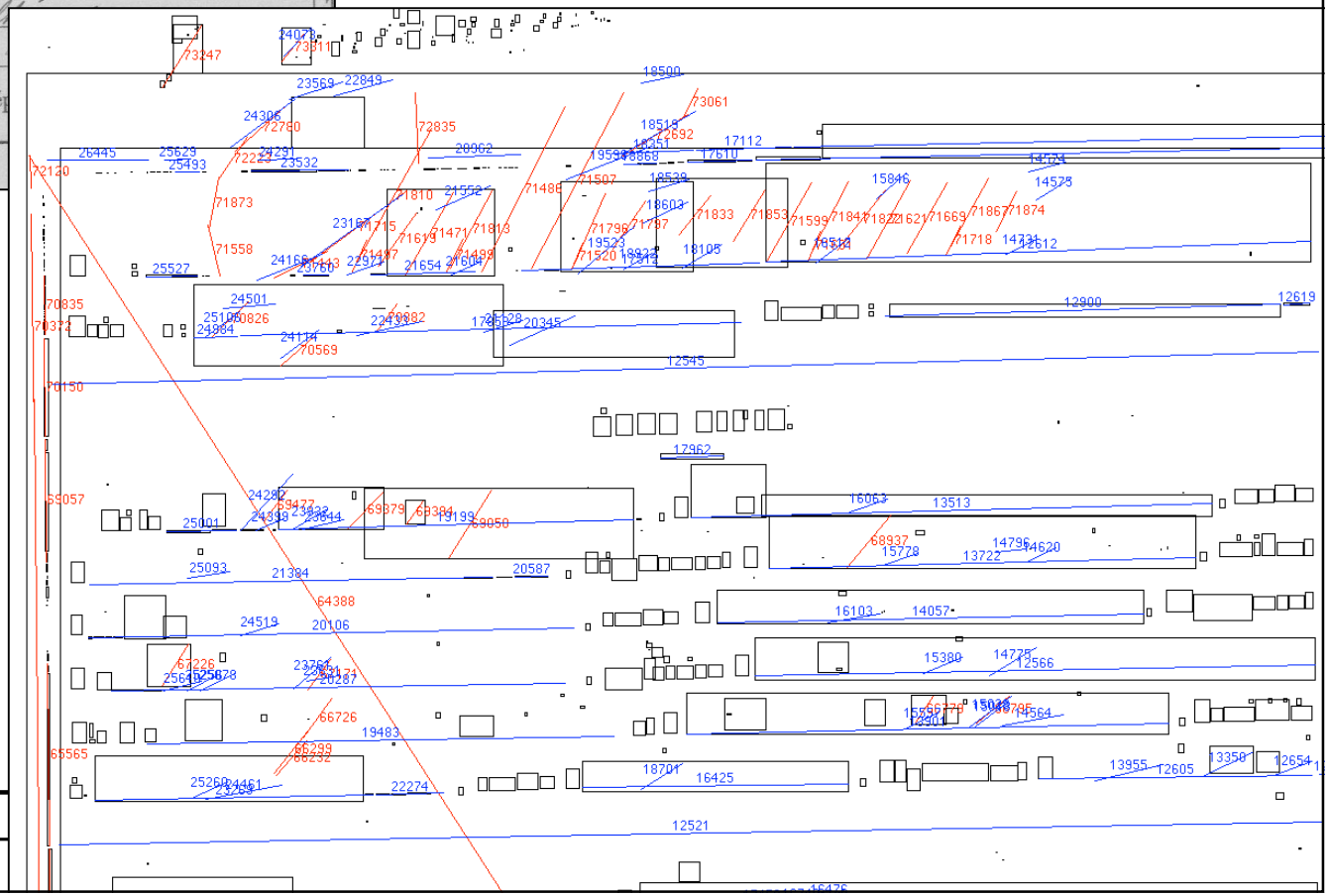


Nom : Antheaume

Prénoms : Auguste Eugene Surnom :

ÉTAT CIVIL.

