DÉVELOPPEMENT D'UN NOUVEAU FILTRE DE DÉTECTION DE CONTOURS ÉTROITS DANS LES IMAGES ET UTILISATION DU MACHINE LEARNING POUR L'ADAPTATION EN MULTI ÉCHELLE

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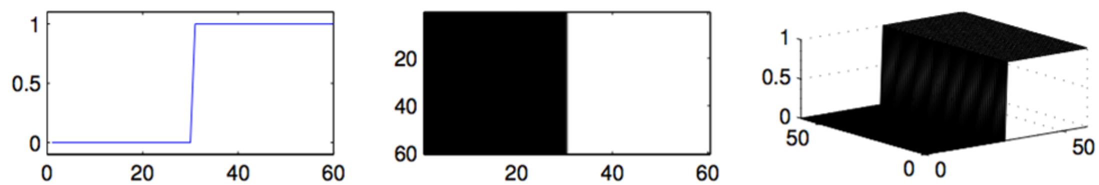
INTRODUCTION

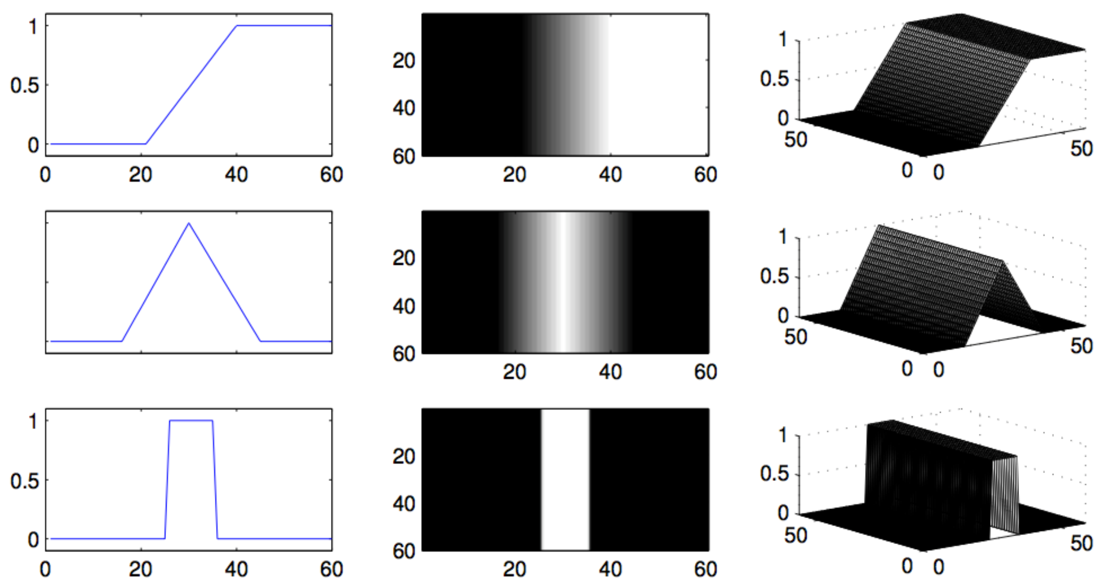
Ideal contour: Heaviside function

$$H(x) = \begin{cases} 1 \; if \; x > 0 \\ 0 \; elsewhere \end{cases}$$



→ Step edge

Other types of contours:



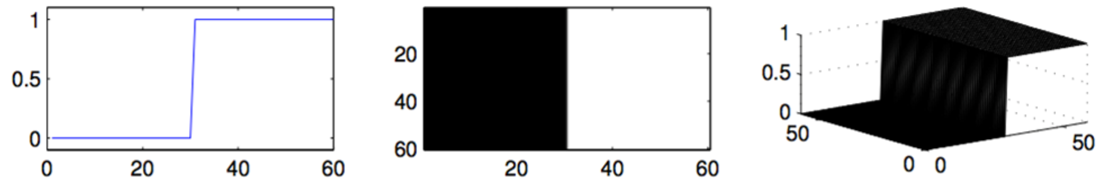
→ Ramp edge

→ Roof edge (ridges/valleys)

