Vision par ordinateur : Approche traditionnelle

Le royaume de la créativité

- ***Hans Moravec***: *"it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility"*

Plan

- Définir une image
- Traitements de base
- Taches de haut niveau
  - Un point clé : La représentation
  - Classification
  - Détection
  - Segmentation

Qu’est-ce que la vision ?

Percevoir le monde

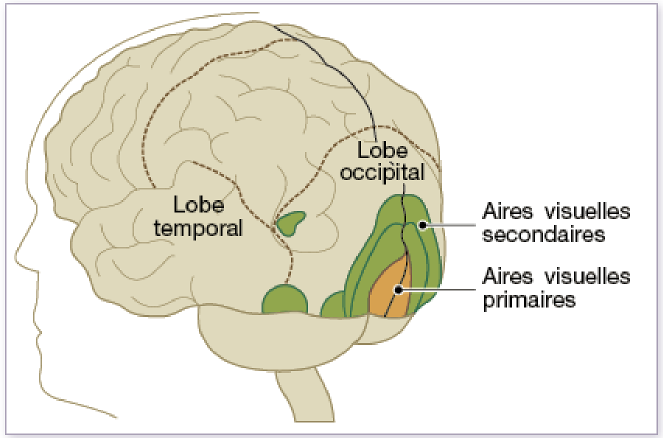
- Structure 3D
- Composé d’objets
- Efficacement interprété par l’être humain

Info recueillie

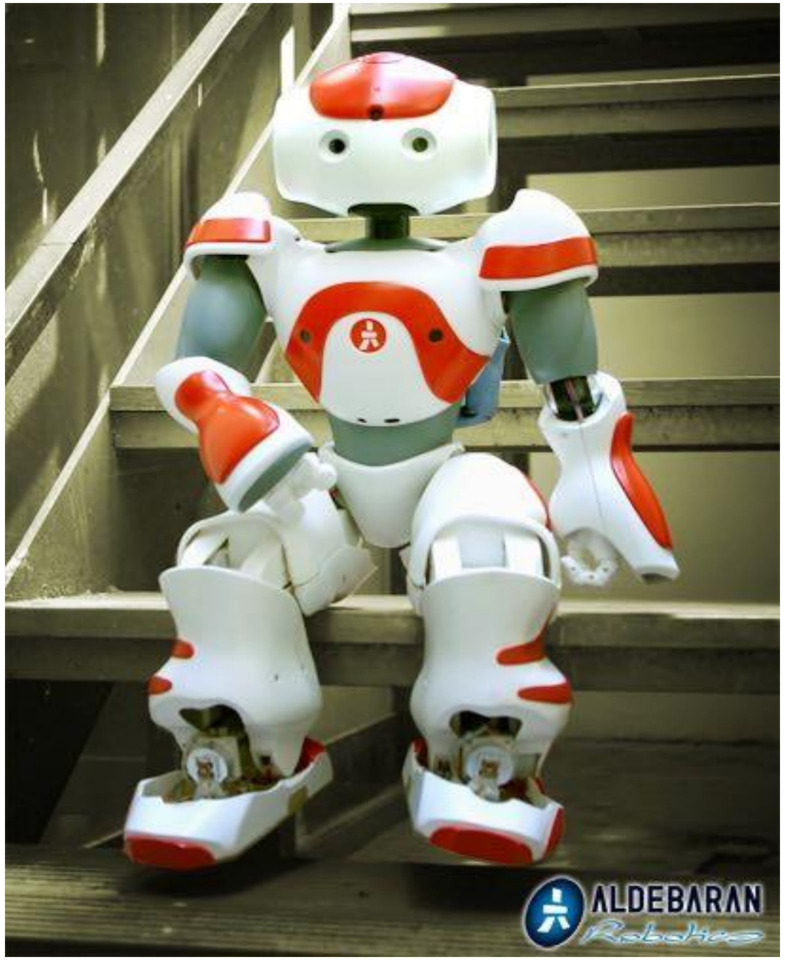
- Ensemble de points
- Pixels -> info sur la lumière
- Quantité et contenu spectral/couleur

Comment « voir » les objets ?

- Les objets n’existent pas sur la rétine
- Interprétation -> processus visuel



Qu’est ce qu’une image pour un ordinateur ?



Représentation des images

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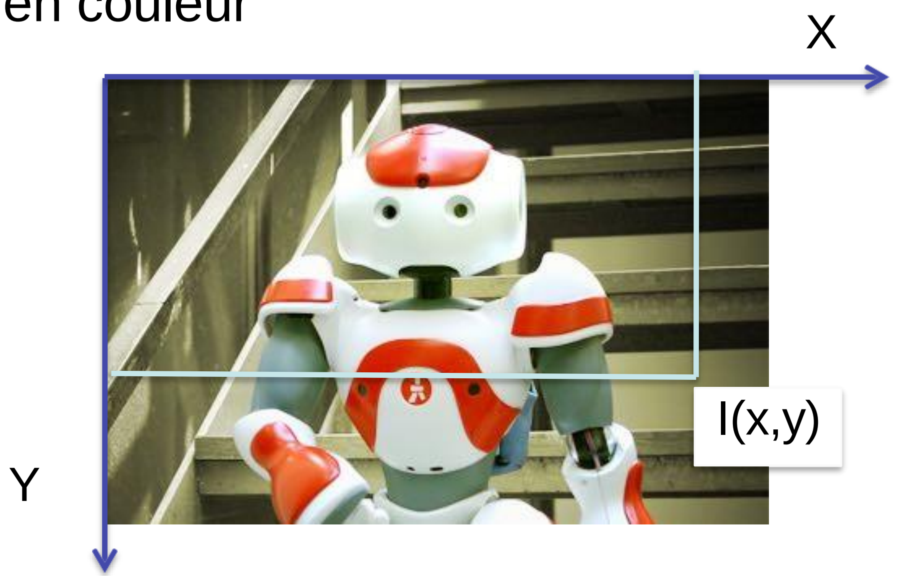
Représentation des images

Fonction

– I(x,y) : valeur d'un pixel

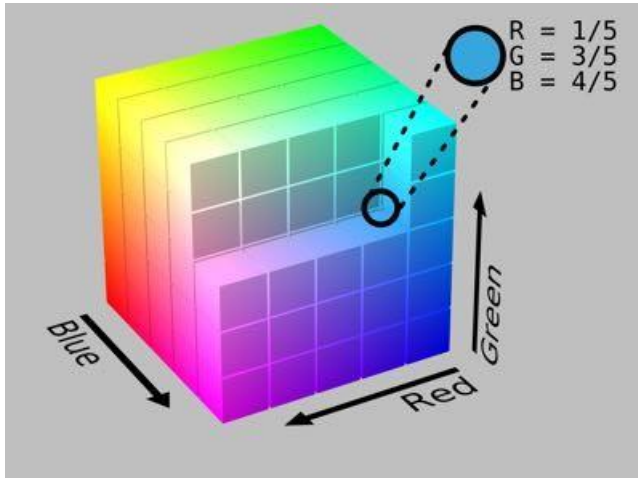
dans R en monochrome

dans R^3 en couleur

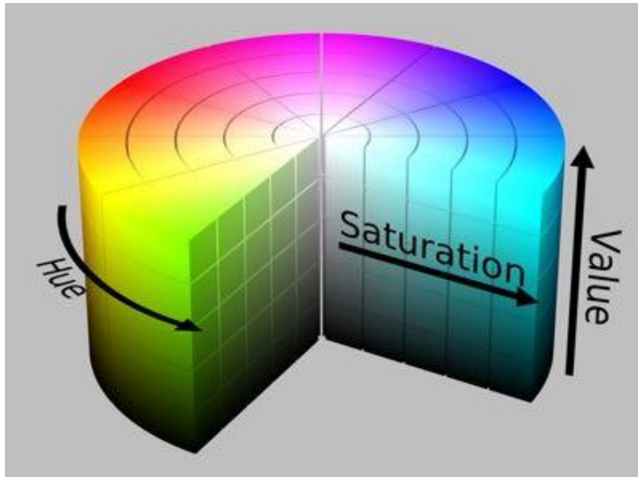


Représentation des images

Espaces colorimétriques

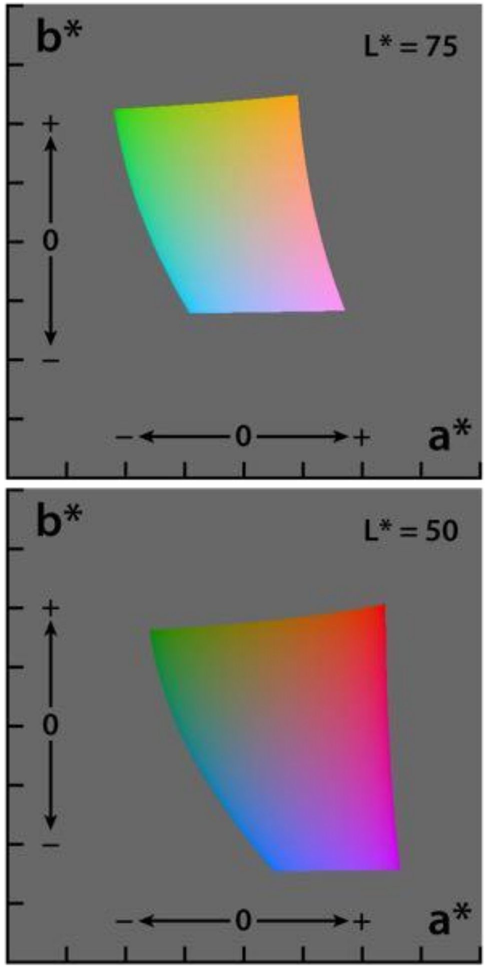


RGB



HSV

Lab



Représentation des images

Variations

- I(x,y) ➔ I(x,y) + α : luminosité globale
- I(x,y) ➔ λI(x,y) : changement de contraste
- I(x,y) ➔ I(x+a,y+b) : translation
- I ➔ A.I+b : transformation affine

➔

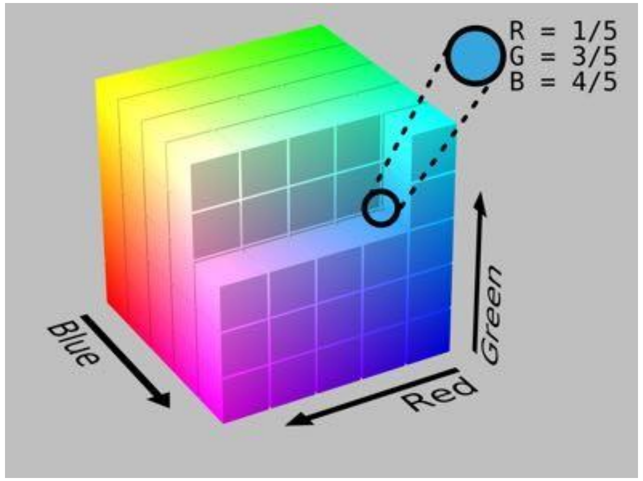
Traitements de base

Filtrage et amélioration

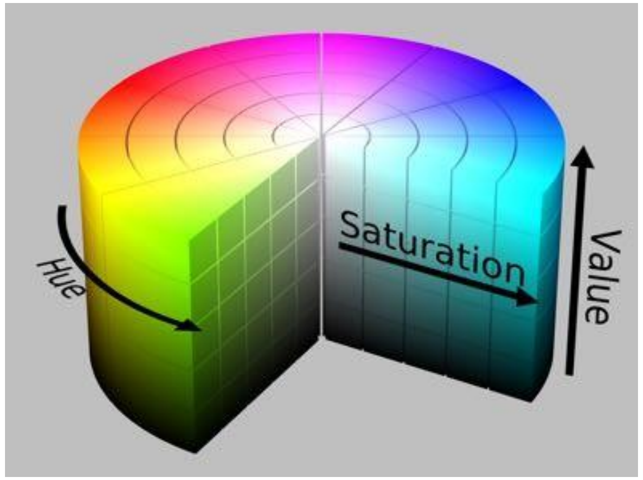
- Changement de color space
- Thresholding
- Egalisation d’histogramme
- Flou
- Morphologie mathématique

Représentation des images

Espaces colorimétriques

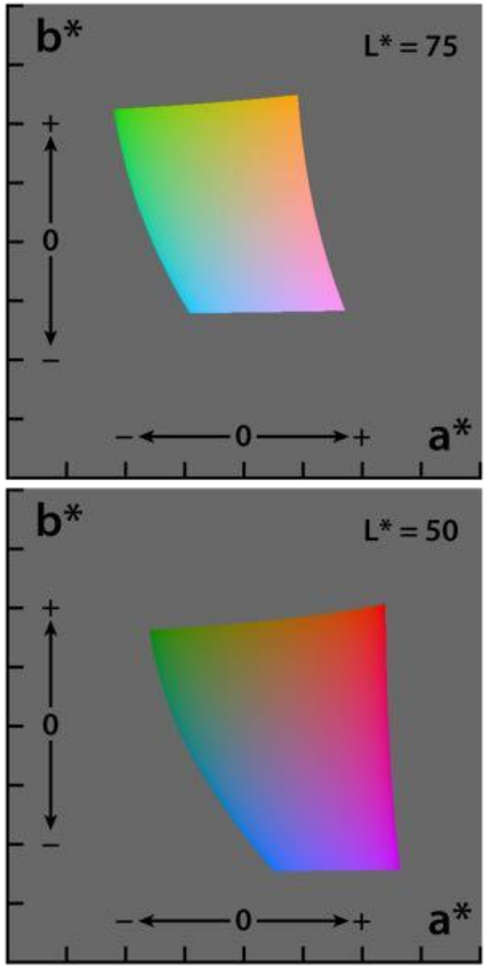


RGB

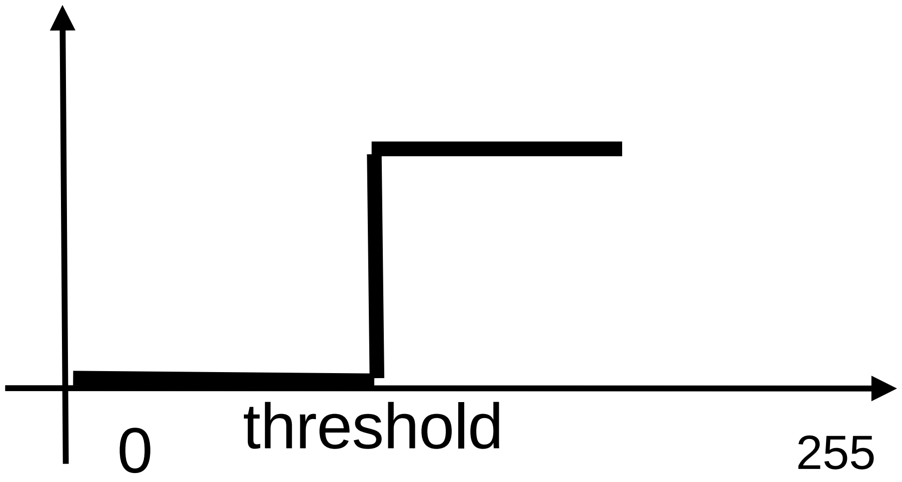


HSV

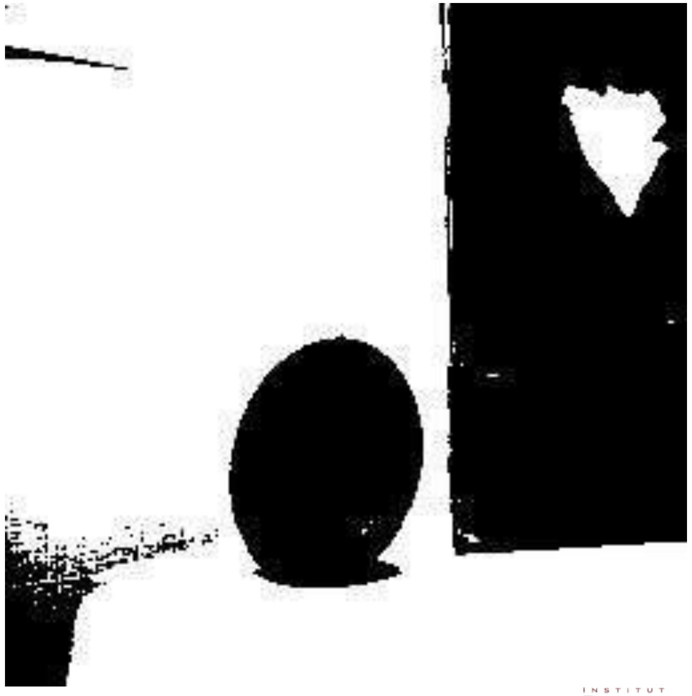
Lab



Binarisation



Input image



T. Chateau

Detections de contours

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Detections de contours

En 2D

– Masques de Sobel

Dérivée selon x : I_x

$$H_1 = \frac{1}{8}\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

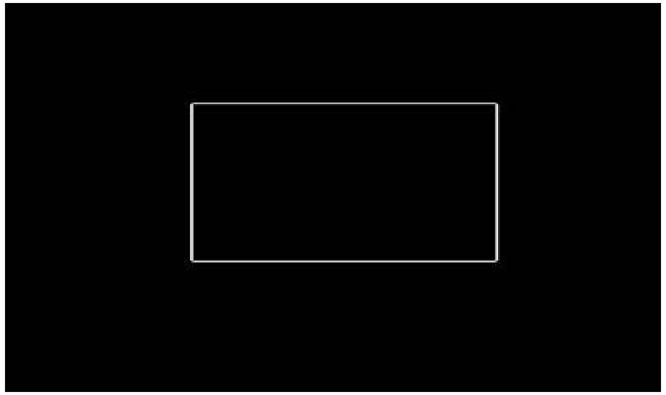
Dérivée selon y : I_y

$$H_2 = \frac{1}{8}\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Detections de contours