Né le 3 Avril 186[illegible], à Ecouen, canton
du dit, département de Seine et Oise, résidant
à Ecouen, canton du dit, département
de Seine et Oise, profession de Cult[illegible]
fils de Louis François Pierre et de Bobard
à Ecouen, canton du dit, dé[illegible]



Outline

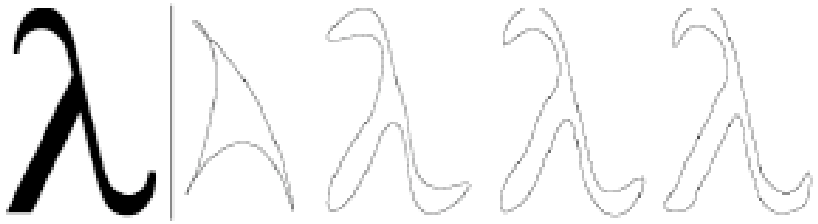
- Difficulties of Feature Extraction
  - Segmentation
  - Recognition in Images
  - Recognition in Document Images
- Feature Extraction/Detection on the whole Signal
  - Global Descriptor
  - Local Descriptor
- Feature Extraction/Detection on Objects
  - Object Localization / Extraction
  - Object Characterization
- Interest of Multi-Resolution
- Using Features

Object Characterization

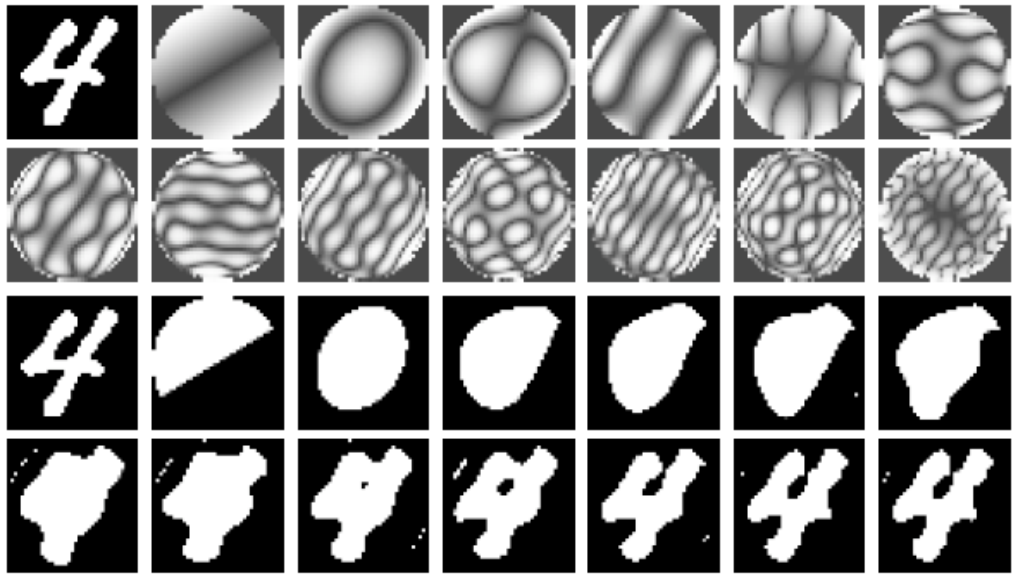
- **Objective**
  - Features for Object Recognition
  - Input of Classification Systems
- **Features compute on**
  - Edges
  - Skeleton
  - Segmented Object Image
    - Binary Image
    - Grey-Level Image
    - Color Image
    - Made of one or several Components (result of segmentation)

Object Characterization

- **Examples of Features**
  - **Moments (see connected components)**
  - **Progressive decomposition using elliptic Fourrier (on edges)**