→ Peak edge (ridges/valleys)

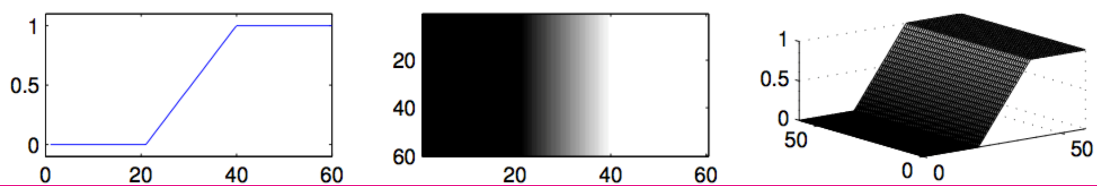
Ideal contour: Heaviside function

$$H(x) = \begin{cases} 1 \; if \; x > 0 \\ 0 \; elsewhere \end{cases}$$

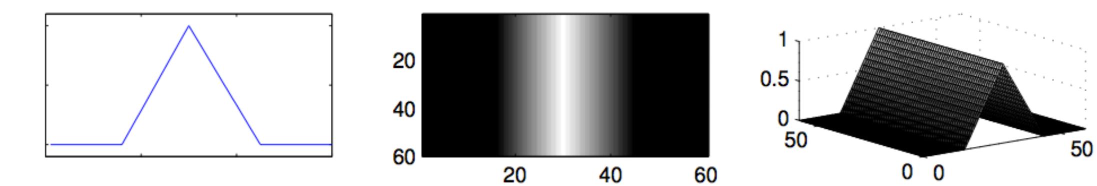


→ Step edge

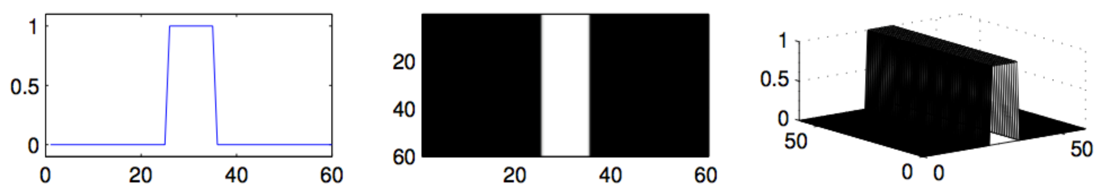
Other types of contours:



→ Ramp edge



→ Roof edge (ridges/valleys)



→ Peak edge (ridges/valleys)

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Platax pinnatus

Image 408× 512

R > 128

Hessian matrix Considering a grey level image I and its partial derivatives:

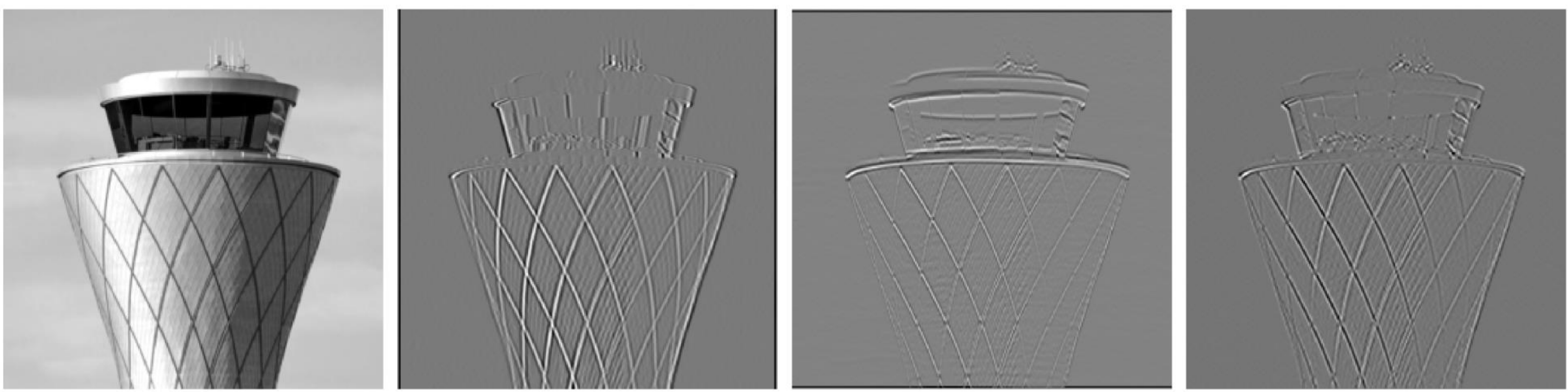
- $I_{xx} = \partial^2 I / \partial x^2$, the 2nd image derivative along the x axis,
- $I_{yy} = \partial^2 I / \partial y^2$, the 2nd image derivative along the y axis,
- $I_{xy} = \partial^2 I / \partial x \partial y$, the crossing derivative of I,