Estimation du gradient

– Norme: $\mathrm{sqrt}(I_x^2+I_y^2)$ Direction: $\mathrm{atan2}(I_y,I_x)$

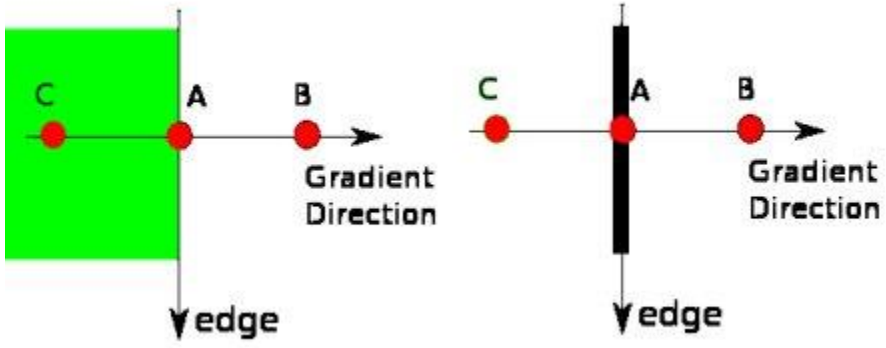


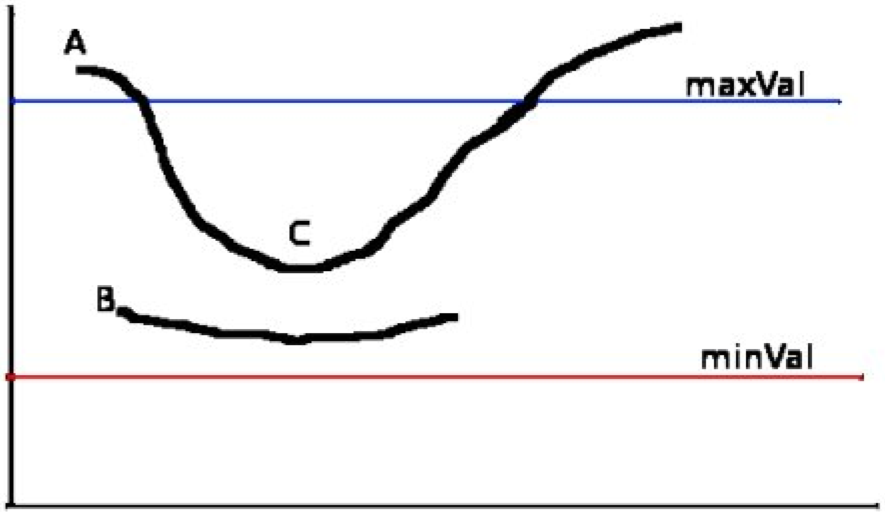
Détections de contours

- Définition
  - Extremas du gradient dans la direction du gradient
  - Zéros du Laplacien
- Filtrage du gradient
  - Suppression des non maxima dans la direction du gradient

Détections de contours : Méthode de Canny

- Suppression du bruit
- Calcul gradient Sobel
- Non maximum suppression
- Seuillage à hysteresis

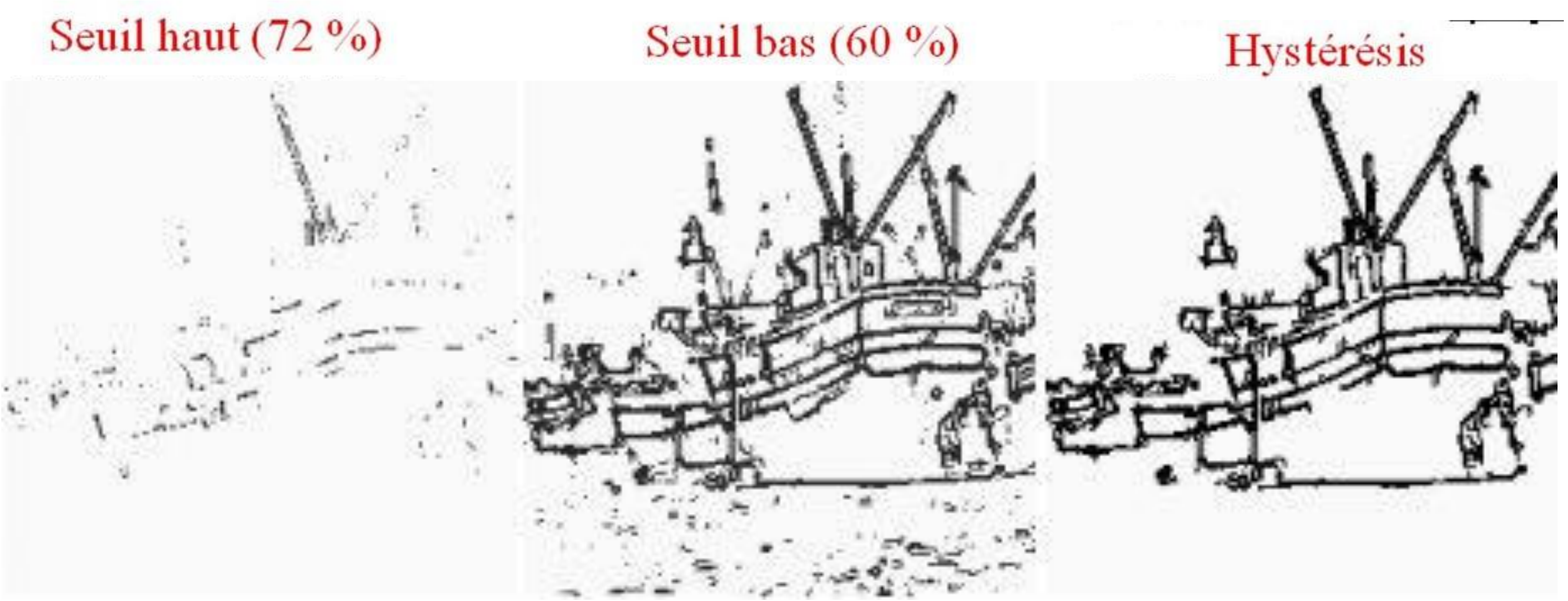




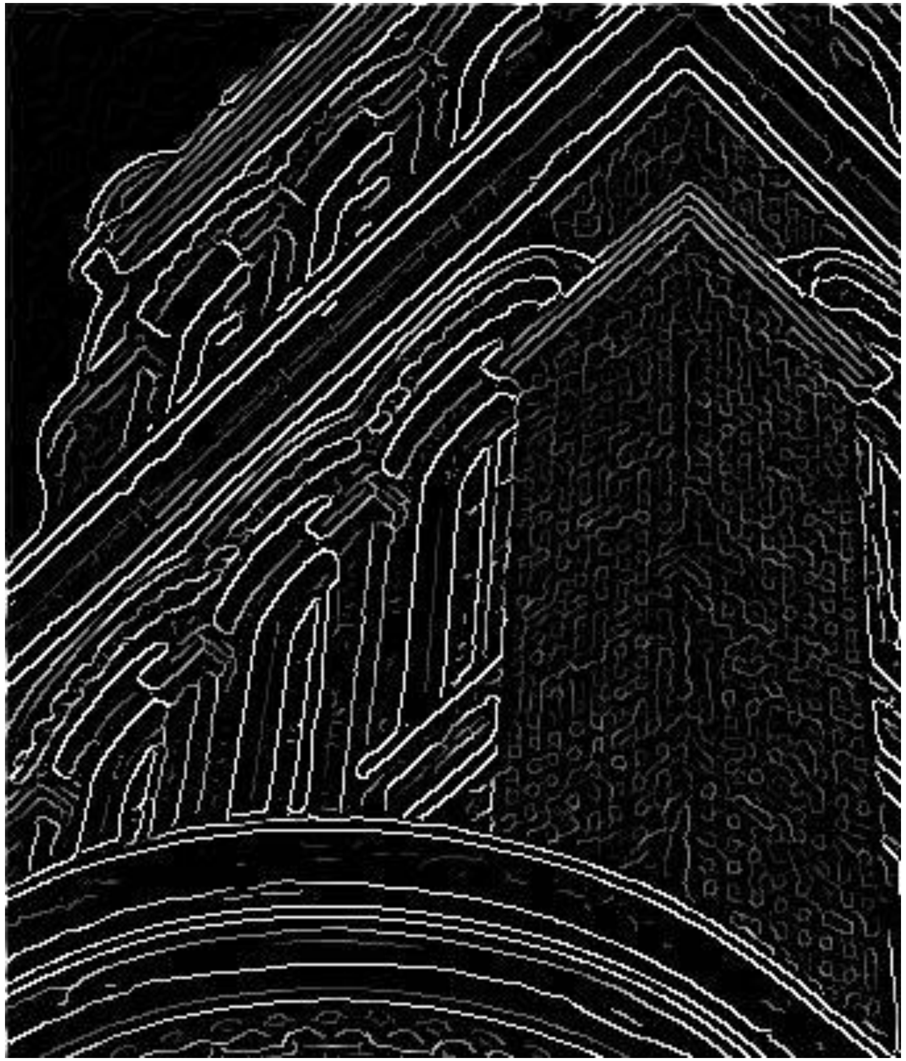
Détections de contours : Méthode de Canny