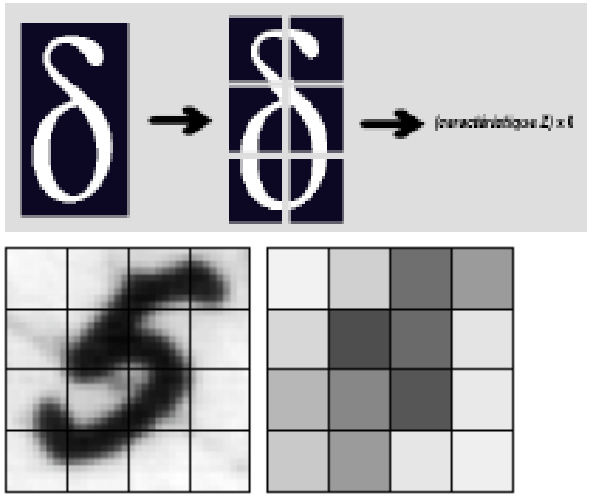


  - **Zernike moments (on image)**

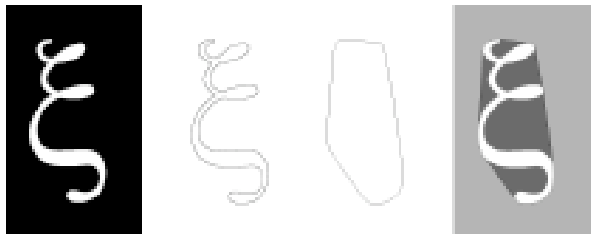


Object Characterization

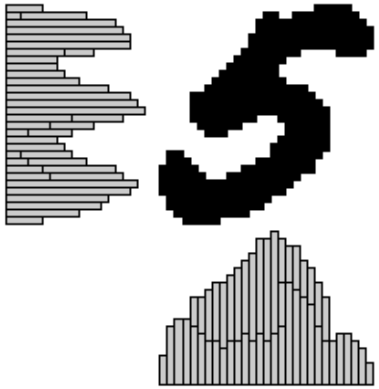
- **Examples of Features**
  - **Zoning**
    - Compute Features in each zone
    - Average Grey Level