the Hessian matrix $\mathcal{H}$ is often computed in image analysis:

$$\mathcal{H}(x,y) = \begin{pmatrix} I_{xx}(x,y) & I_{xy}(x,y) \\ I_{xy}(x,y) & I_{yy}(x,y) \end{pmatrix} = \begin{pmatrix} \mathcal{H}_{11} & \mathcal{H}_{12} \\ \mathcal{H}_{21} & \mathcal{H}_{22} \end{pmatrix}.$$

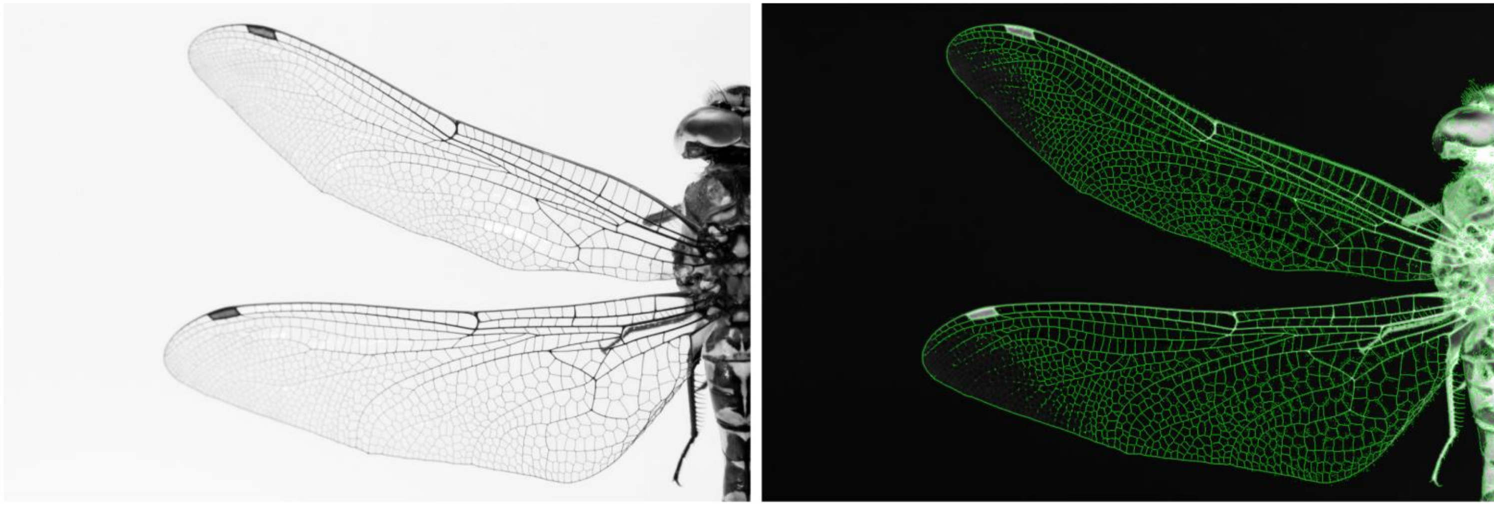
Theoretically, eigenvalues (k_1, k_2) are computed by:

$$\begin{cases} k_1(x,y) & = \frac{1}{2} \cdot (\mathcal{H}_{11} + \mathcal{H}_{22}) - \frac{1}{4}\sqrt{(\mathcal{H}_{11} + \mathcal{H}_{22})^2 + 4 \cdot \mathcal{H}_{12}^2} \\ k_2(x,y) & = \frac{1}{2} \cdot (\mathcal{H}_{11} + \mathcal{H}_{22}) + \frac{1}{4}\sqrt{(\mathcal{H}_{11} + \mathcal{H}_{22})^2 + 4 \cdot \mathcal{H}_{12}^2} \end{cases}$$

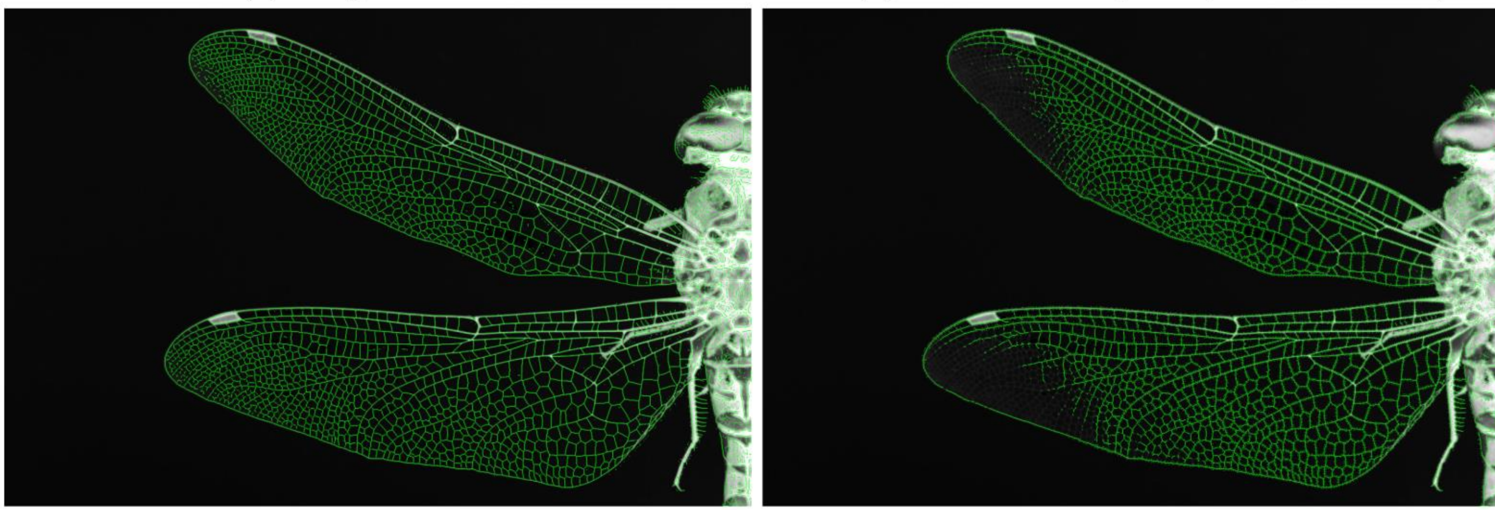


(a) Image 256×256 (b) I_{xx} image of (a) (c) I_{yy} image of (a) (d) I_{xy} image of (a)

Several filters



(a) Image 800×1200 (b) $\mathcal{H}$ with filters [-1 0 1] and [1 0 -2 0 1]



(c) $\mathcal{H}$ with filter Z, parameter $s_Z = 1.696$ (d) $\mathcal{H}$ with filter G and D_1, parameter $\sigma = 0.58$