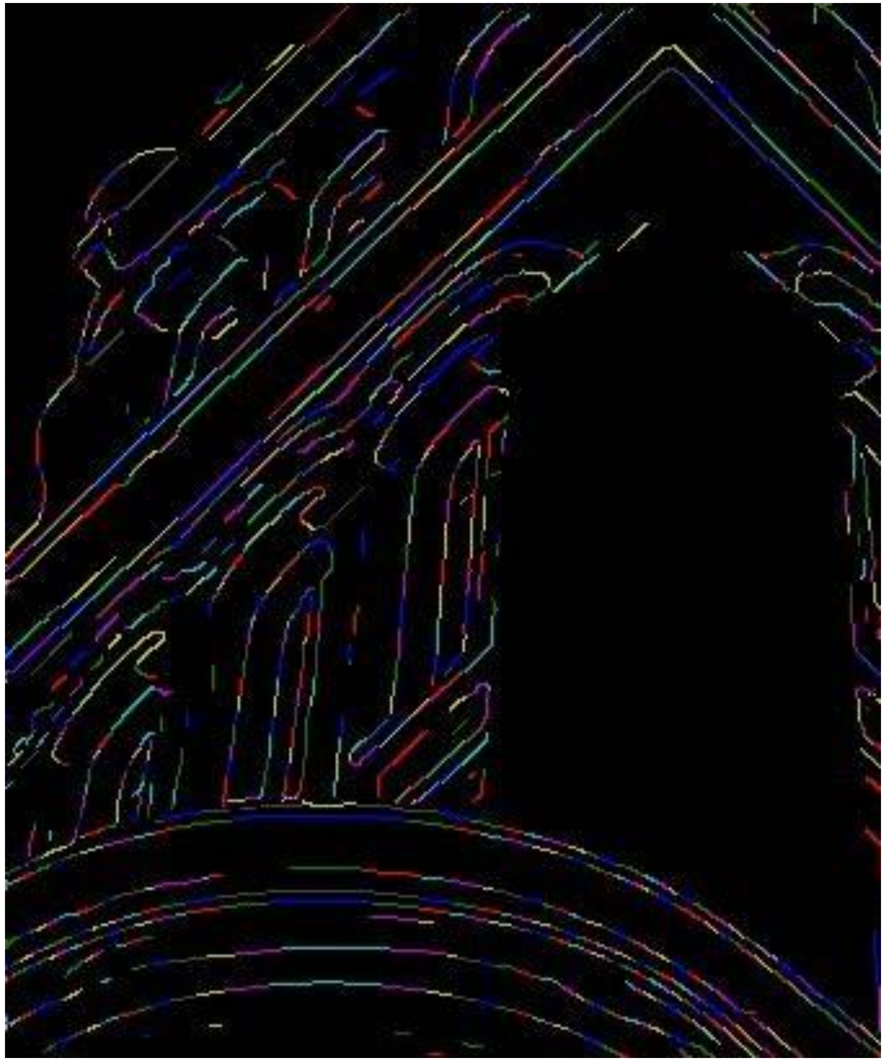
Seuillage par hystérésis

– Gradients > s_1, connectés à des gradients > s_2

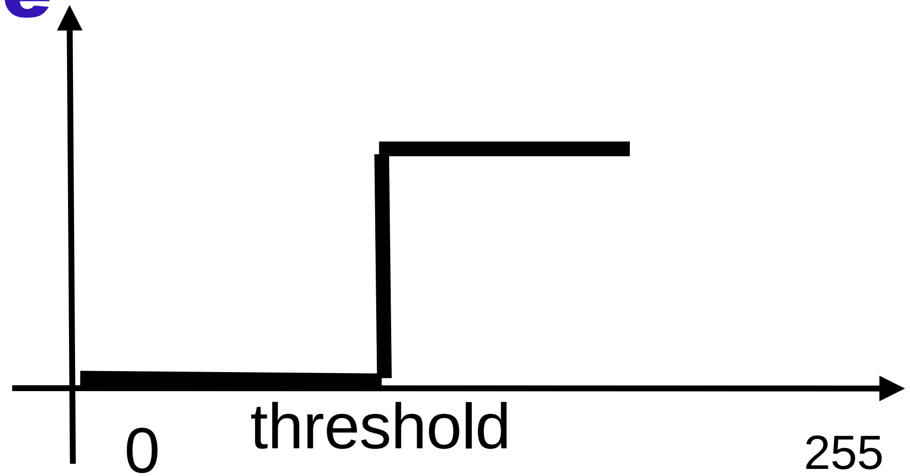


Détections de contours : Méthode de Canny



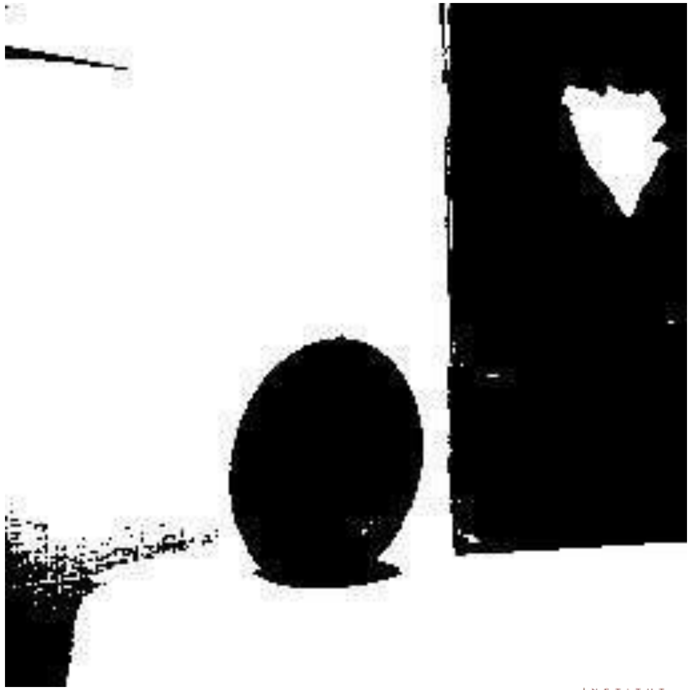


Egalisation d'histogramme



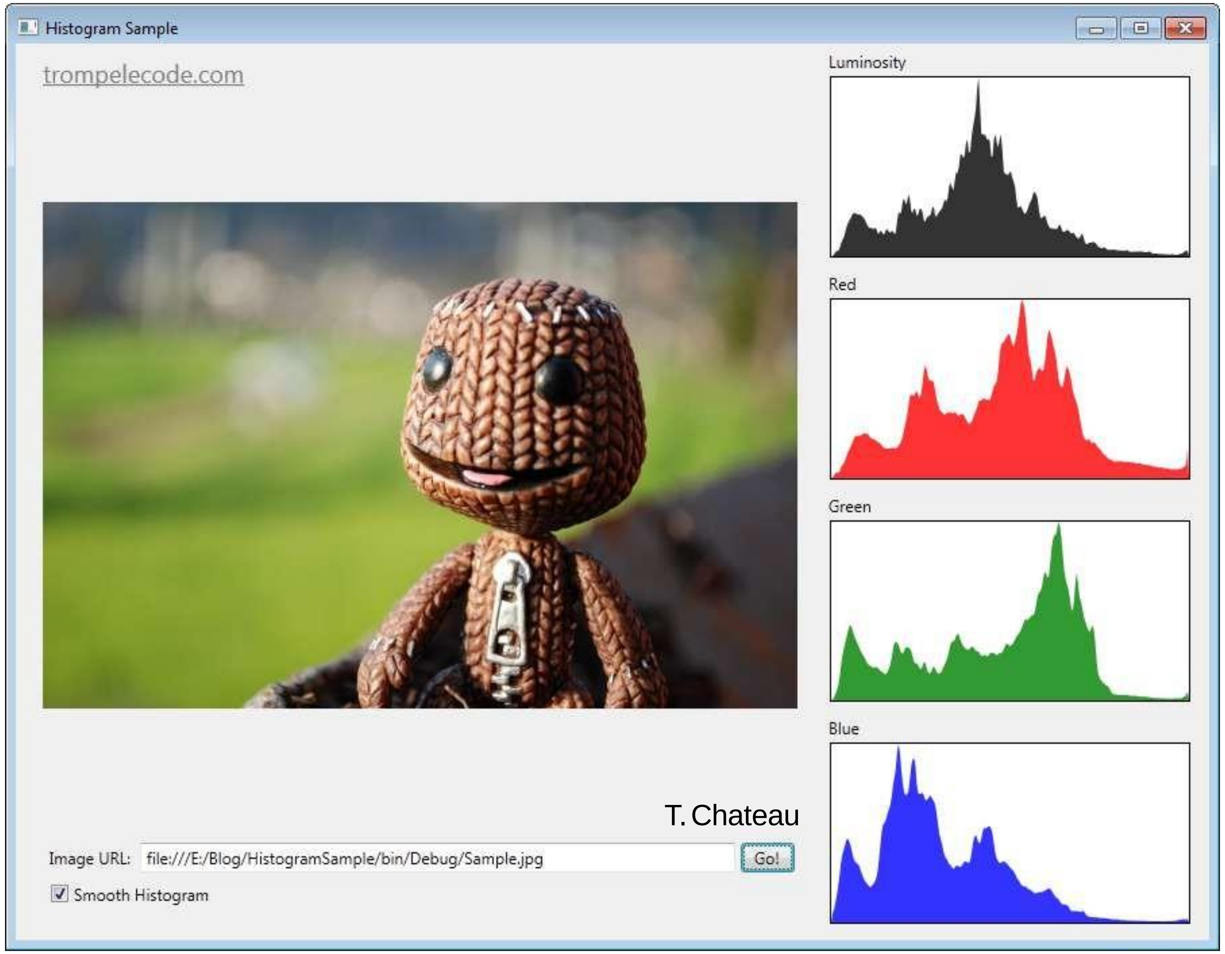
Input image

T. Chateau



Egalisation d'histogramme

$$H(x) = Card\{\mathbf{p} : I(\mathbf{p}) = x\}$$

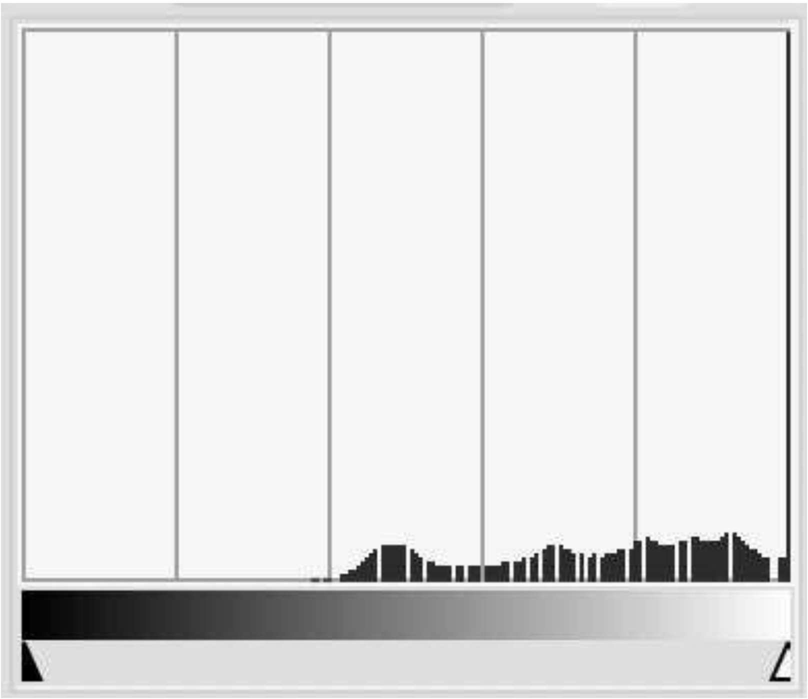


T. Chateau

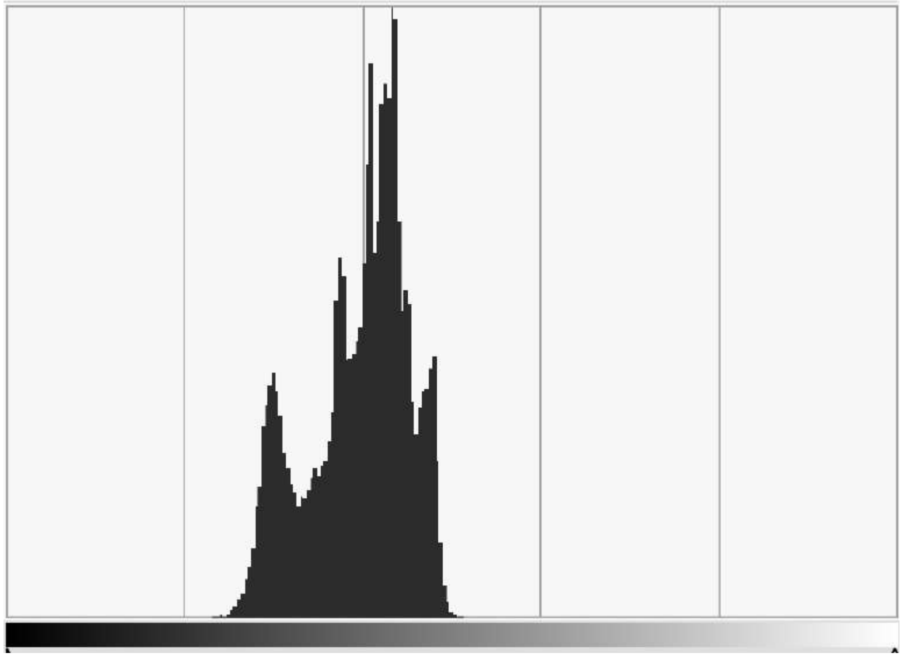
Histogramme

T. Chateau

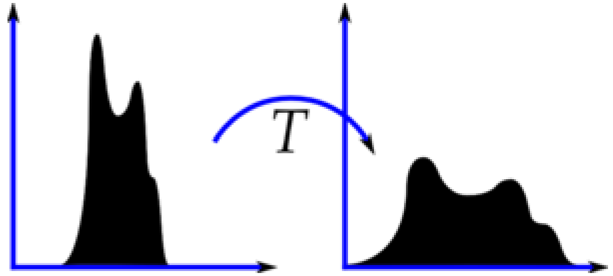
Histogramme

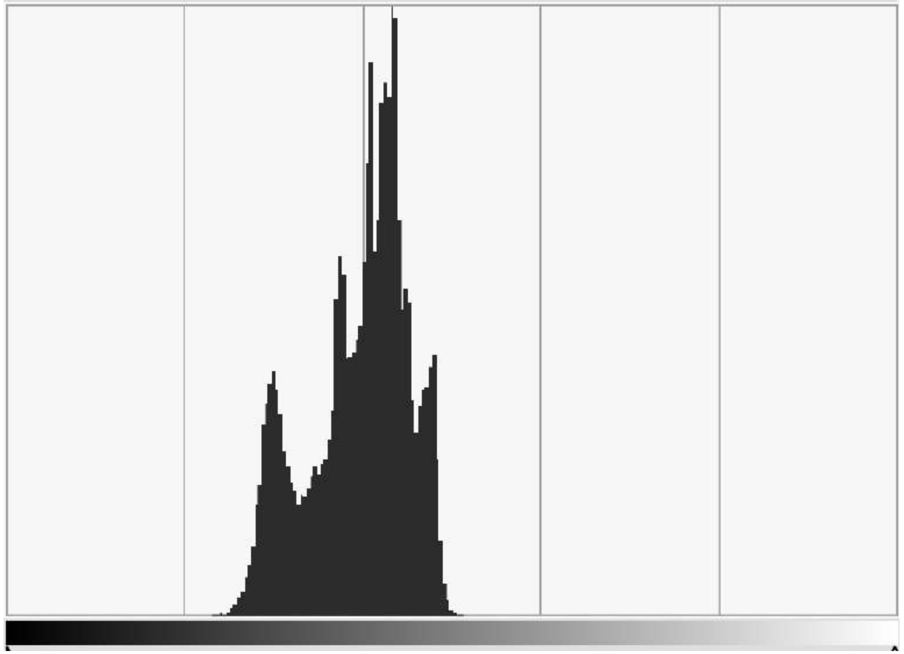


Histogramme

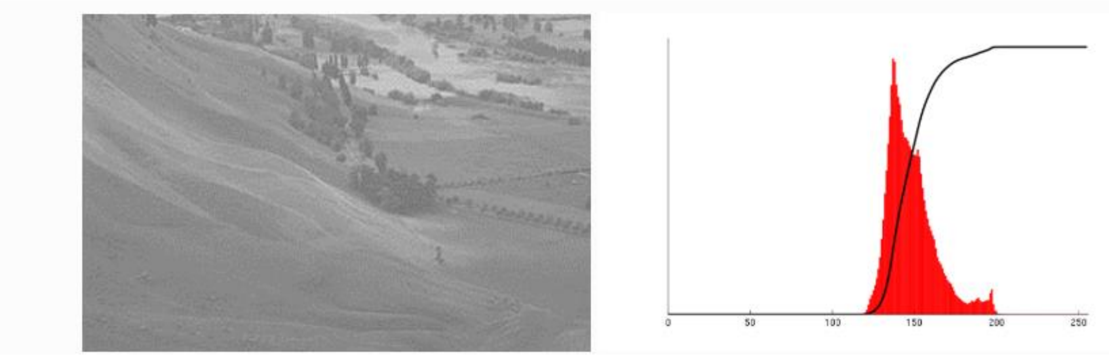


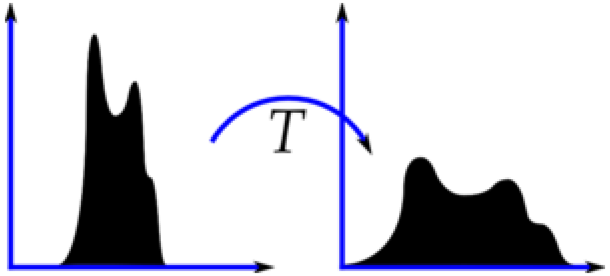
Egalisation d'histogramme



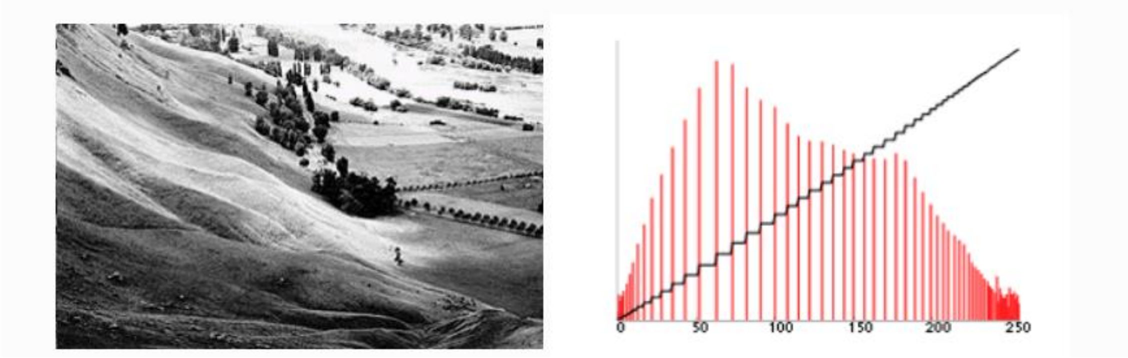


Egalisation d’histogramme

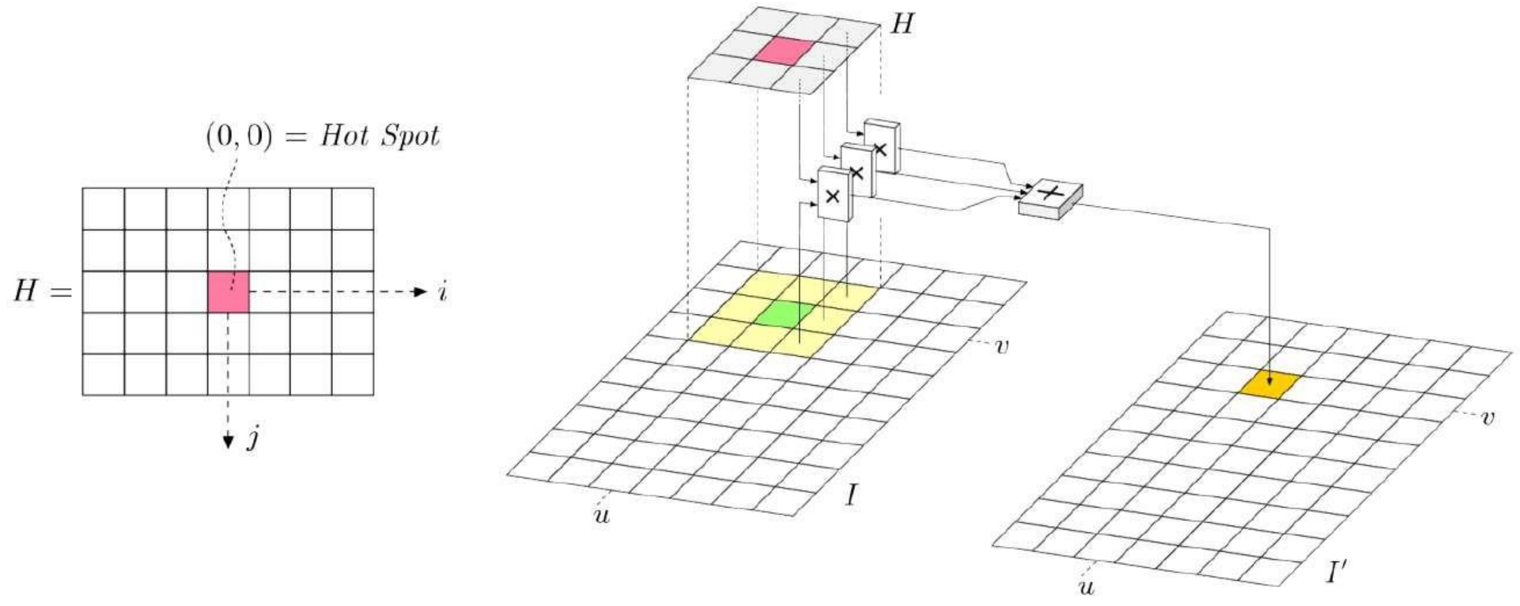




$$\forall v \in [0..n], eg(v) = \frac{V_{max} - V_{min}}{N} C_f(v) + V_{min}$$



Filtrage par convolution



10	5	3
4	5	1
1	1	7

Local image data

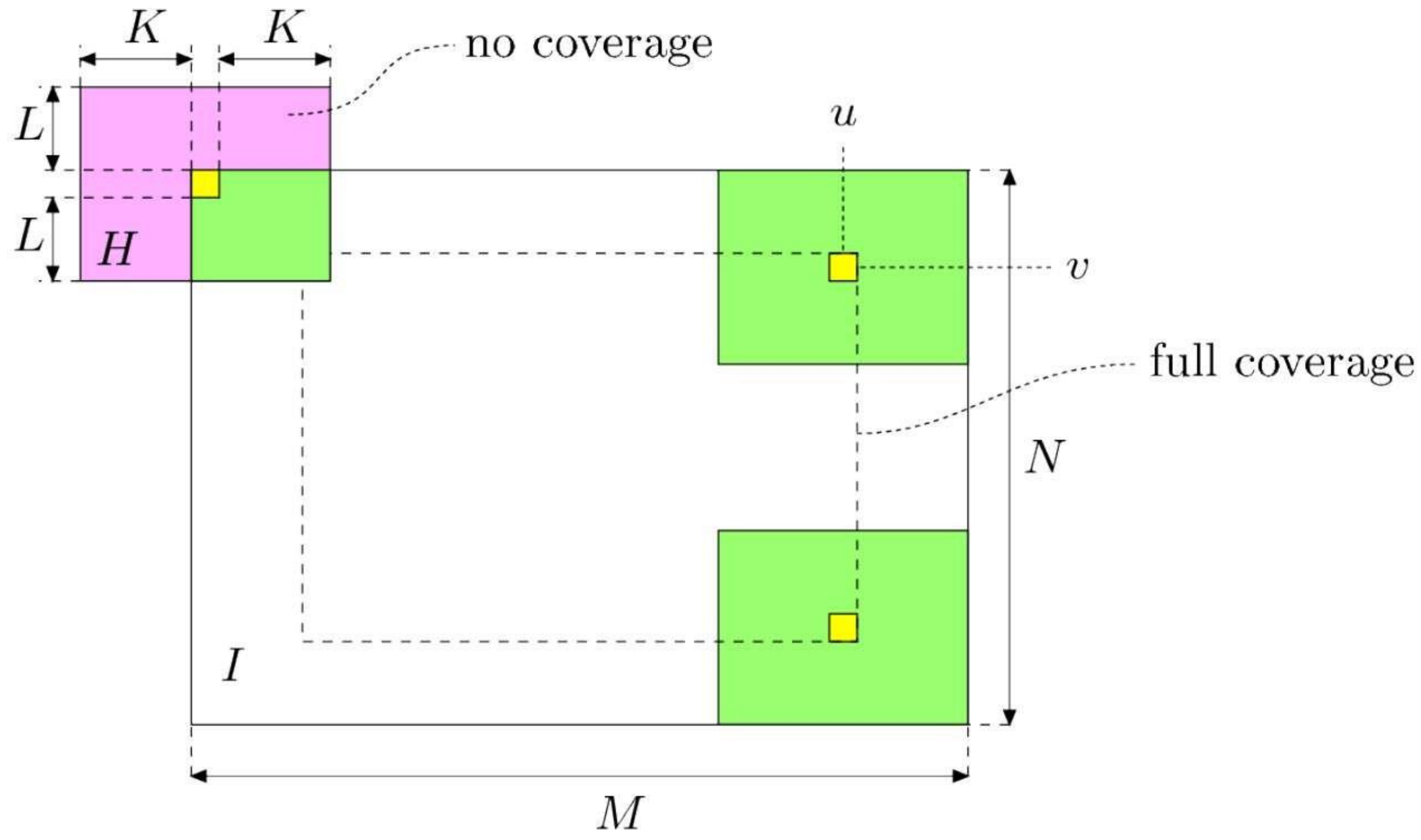