  - **Holes and Hollows**

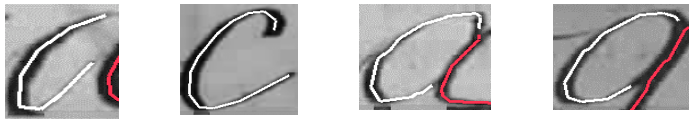


  - **Horizontal and Vertical Projection Histogram**

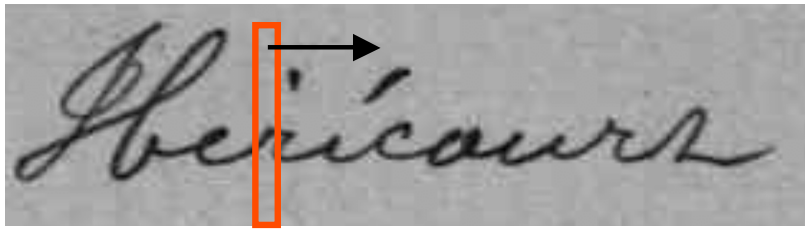


Object Characterization

- **Off-line Handwriting**
  - **Features compute on**
    - Part of letters



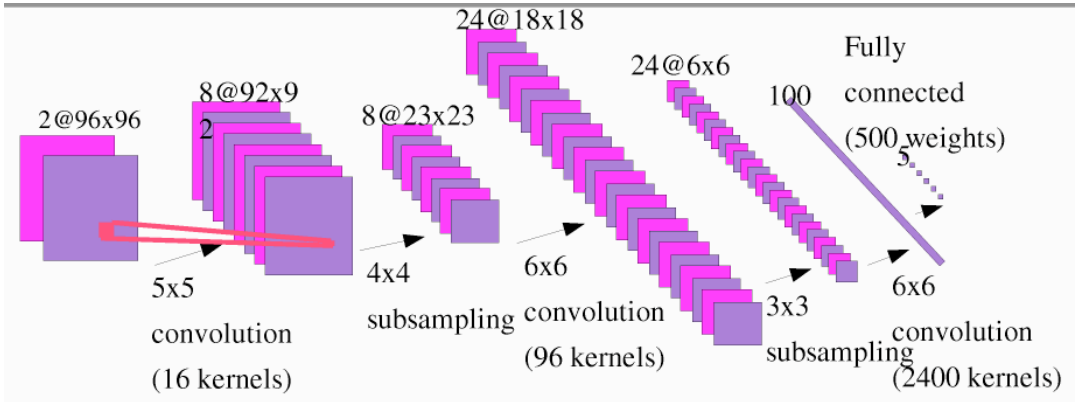
    - Sliding window in a word



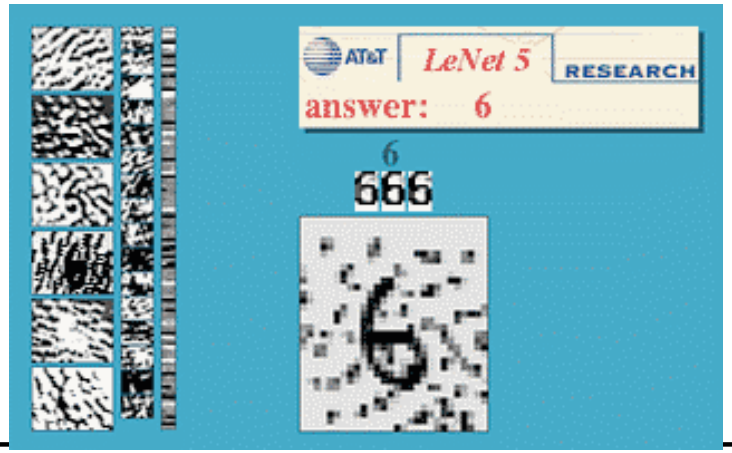
    - Word
- **Examples of On-Line Handwriting Features**
  - **Relative positions of beginning and ending of strokes**
  - **Average curve openness**
  - **Relative size along vertical axis**
  - **…**
- **Don’t forget Standardization!**

Learning Features

- **Learning Features and Classification**
- **Example: Neural Network Architecture**
  - Convolutional Network LeNet 7 [LeCun]
    - Input: Image ; Output: Recognized Class

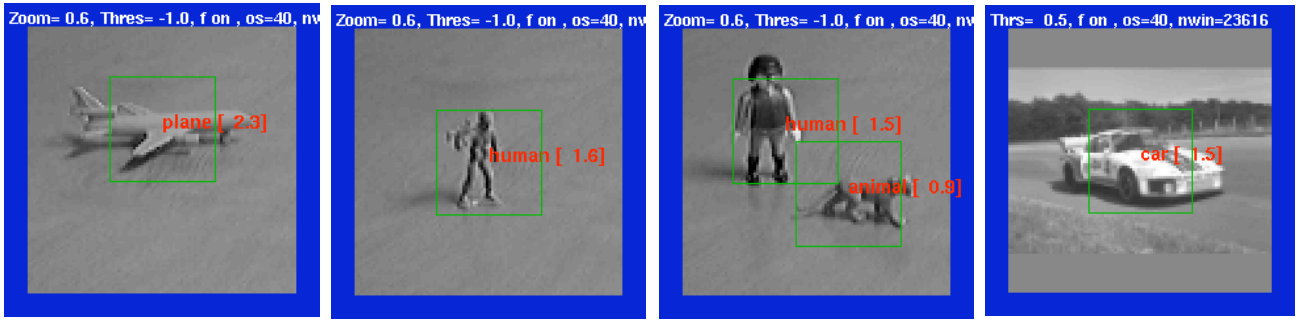


  - Character Recognition (LeNet 5)