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G.S Shokouh, B. Magnier, B. Xu, P. Montesinos.
Ridge Detection by Image Filtering Techniques: A Review and an Objective Analysis.
Pattern Recognition and Image Analysis, 2021

Multiscale ridge detection

$$\mathcal{N}_\gamma(I) = \sigma^{2\gamma} \cdot \left(\left(I_{\sigma,xx} - I_{\sigma,yy}\right)^2 + 4 \cdot I_{\sigma,xy} \right)$$

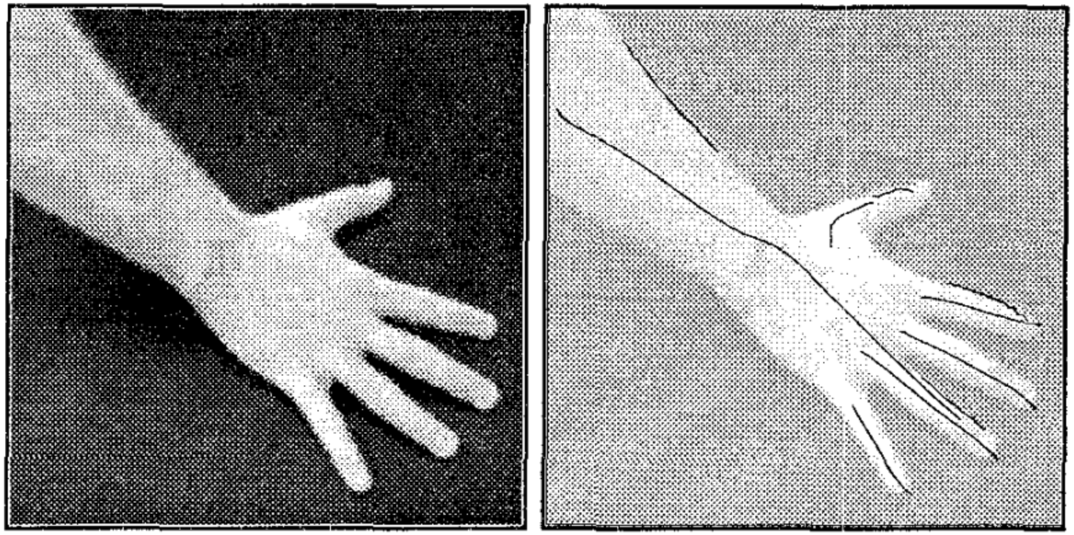

Figure 7: The 10 strongest bright ridges extacted using scale selection based on local maxima over scales of $\mathcal{A}_{\gamma-norm}$ (with $\gamma = \frac{3}{4}$). (Image size: 140 × 140.)