0	0	0
0	0.5	0
0	1	0.5

kernel

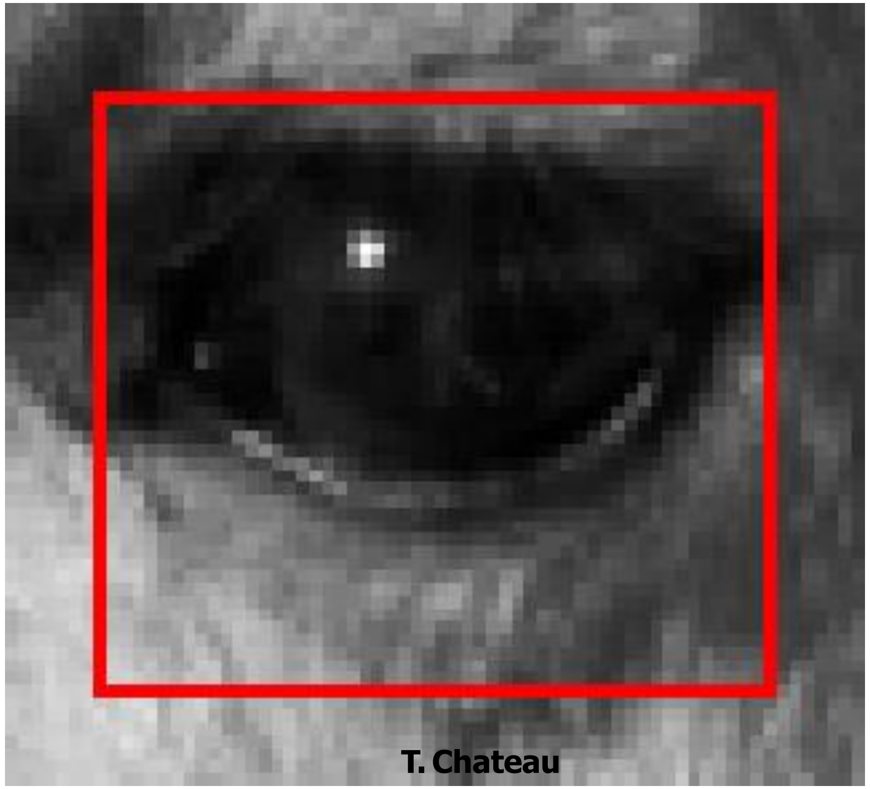
	7	

Modified image data

How to cope with image boundary?



Filtrage par convolution : Crop

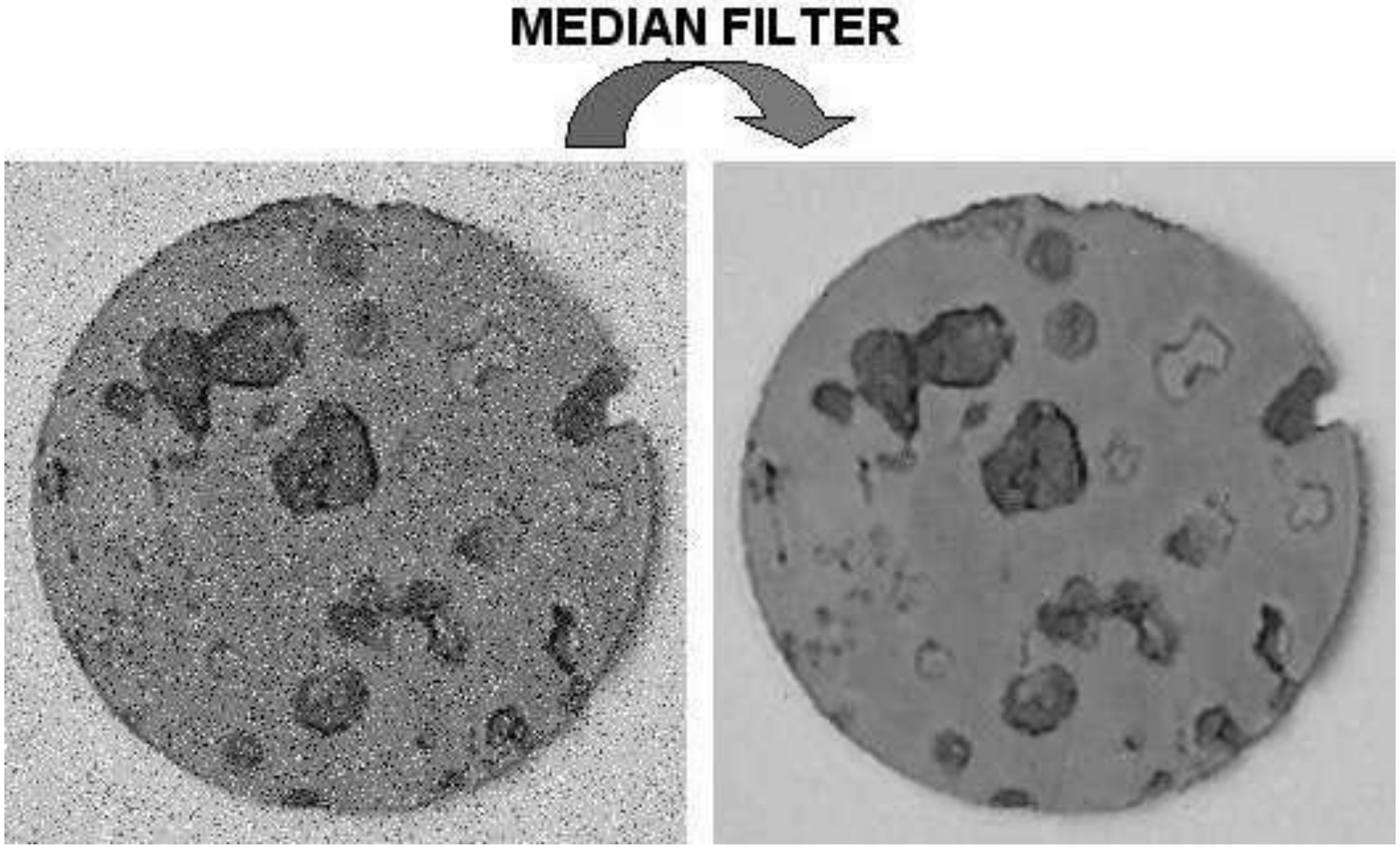


Filtrage par convolution : PAD

Filtrage médian (Bruit poivre et sel)

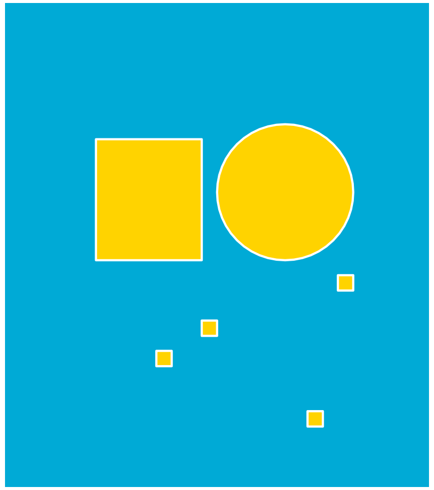
- Robuste
- Non-lineaire
- Chaque pixel est modifié selon la valeur médiane de son voisinage

Filtrage par convolution : Filtre médian

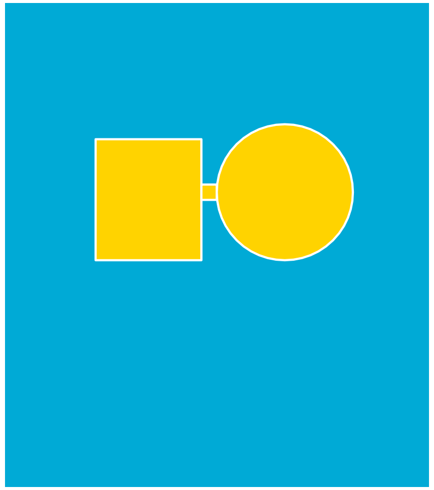


Binary image filtering: Mathematical morphology

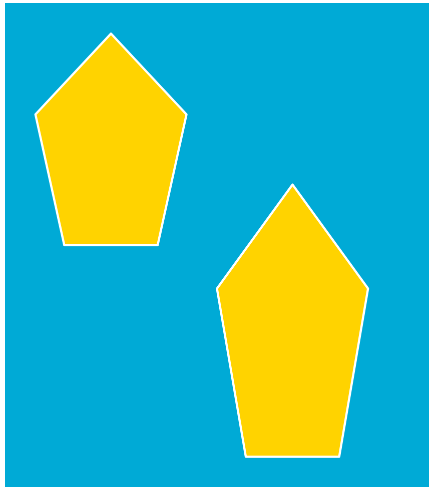
What can we do with MM ?



Remove noise



separate shapes



compare shapes

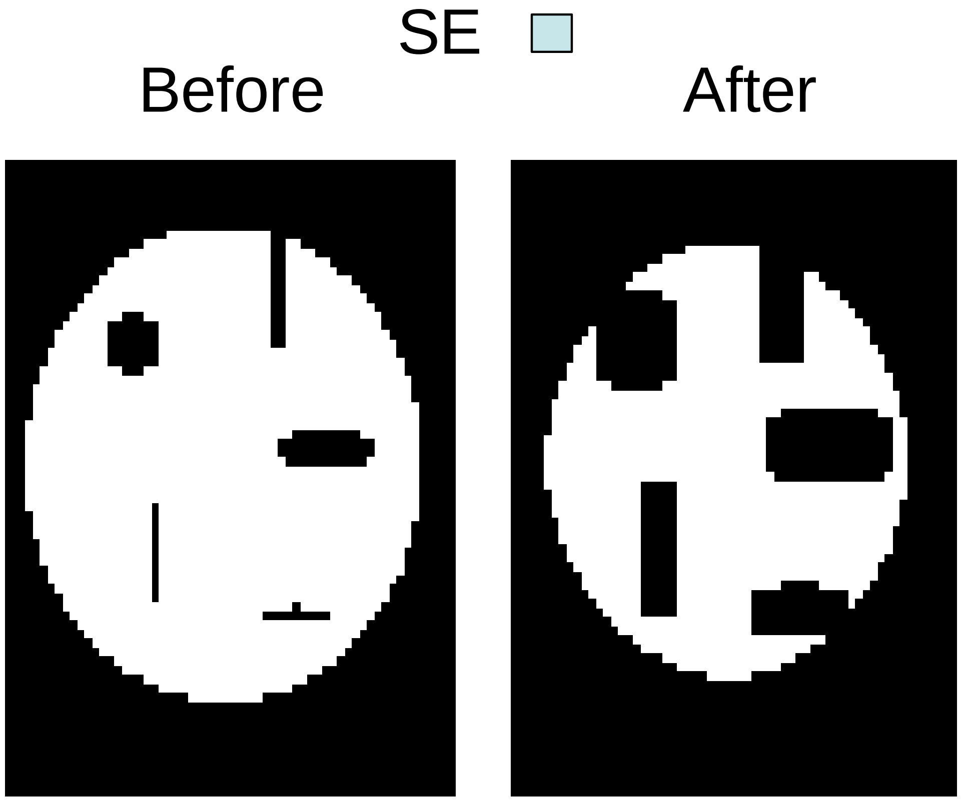
Binary image filtering: Mathematical morphology

- Main idea: probe an image with a simple, pre- defined shape, drawing conclusions on how this shape fits or misses the shapes in the image.

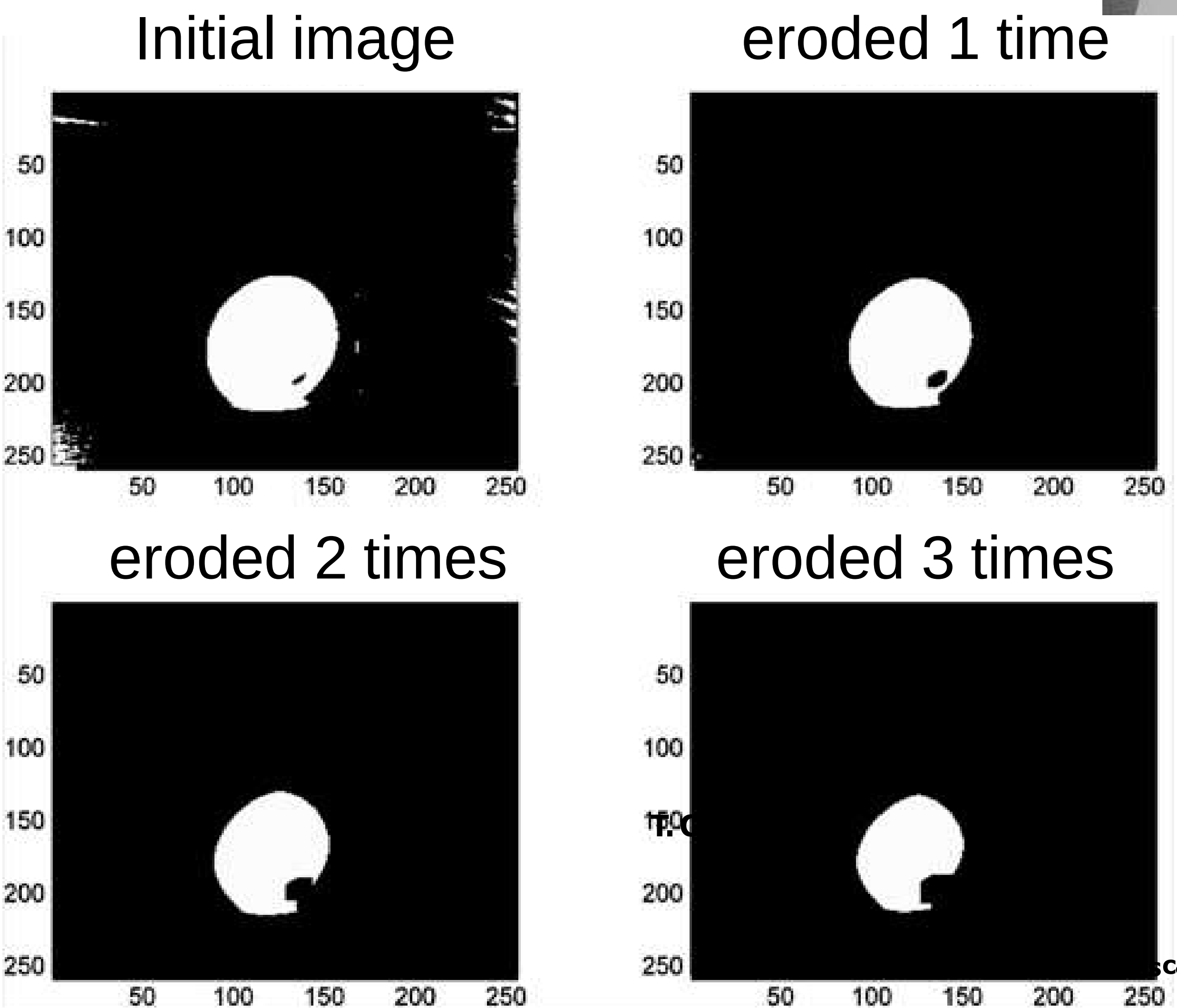
- This simple "probe" is called structuring element, and is itself a binary image (i.e., a subset of the space or grid).