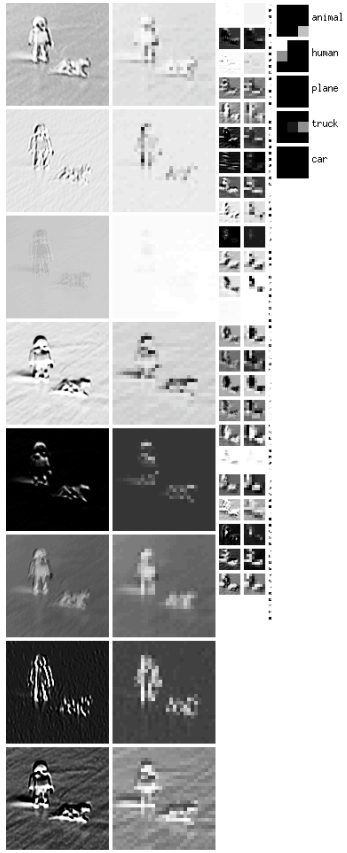


Learning Features

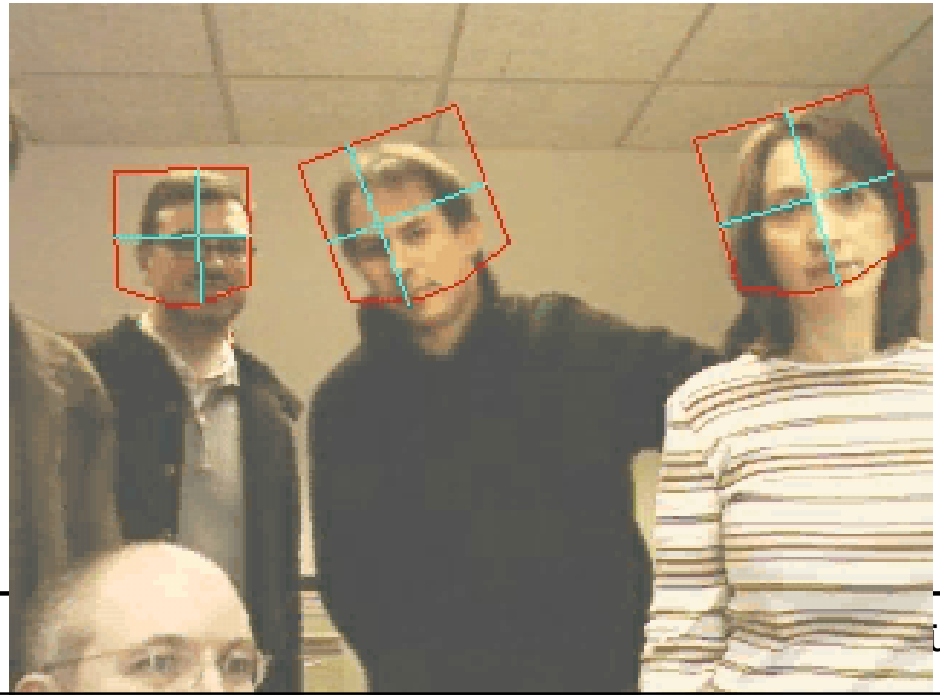
- **Example**
  - **Convolutional Network LeNet 7 [LeCun]**
    - Object Recognition/localization (Here 5 classes)