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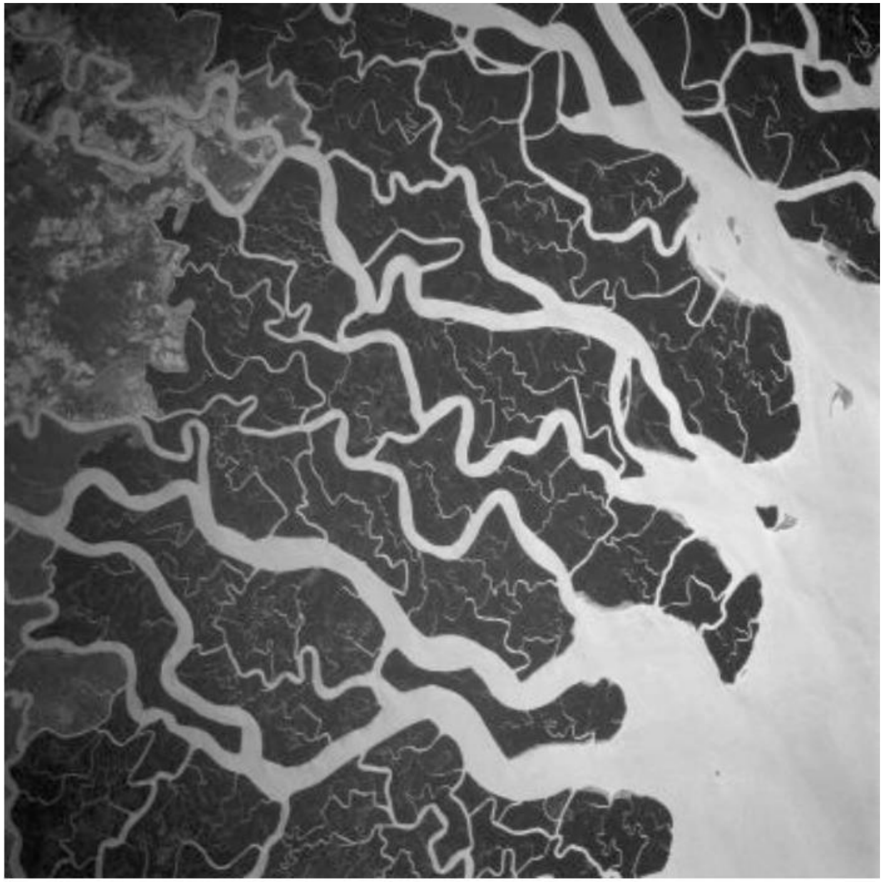
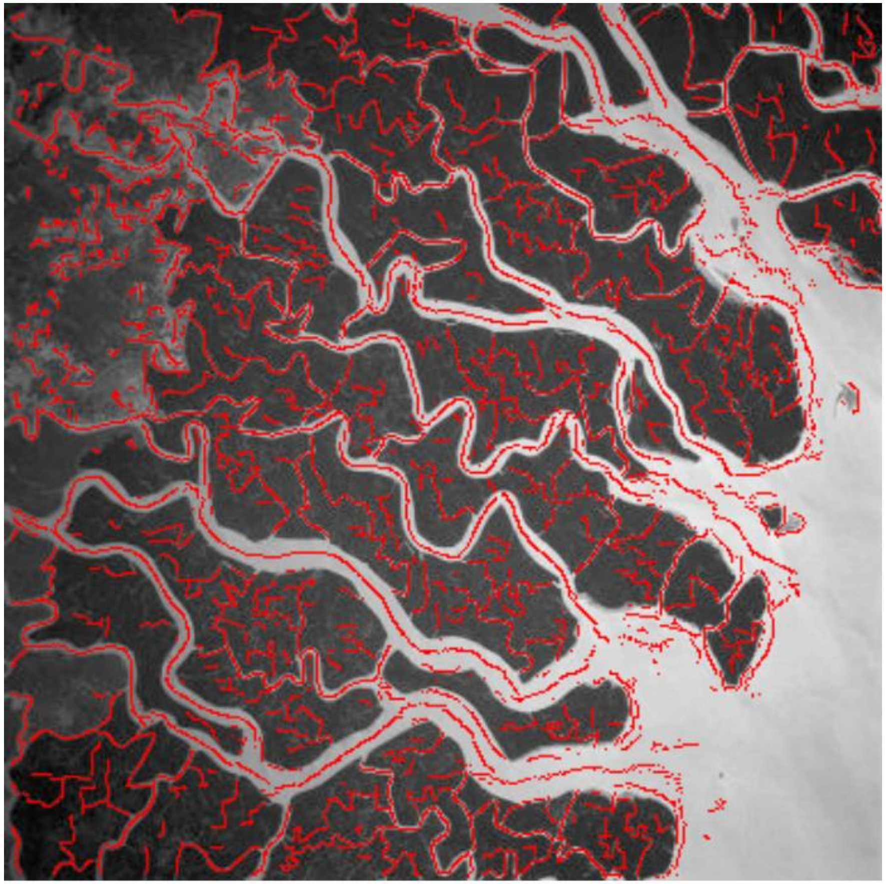
Lindeberg, T.
Edge detection and ridge detection with automatic scale selection, IEEE *CVPR, pp. 465–470, 1996*

Multiscale ridge detection



(a) Original image, 384×384



(f) Oriented half Gaussian kernels

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Magnier, B., Aberkane, A., Borianne, P., Montesinos, P., & Jourdan, C. (2014, May).
Multi-scale crest line extraction based on half Gaussian Kernels.
IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) (pp. 5105-5109). 2014.