Binary image filtering: Mathematical morphology

Basic operators: erosion

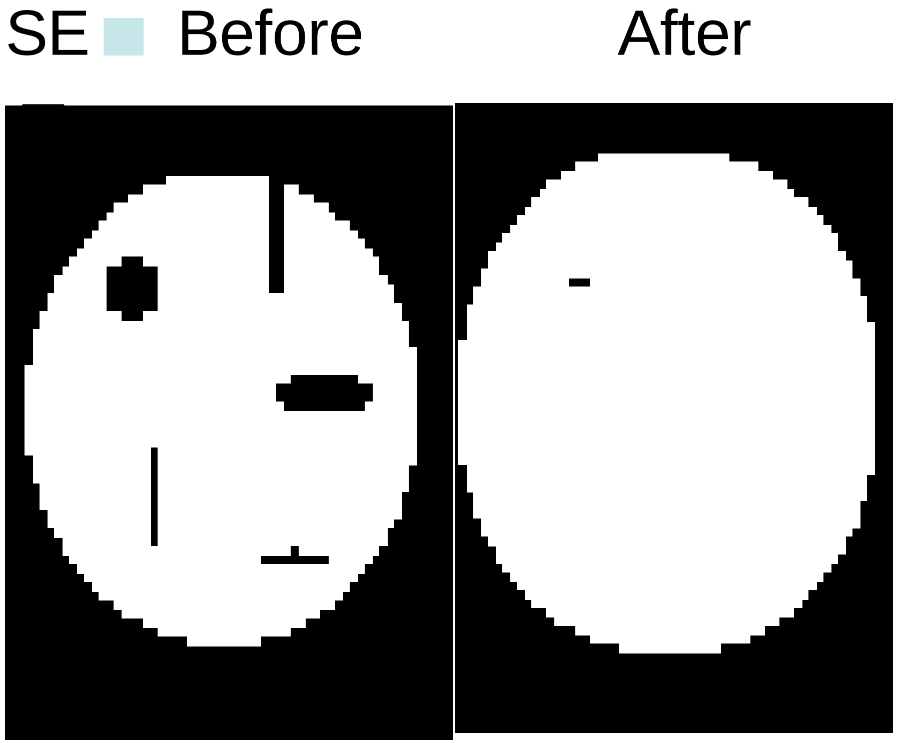


Binary image filtering: Mathematical morphology



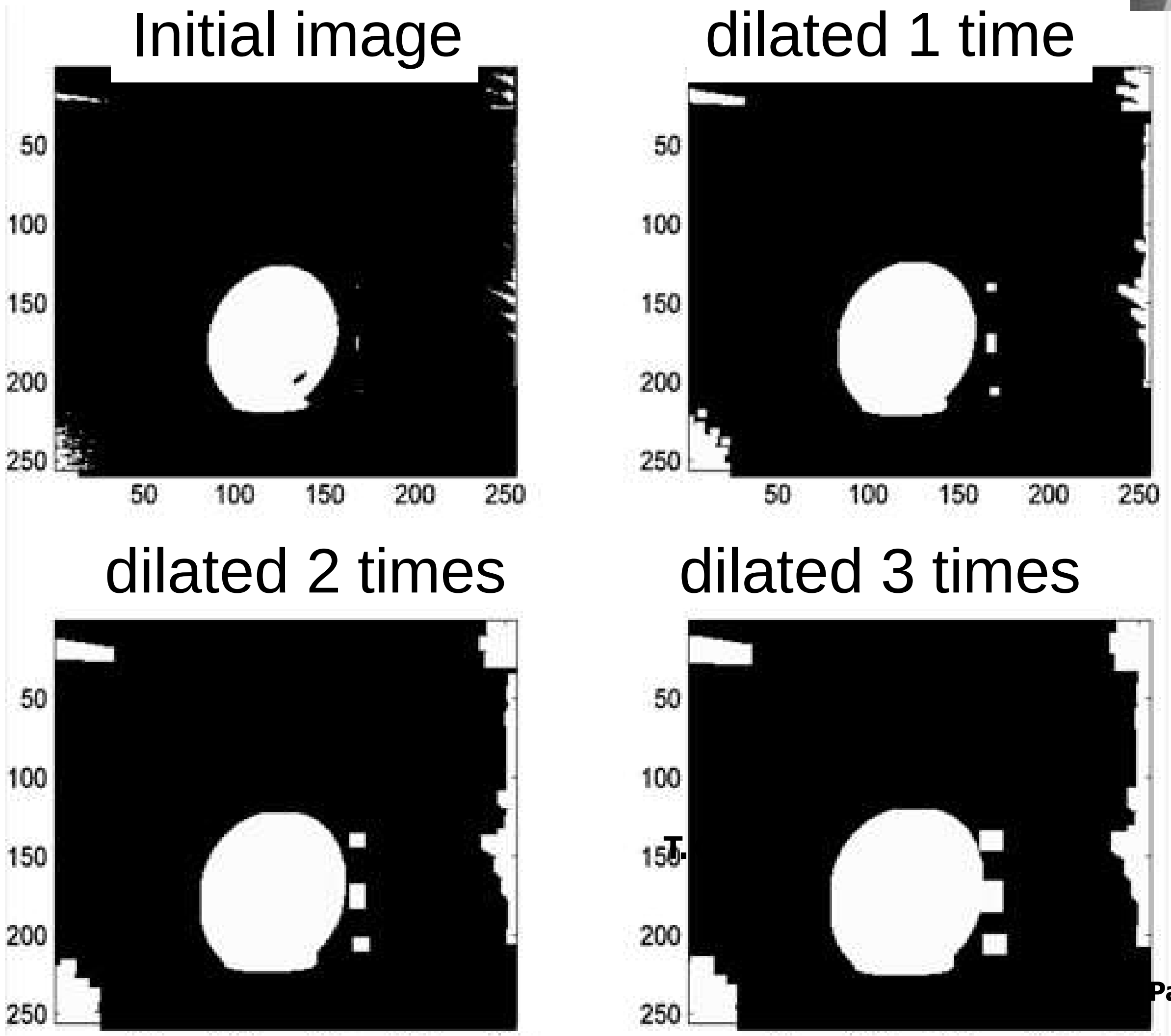
Binary image filtering: Mathematical morphology

Basic operators: dilation



Binary image filtering: Mathematical morphology

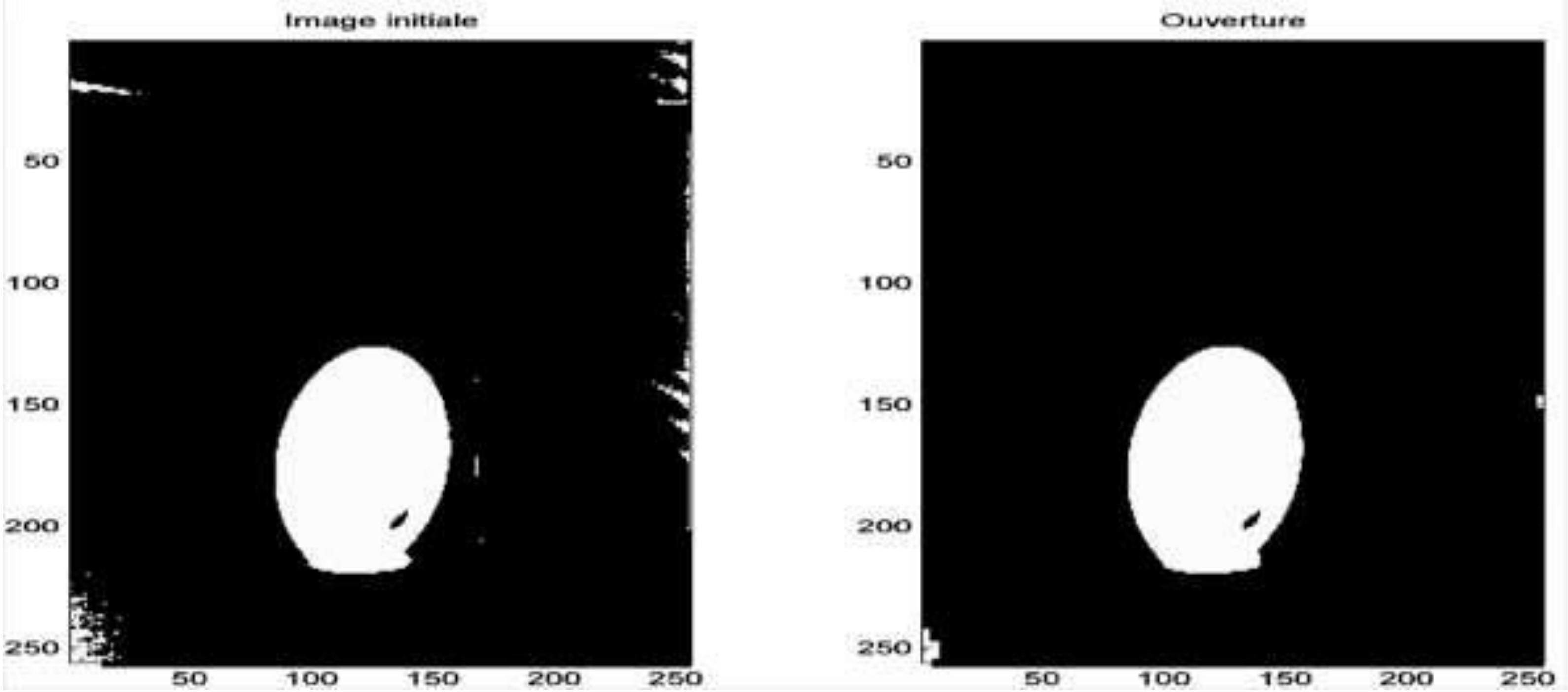
Example



Binary image filtering: Mathematical morphology

Basic operators:

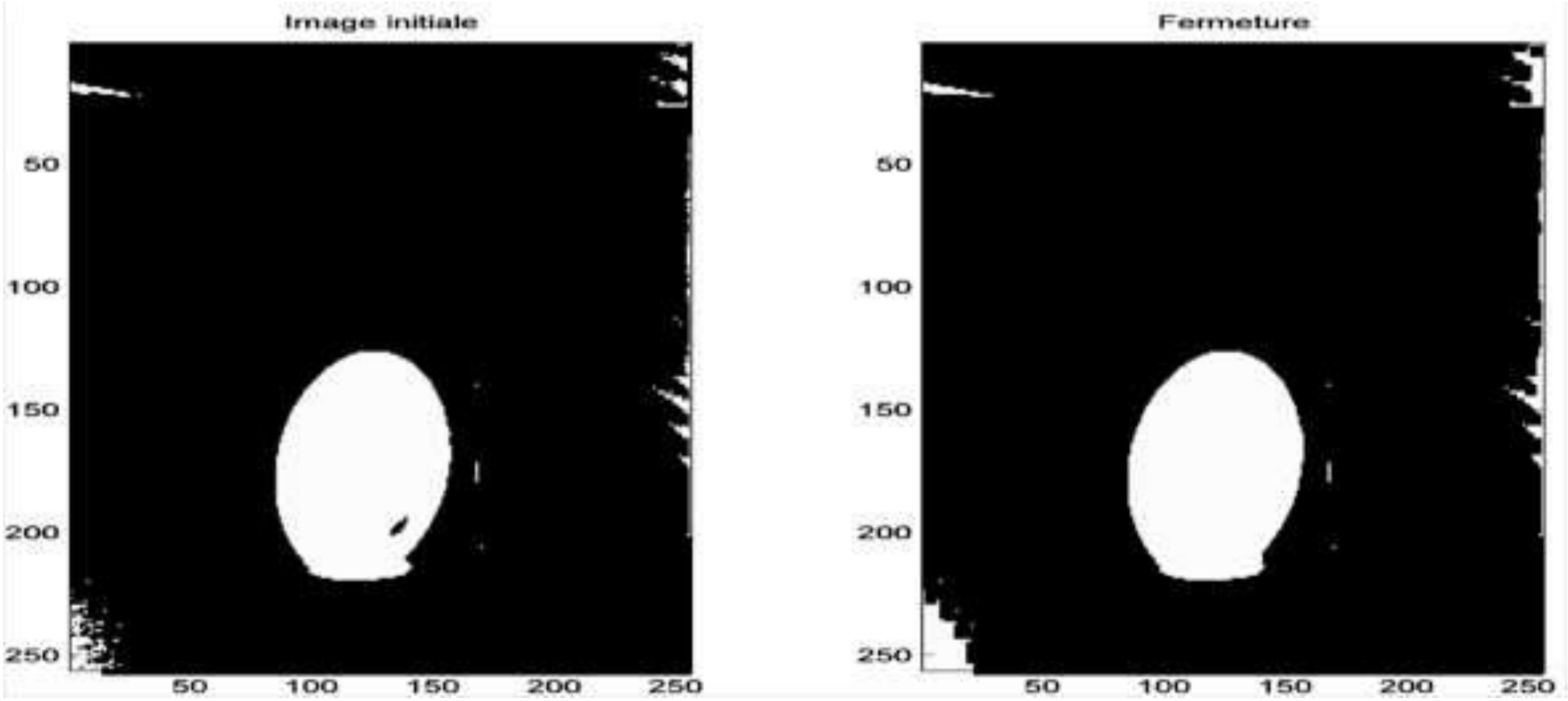
ouverture



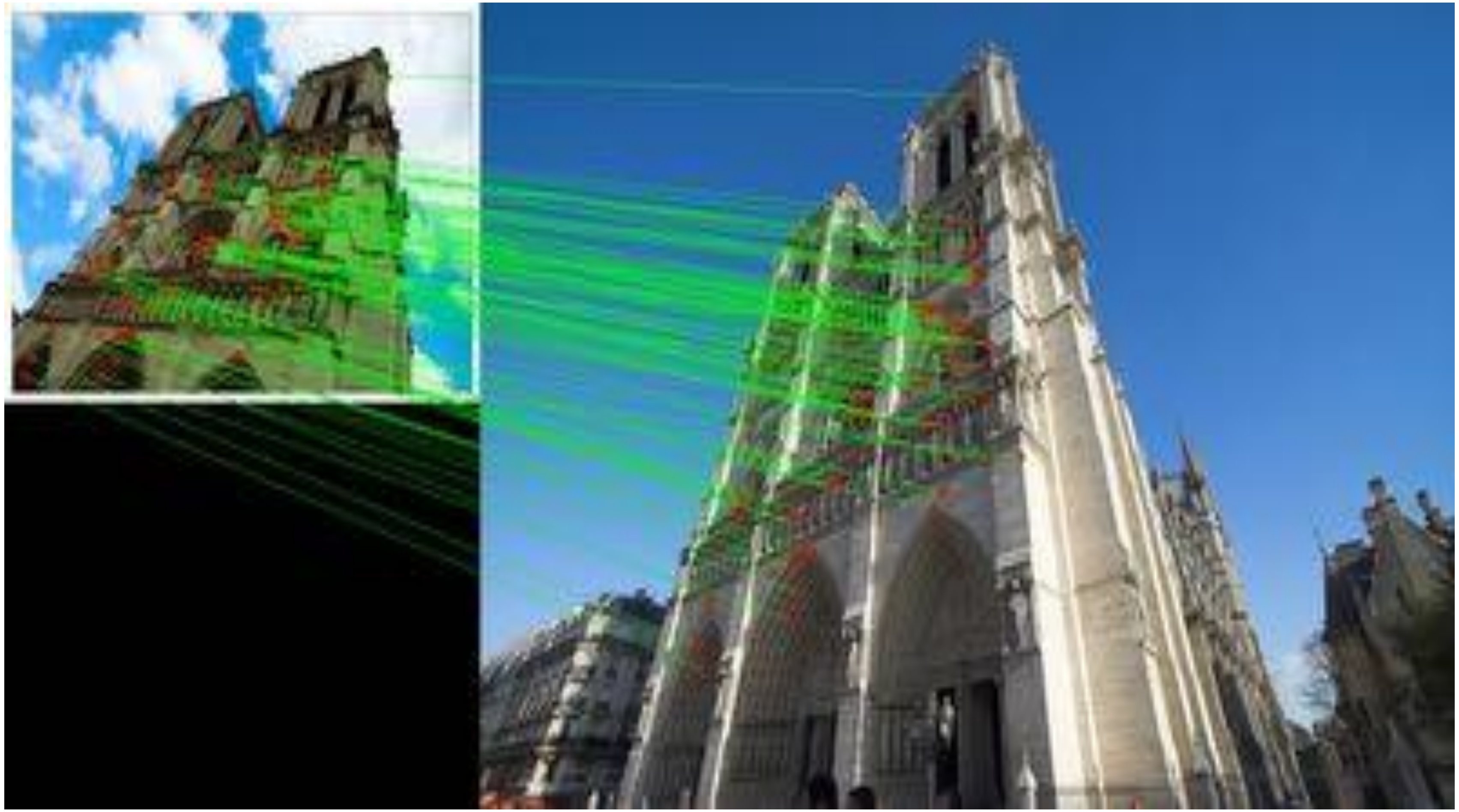
Binary image filtering: Mathematical morphology