Internal State of the Convolutional Network



    - Face Detection



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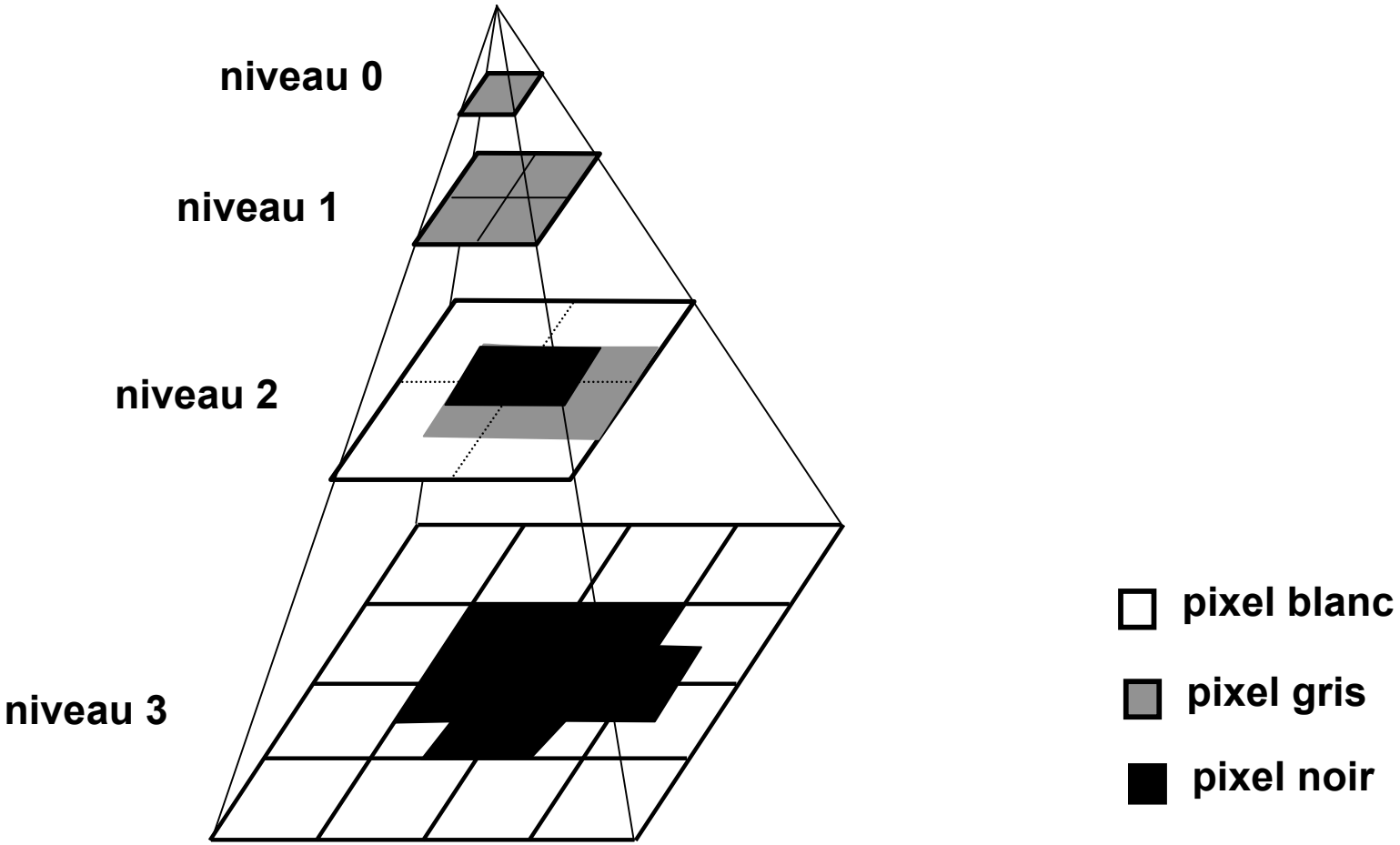
Interest of Multi-Resolution

- Multi-resolution
- Sizes
  - 512x512
  - 256x256
  - 128x128
  - 64x64
  - 32x32
  - 16X16
  - 8x8

Interest of Multi-Resolution



Interest of Multi-Resolution

256x256

Interest of Multi-Resolution

128x128

128x128

Interest of Multi-Resolution

64x64

64x64

Interest of Multi-Resolution

- **Computation Time**
  - This is not more the real interest
- **Perceptive interest**
  - To extract different element at different level
  - Far Vision
    - Global
  - Close Vision
    - Details
  - Same Feature does not represent the same thing
    - Depends on Image Level