Multiscale ridge detection: système nerveux dentaire

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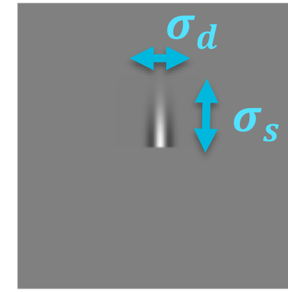


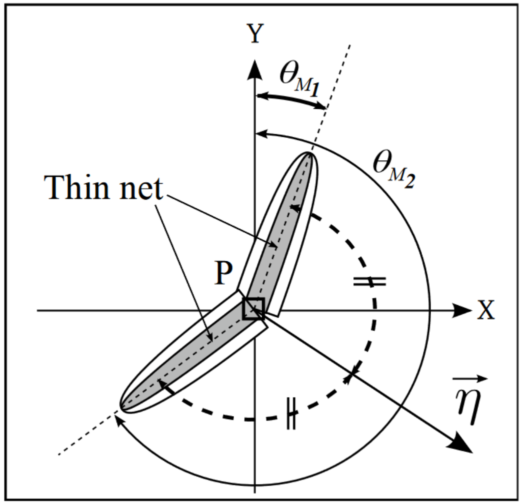
Mathematically, it is defined as:

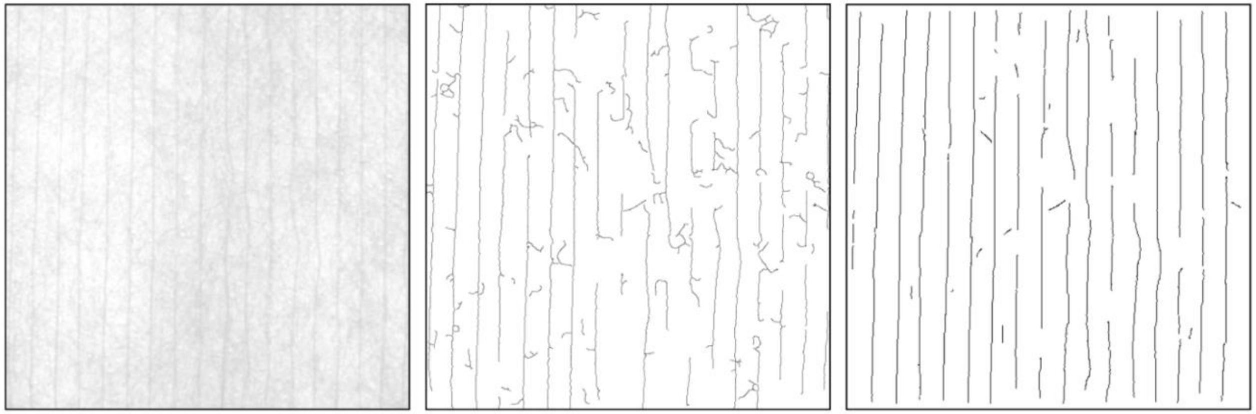
1. a semi-Gaussian for the smoothing in the y direction (vertically):
   $\mathcal{G}(\sigma_s, t) = H(t) \cdot \mathbf{e}^{\frac{-t^2}{2 \cdot \sigma_s^2}}$, with $\sigma_s \in \mathbb{R}_+^*$, $t \in \mathbb{R}$ and H the Heaviside function,
2. a second derivative of a Gaussian in the x direction (horizontally):
   $\mathcal{G}''(\sigma_d, t) = \frac{t^2 - \sigma_d^2}{\sigma_d^4} \cdot \mathbf{e}^{\frac{-t^2}{2 \cdot \sigma_d^2}}$, with $\sigma_d \in \mathbb{R}_+^*$ and $t \in \mathbb{R}$.