Basic operators:

fermeture



Un concept important : La représentation



- On veut raisonner sur une image
- Il nous faut trouver des descripteurs
- Pour avoir une représentation
  - Identifiables dans plusieurs images
  - Reconnaissables / mouvement caméra
  - Robustes aux changements de d’éclairage
  - Robustes aux déformations liées au mouvement

Comparaison de points

Trouver le point le plus similaire

– Hypothèse de décalage en translation

Comment comparer $I_1(x_1,y_1)$ et $I_2(x_2,y_2)$?

Robustesse changement luminosité / contraste ?

Comparaison de points

Sum of Squared Differences

$$SSD(I_1, x_1, y_1, I_2, x_2, y_2) = \sum_{i=-n}^{n} \sum_{j=-p}^{p} (I_1(x_1+i, y_1+j) - I_2(x_2+i, y_2+j))^2$$

Cross corrélation

- Invariance / luminosité et contraste

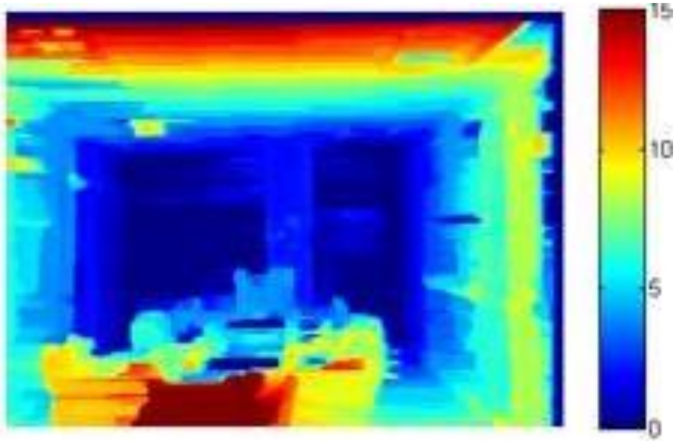
$$NCC(I_1, x_1, y_1, I_2, x_2, y_2) = \frac{\sum_{i,j}(I_1(x_1+i, y_1+j) - \overline{I_1(x_1, y_1)})(I_2(x_2+i, y_2+j) - \overline{I_2(x_2, y_2)})}{\sqrt{\sum_{i,j}(I_1(x_1+i, y_1+j) - \overline{I_1(x_1, y_1)})^2 \sum_{i,j}(I_2(x_2+i, y_2+j) - \overline{I_2(x_2, y_2)})^2}}$$

Application : stéréo-vision

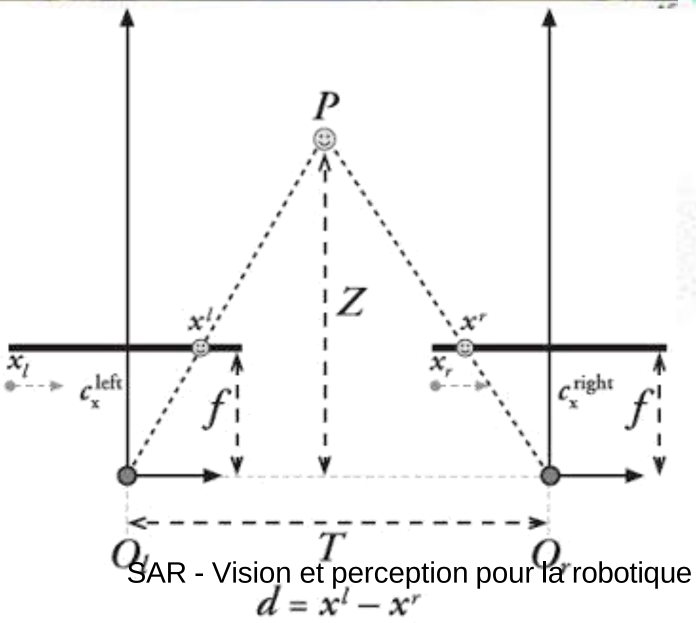
Gauche

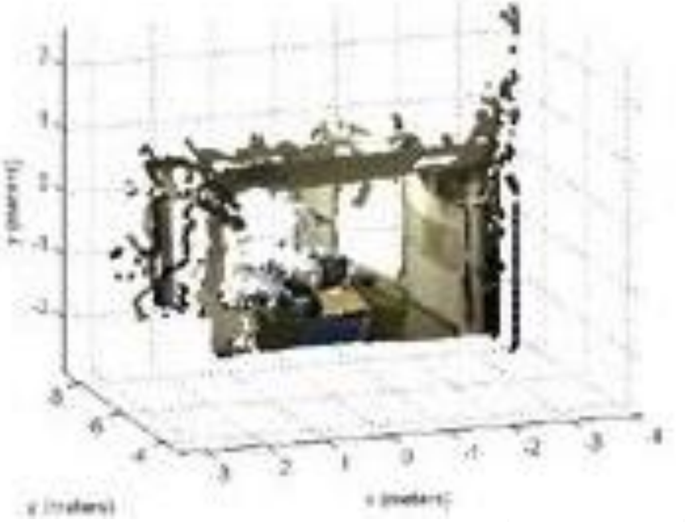
Droite

Disparité



Validité ?





Comparaison de points

Trouver le point le plus similaire

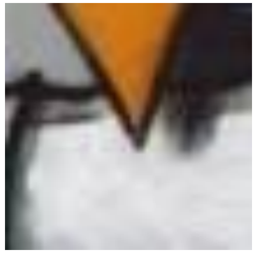
- Translation -> SSD

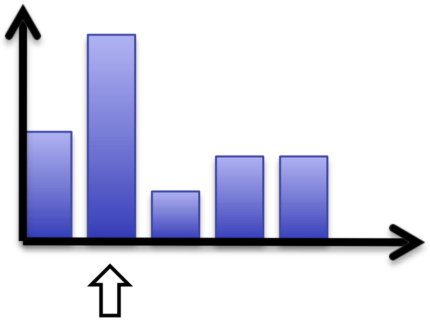
Comment reconnaître un point après rotation ?

Descripteurs SIFT [Lowe99]

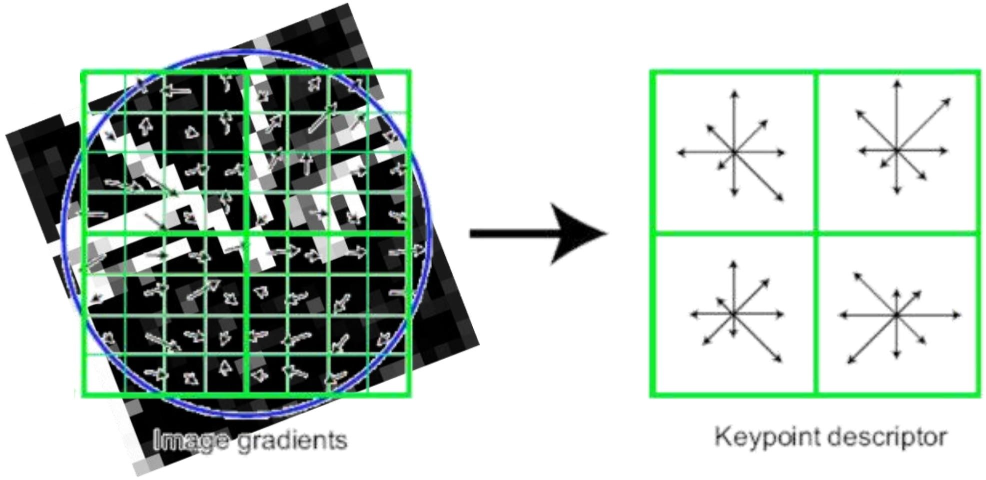
Histogramme d'orientation du gradient

– Orientation de référence





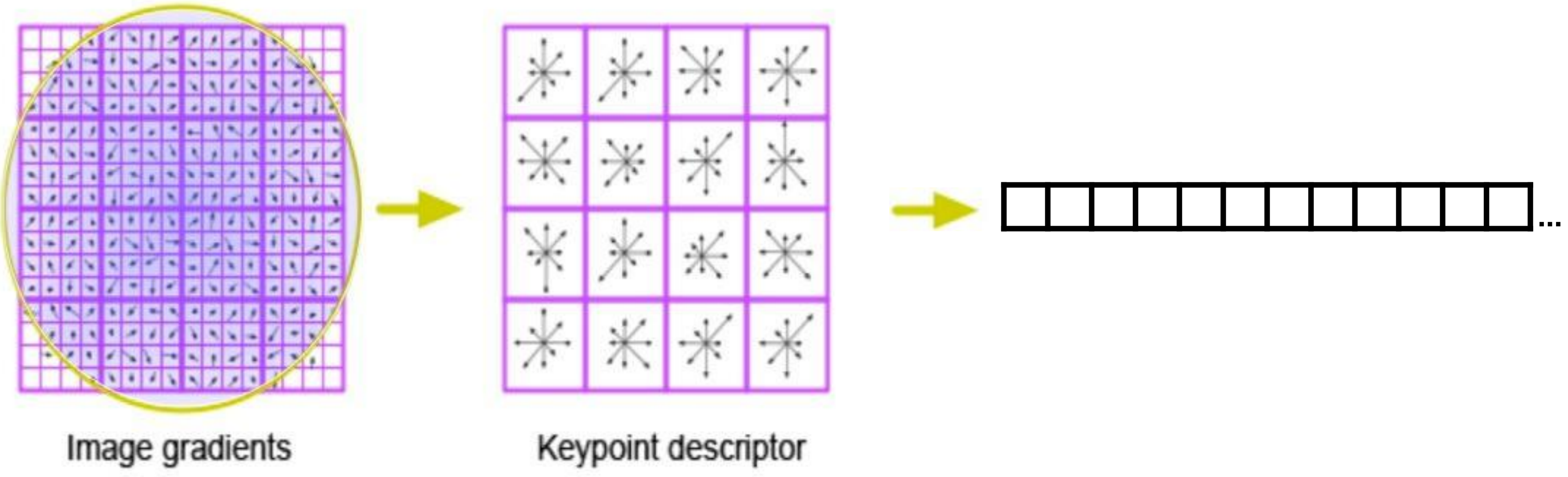
– Histogramme des orientations



Descripteurs SIFT [Lowe99]

Histogramme d’orientation du gradient

- 4x4 fenêtres
- Histogrammes sur 8 directions
- Pondération gaussienne autour du centre
- Dimension 128



Invariance au changement d'échelle

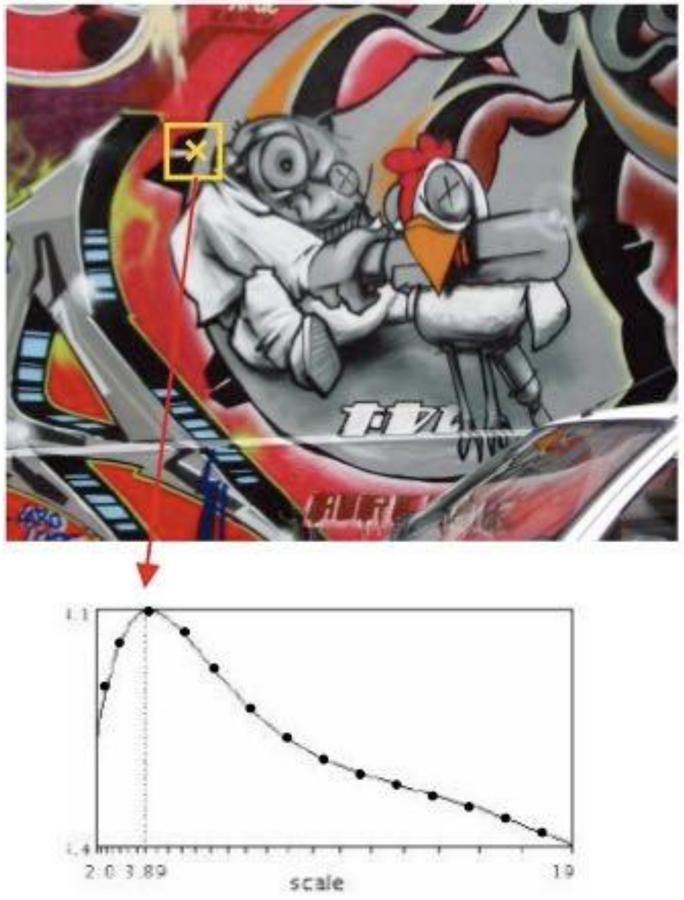
Trouver des point similaires quelque soit l'échelle

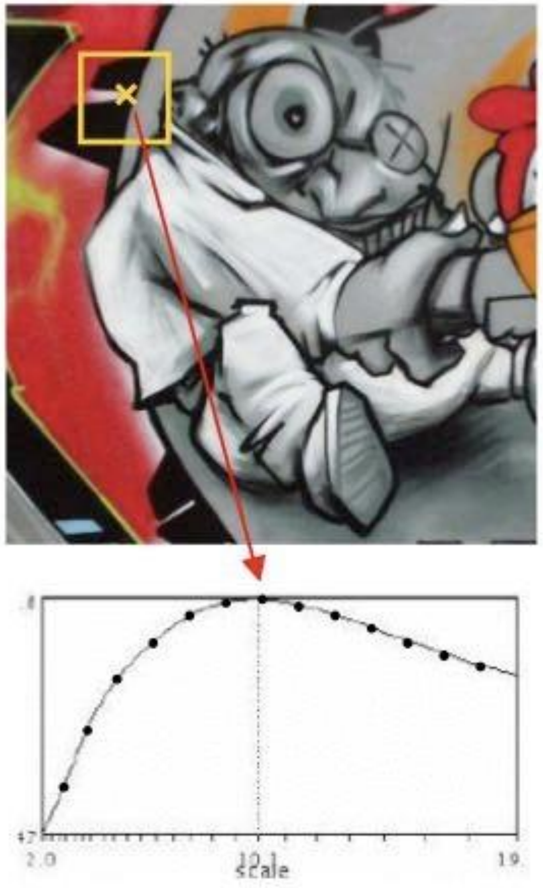
- Translation -> SSD
- Rotation -> orientation de référence

Comment comparer des points à des échelles différentes ?