Interest of Multi-Resolution

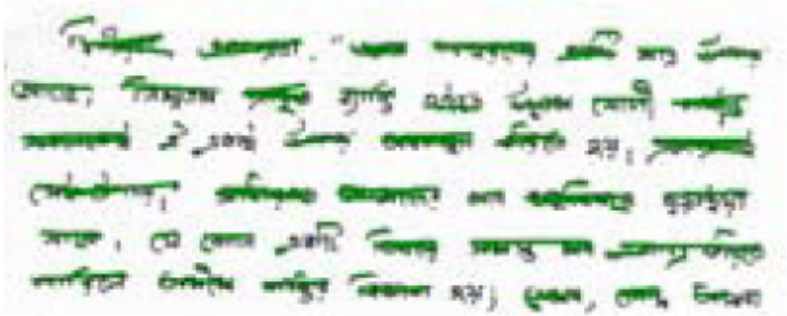
- **Example**

Resolution -16

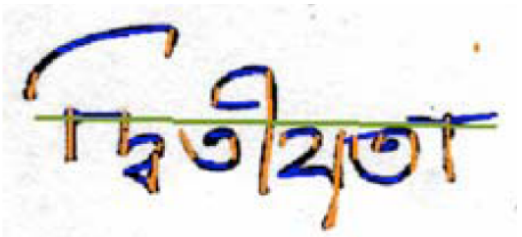
Line segment extraction: part of text lines