Détection d’échelle de référence

Analyse par fonction de signature

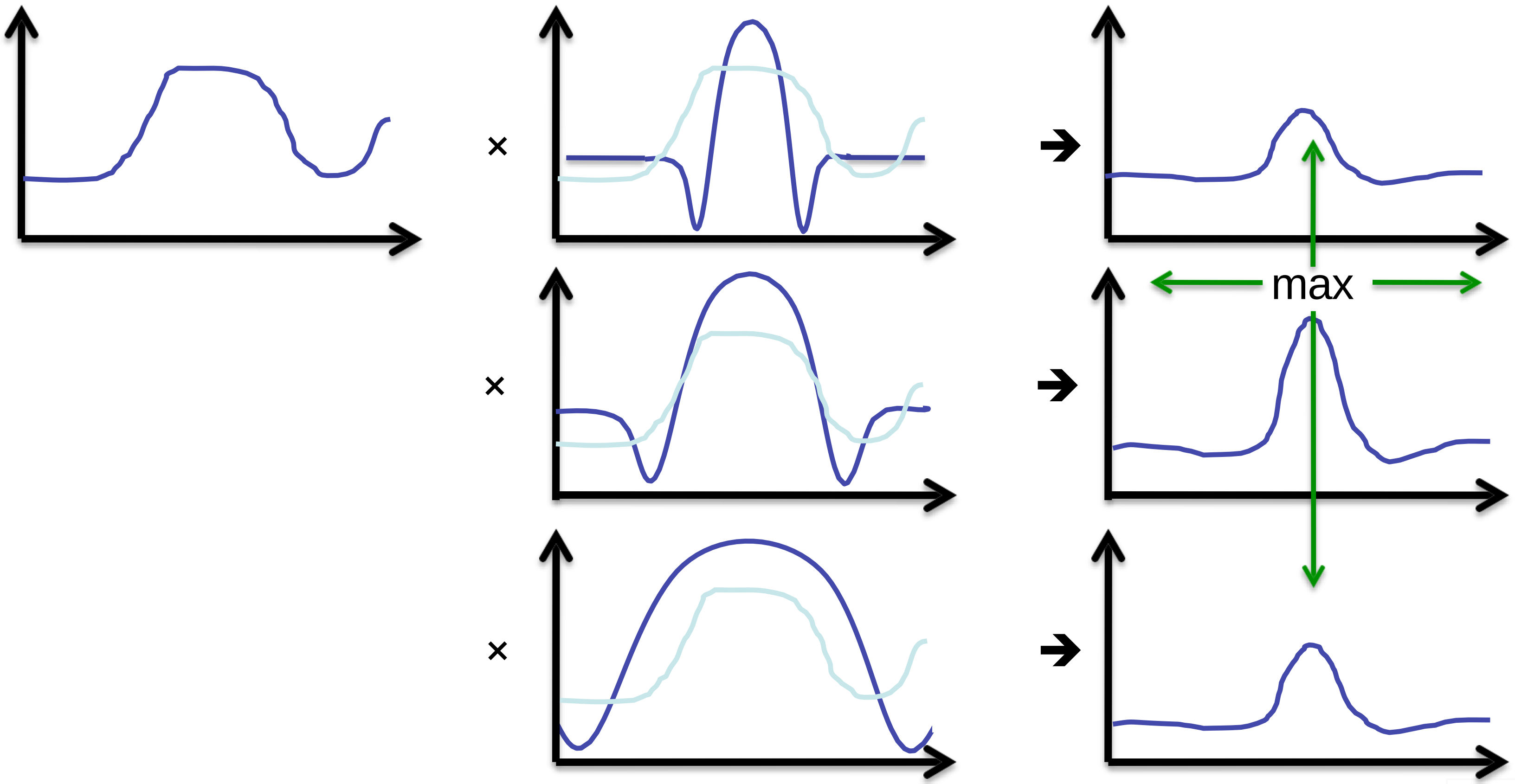




Détection de « blobs »

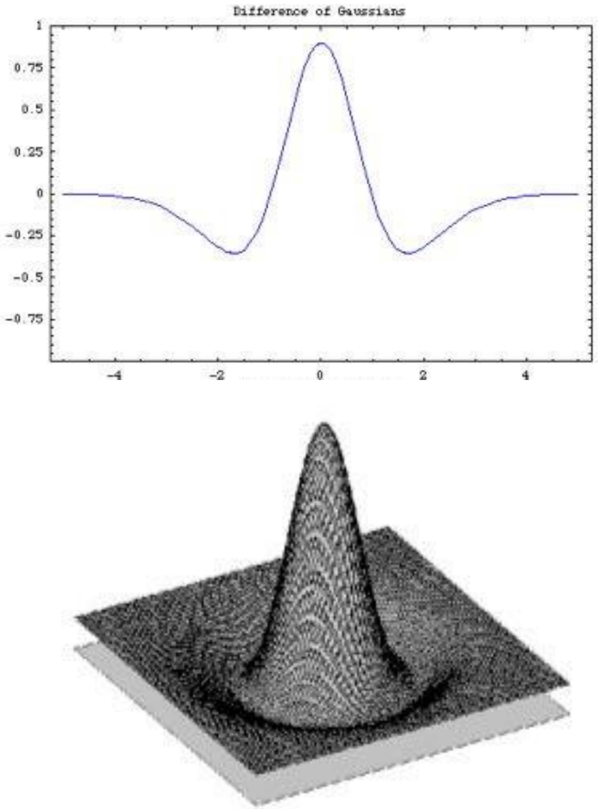
Détection d'échelle avec fonction en « cloche »

– Recherche de points au centre de « blobs »

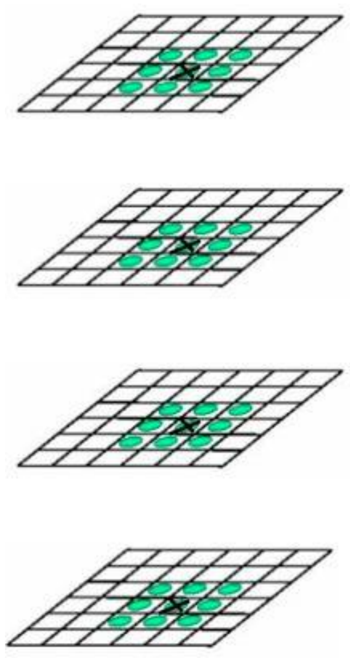


Détecteur SIFT

Détection par différence de gaussiennes



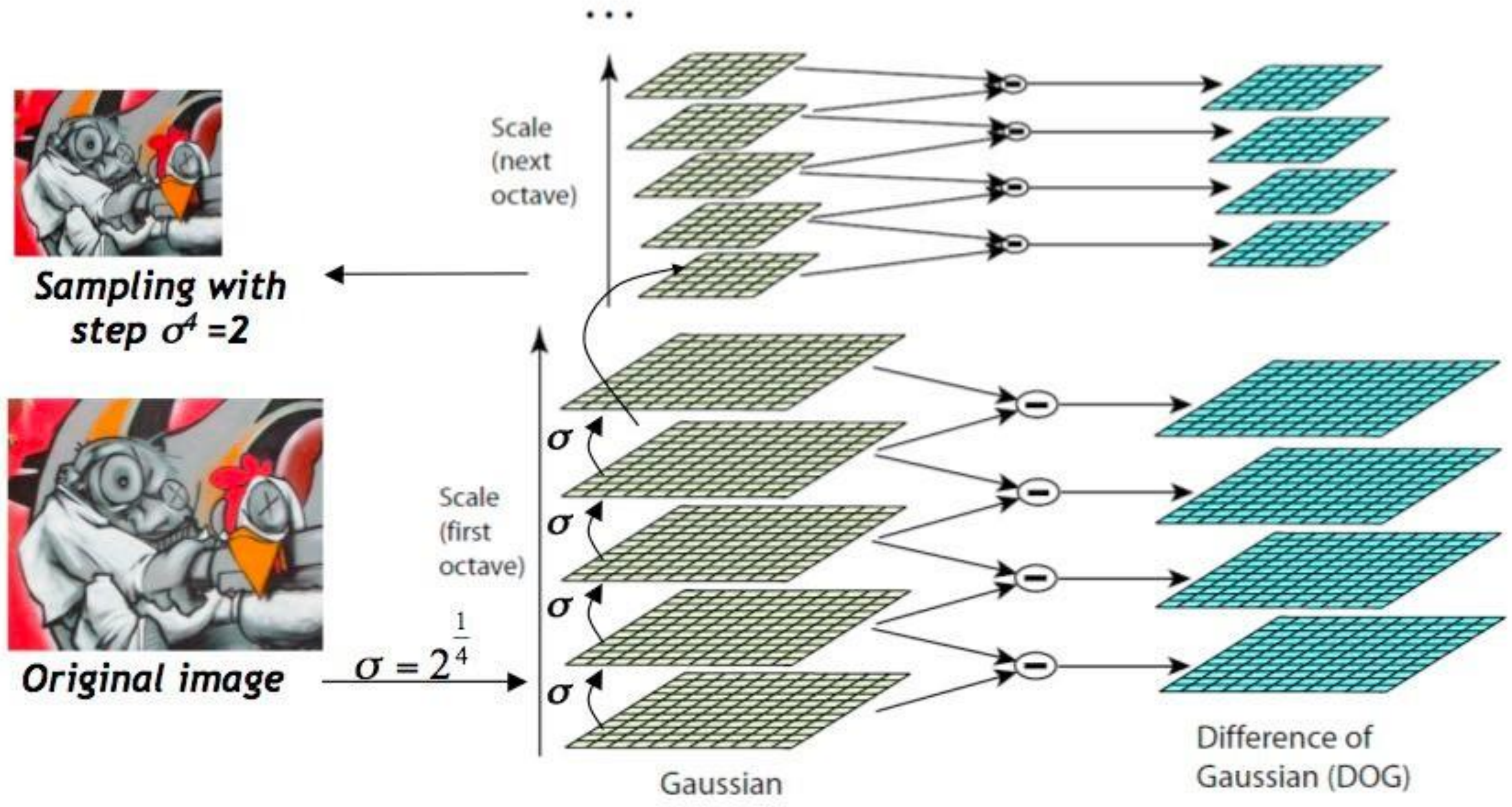
Convolution



Max échelle/espace

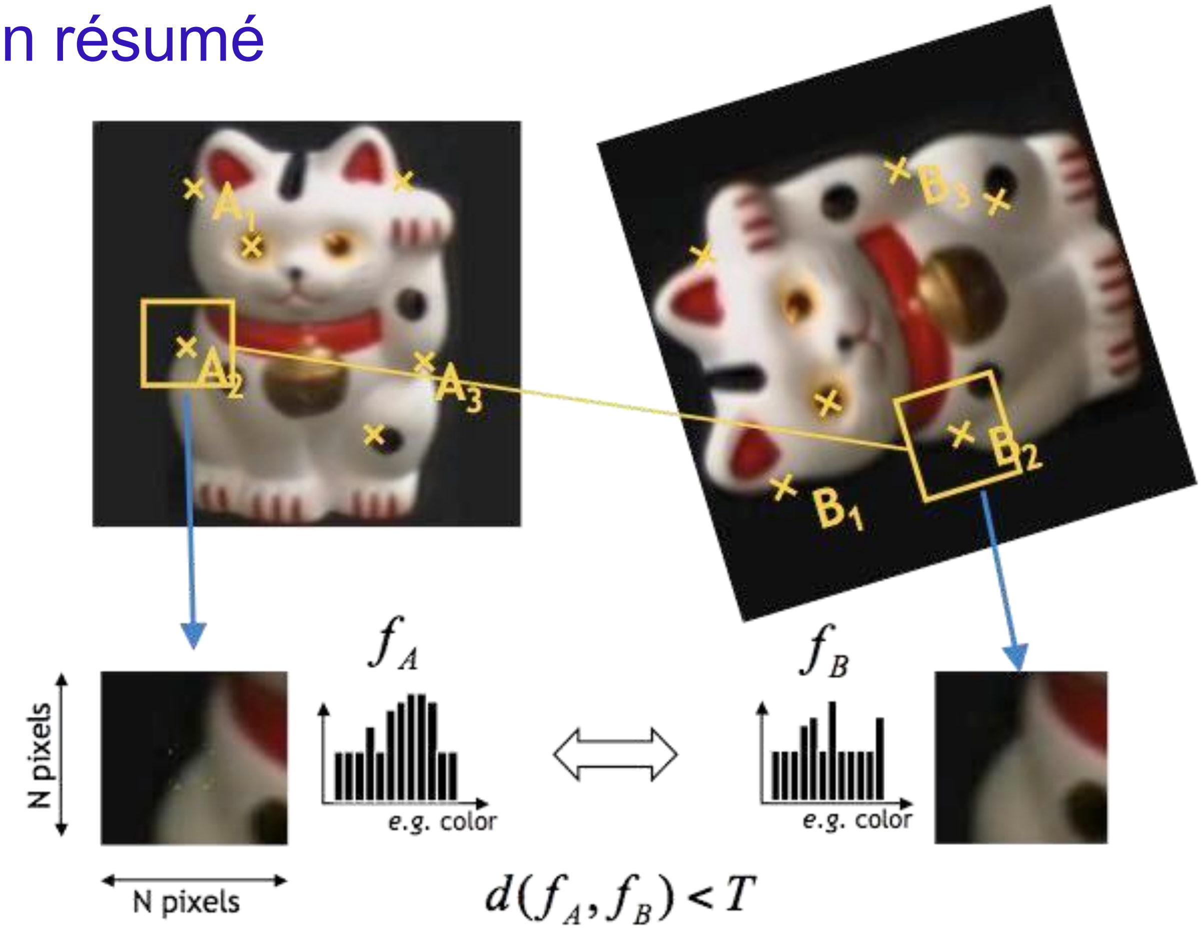
Détecteur SIFT

Implémentation optimisée



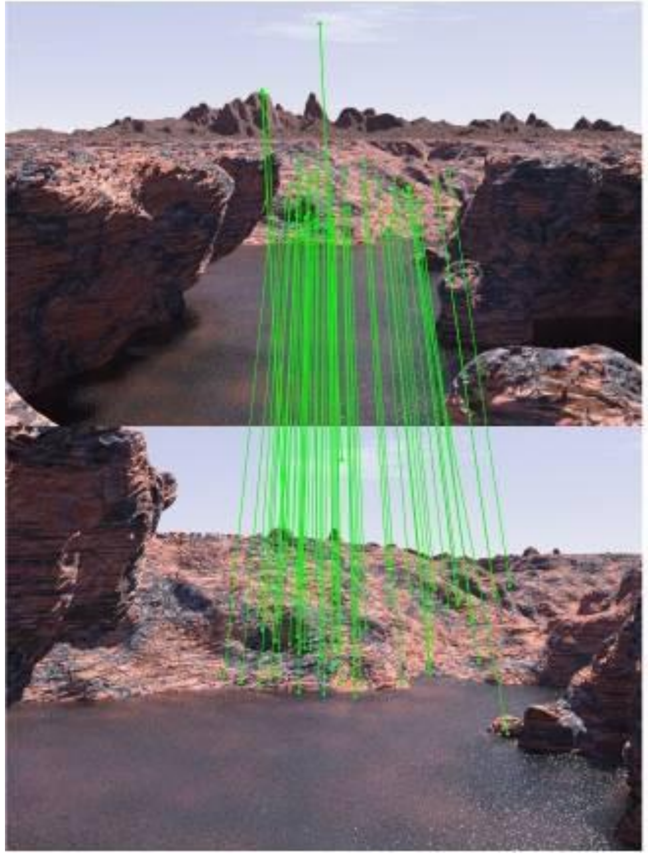
Détecteur SIFT

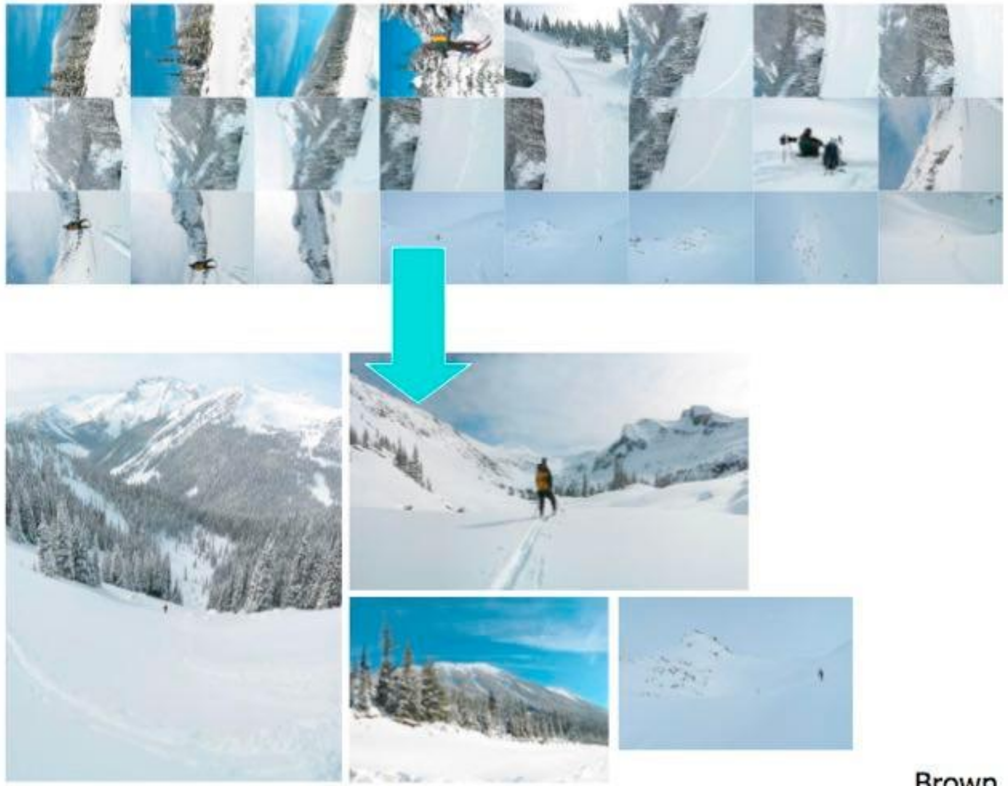
En résumé



Détecteur SIFT

Exemples de correspondances

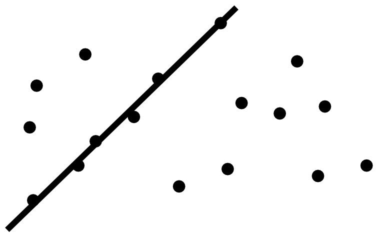




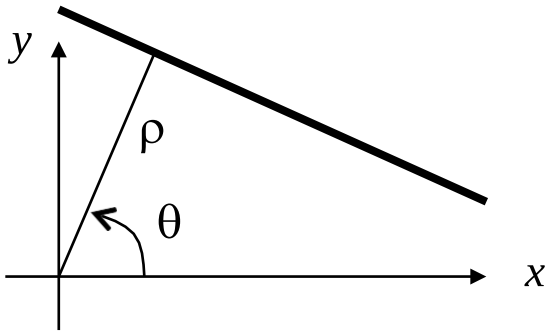
Brown, ICCV 2003

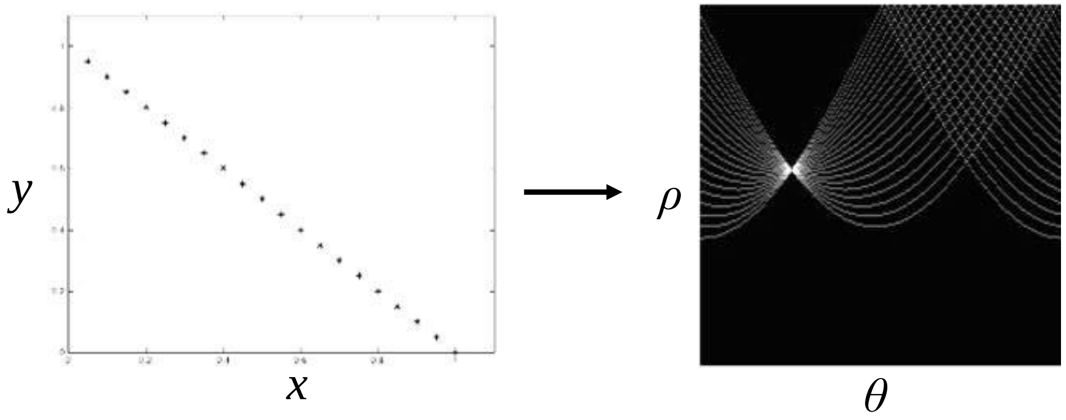
Hough Transform

- Origin: Detection of straight lines in clutter
  - Basic idea: each candidate point votes for all lines that it is consistent with.
  - Votes are accumulated in quantized array
  - Local maxima correspond to candidate lines

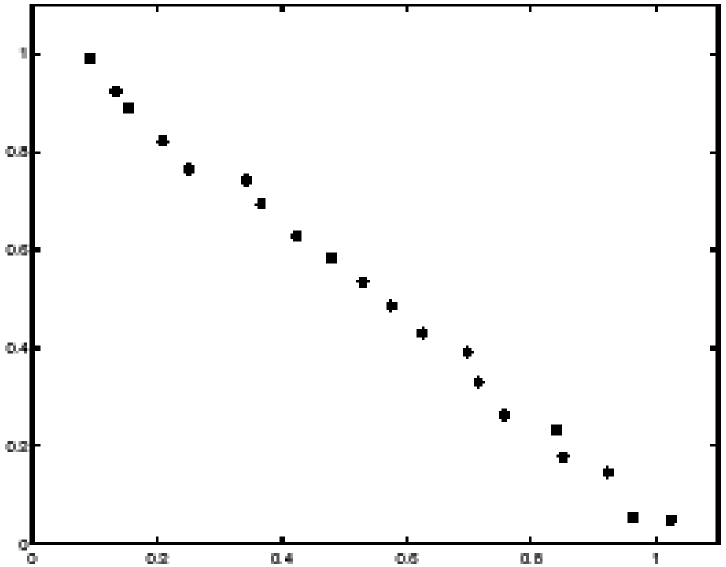


- Representation of a line
  - Usual form $y = a\,x + b$ has a singularity around 90°.
  - Better parameterization: $x \cos(\theta) + y \sin(\theta) = \rho$

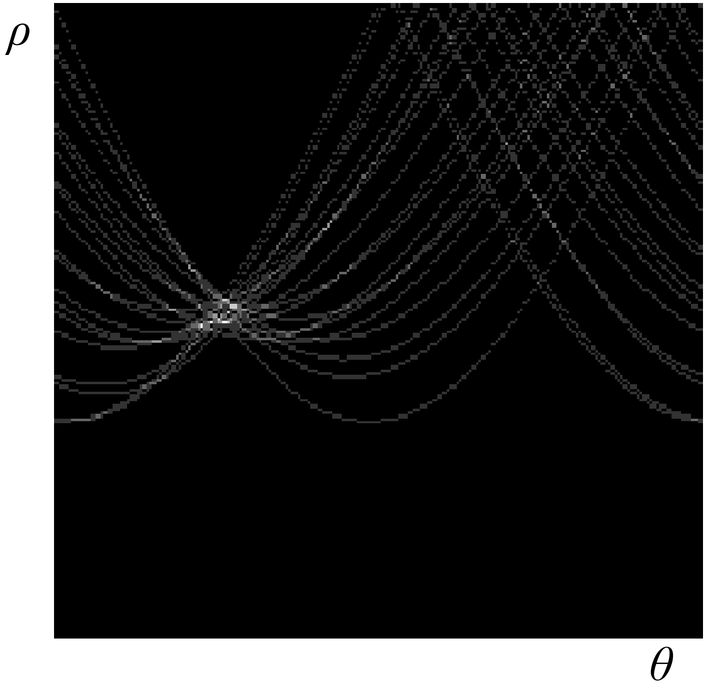




Hough Transform: Noisy Line



Tokens

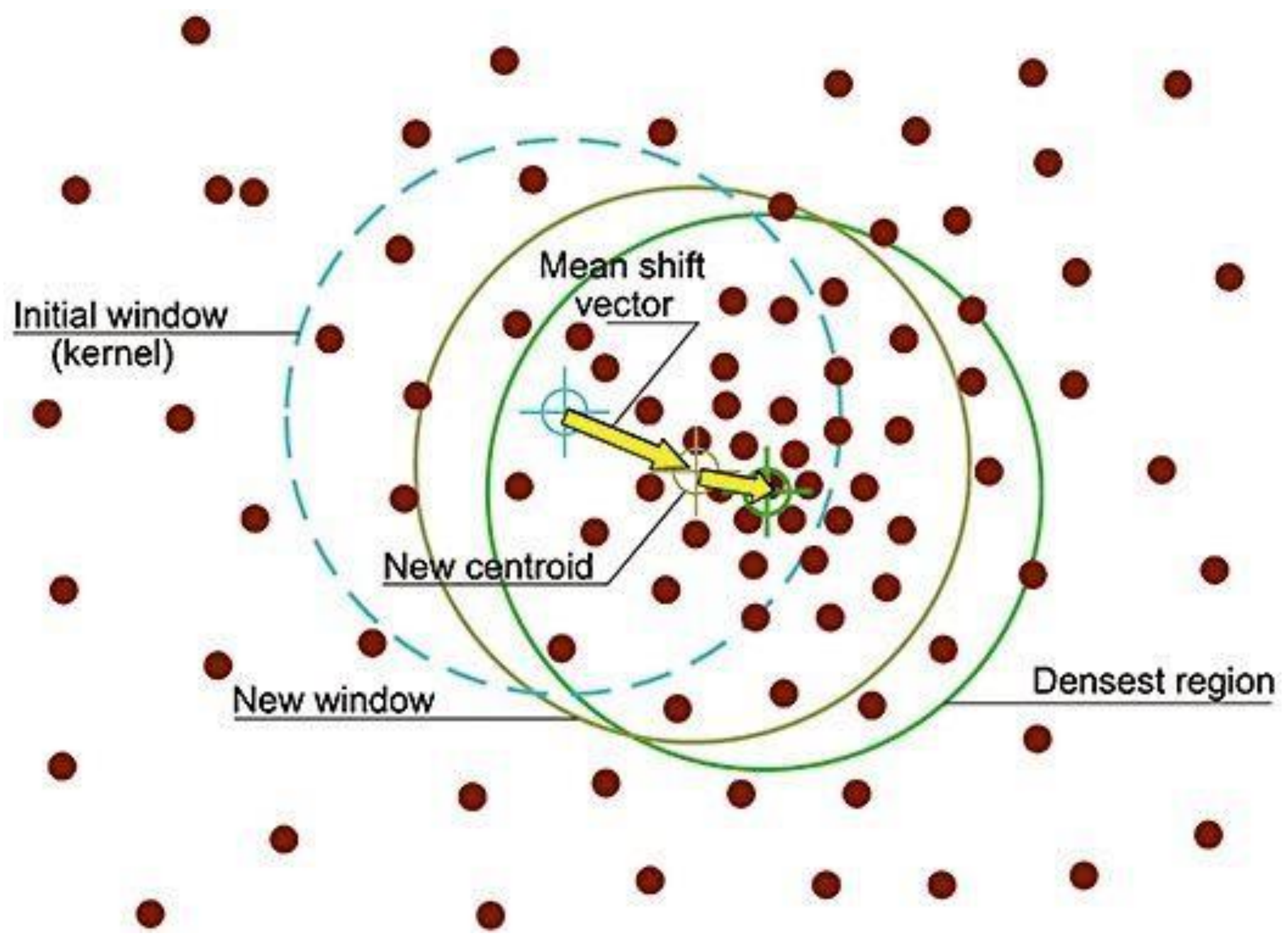


Votes

- Possible problem: Finding the true maximum
  - Mean-shift, Gaussian convolution…

Mean-Shift

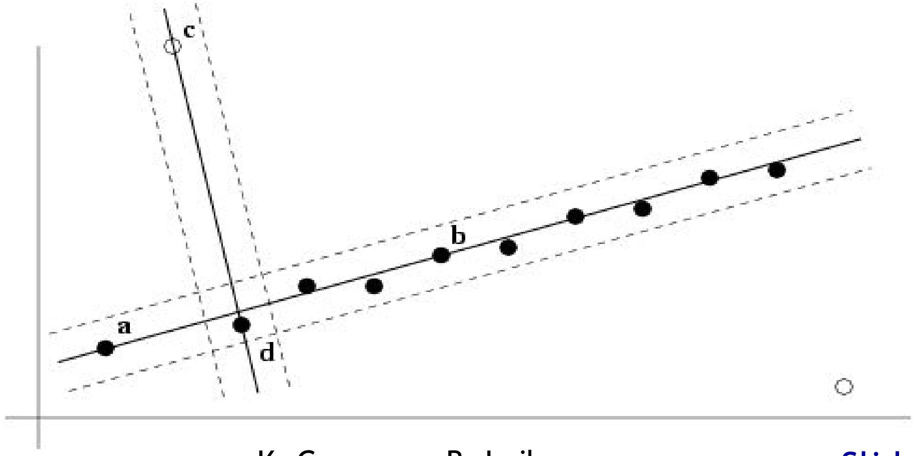
Recherche de max local itératif



RANSAC (RANdom SAmple Consensus)

[Fischler81]

- Randomly choose a minimal subset of data points necessary to fit a model (a *sample*)
- Points within some distance threshold t of model are a *consensus set*. Size of consensus set is model's *support*.
- Repeat for N samples; model with biggest support is most robust fit
  - Points within distance t of best model are inliers
  - Fit final model to all inliers



Slide credit: David Lowe

RANSAC: How many samples?

- How many samples are needed?
  - Suppose w is fraction of inliers (points from line).
  - n points needed to define hypothesis (2 for lines)
  - k samples chosen.
- Prob. that a single sample of n points is correct: w^n
- Prob. that all samples fail is: $(1-w^n)^k$

$\Rightarrow$ Choose k high enough to keep this below desired failure rate.

Slide credit: David Lowe

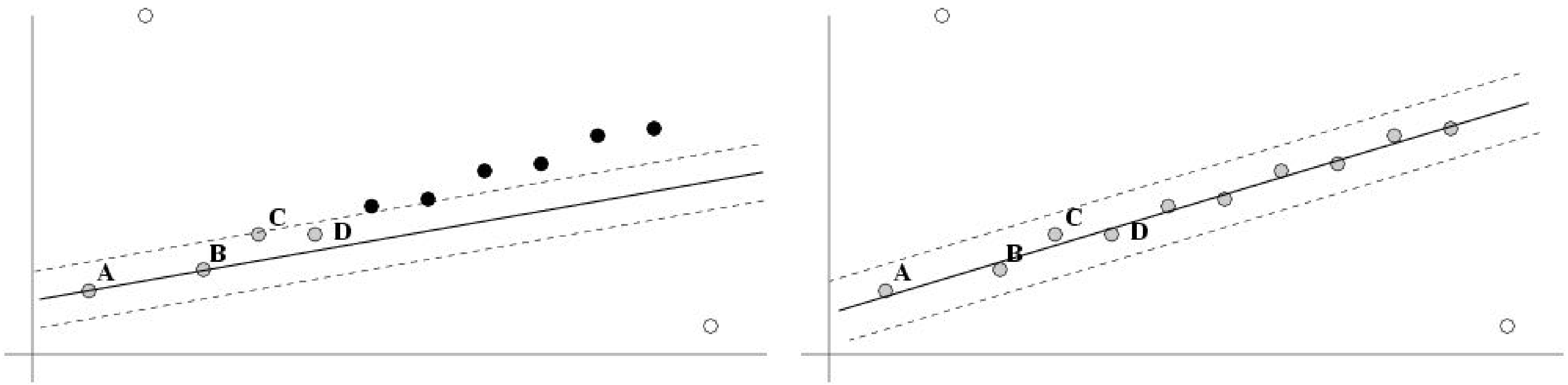
RANSAC: Computed k (p=0.99)

Sample size n	Proportion of outliers						
	5%	10%	20%	25%	30%	40%	50%
2	2	3	5	6	7	11	17
3	3	4	7	9	11	19	35
4	3	5	9	13	17	34	72
5	4	6	12	17	26	57	146
6	4	7	16	24	37	97	293
7	4	8	20	33	54	163	588
8	5	9	26	44	78	272	1177

Slide credit: David Lowe

After RANSAC

- RANSAC divides data into inliers and outliers and yields estimate computed from minimal set of inliers
- Improve this initial estimate with estimation over all inliers (e.g. with standard least-squares minimization)
- But this may change inliers, so alternate fitting with re-classification as inlier/outlier



Slide credit: David Lowe

Comparison

Gen. Hough Transform

- Advantages
  - Very effective for recognizing arbitrary shapes or objects
  - Can handle high percentage of outliers (>95%)
  - Extracts groupings from clutter in linear time
- Disadvantages
  - Quantization issues
  - Only practical for small number of dimensions (up to 4)
- Improvements available
  - Probabilistic Extensions
  - Continuous Voting Space

  [Leibe08]

RANSAC

- Advantages
  - General method suited to large range of problems
  - Easy to implement
  - Independent of number of dimensions
- Disadvantages
  - Only handles moderate number of outliers (<50%)
- Many variants available, e.g.
  - PROSAC: Progressive RANSAC [Chum05]
  - Preemptive RANSAC [Nister05]

Segmentation et detection d’objets

- Ligne de partage des eaux
- Cascade de Haar (Viola Jones detor

En pratique

- Non trivial de faire des opérations basiques de vision
- Problème de robustesse
- Avantage de la compréhension
- Bienvenue dans l’ère du Deep learning (2012)

Quelle heure est t'il ?

Et maintenant ! TP A vous de jouer?