Resolution -8

Line segment extraction: part of words



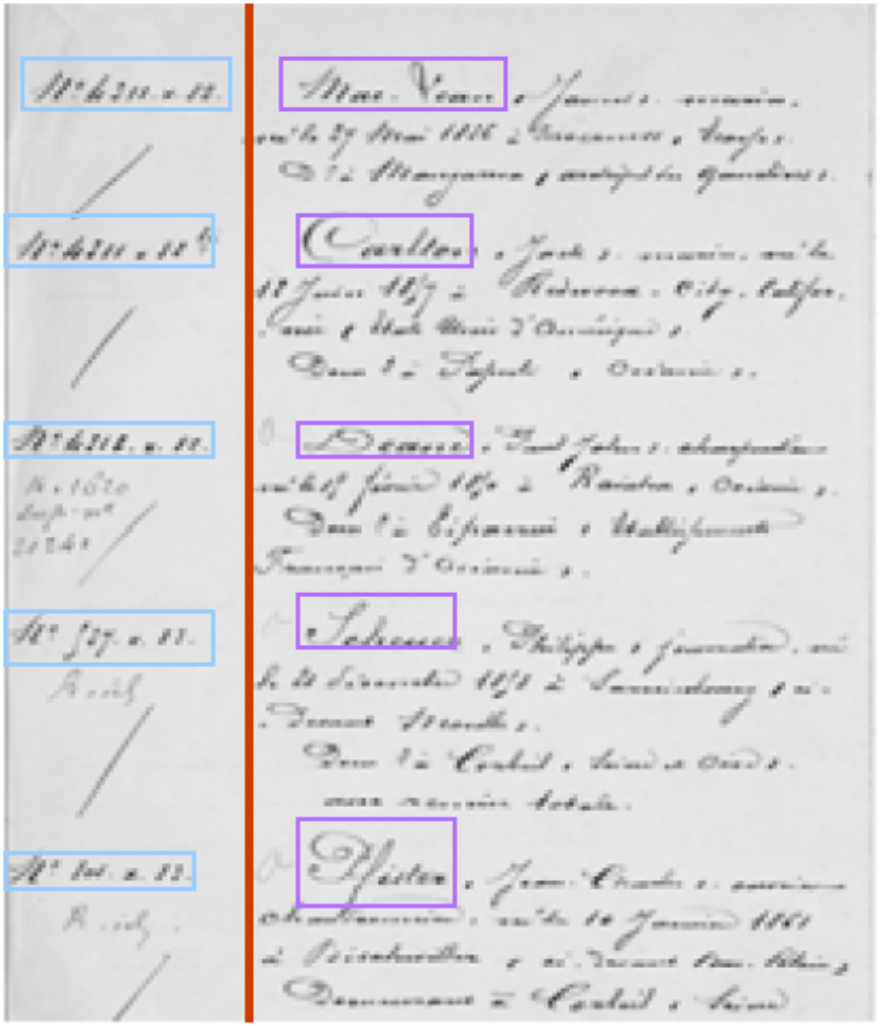
High Resolution



Interest of Multi-Resolution

- **Structure at low Resolution**

- **Word Localization at High Resolution**



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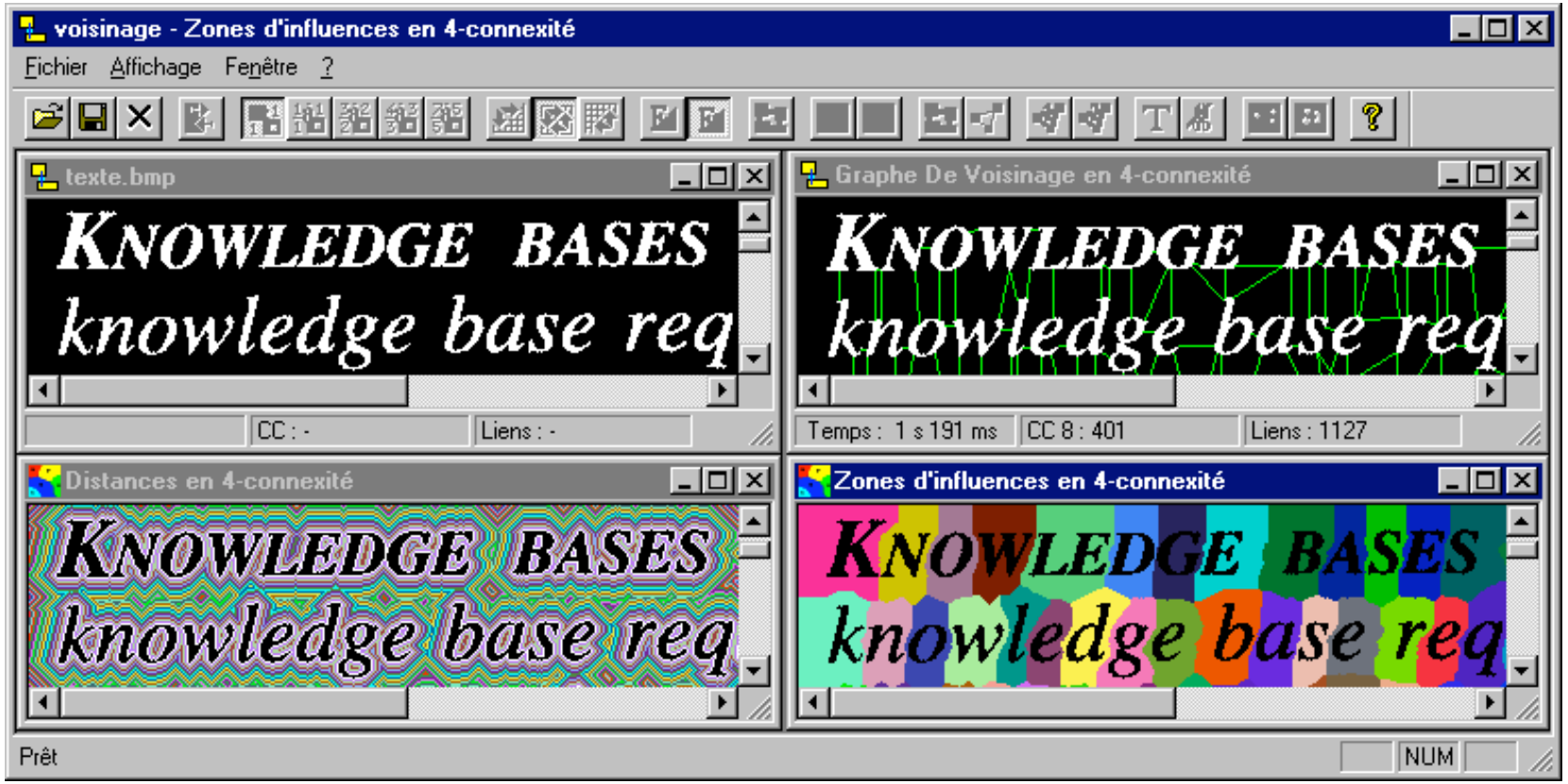
Using Features

- **Graph Representation**
  - Organization of Objects
  - Example: Adjacency Graph



Using Features

- **Classification Methods**
  - **Features are input of**
    - Classifiers
    - HMM
    - …
- **Recognition Systems**
  - **Strategy**
    - Bottom-up
    - Top-down
    - Mix
  - **Knowledge introduction**

References

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