(a) $\theta = 0°$ (b) $\theta = 45°$ (c) $\theta = 217°$

Magnier, B., Shokouh, G. S., Xu, B., & Montesinos, P.
A Multi-scale Line Feature Detection Using Second Order Semi-Gaussian Filters.
In *International Conference on Computer Analysis of Images and Patterns* (pp. 98-108), 2021

The line structures can be extracted with non-maxima suppression (NMS) process by deleting local non-maxima in the η direction (bisector between these two local directions -maxima or minima-).





Original image

Hessian matrix Weingarten

SDSG

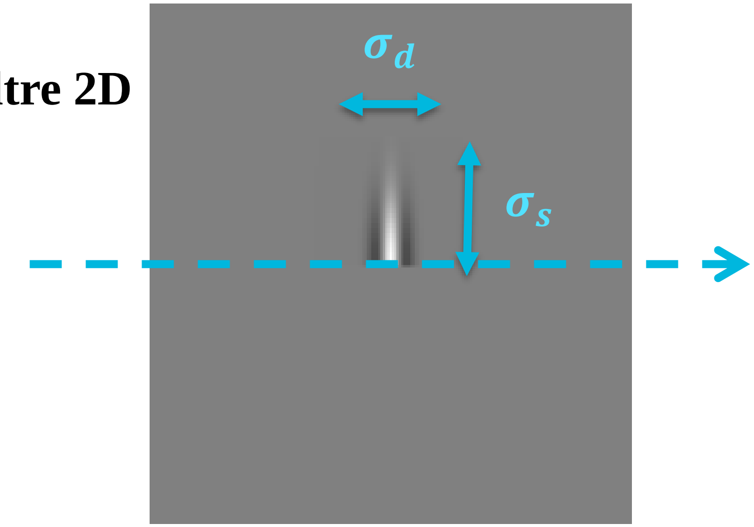
B. Magnier, P. Montesinos, D. Diep.
Ridges and Valleys Detection in Images using Difference of Rotating Half Smoothing Filters.
ACIVS 2011

NEW FILTER

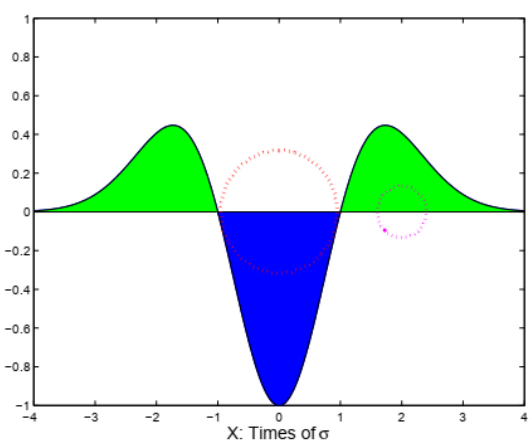
Objectif numéro 1 :

Développer un nouveau filtre 2D

(Matlab).

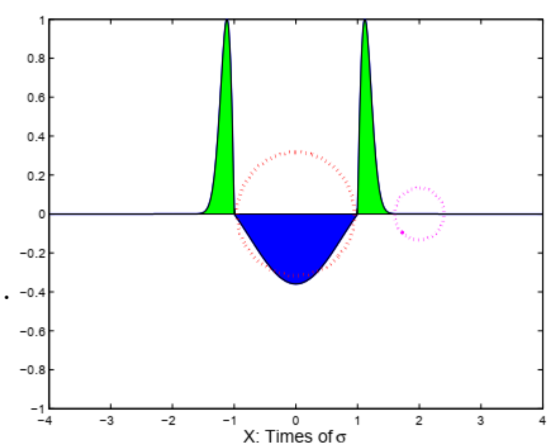


Séparabilité du filtre :
Dérivée seconde en X



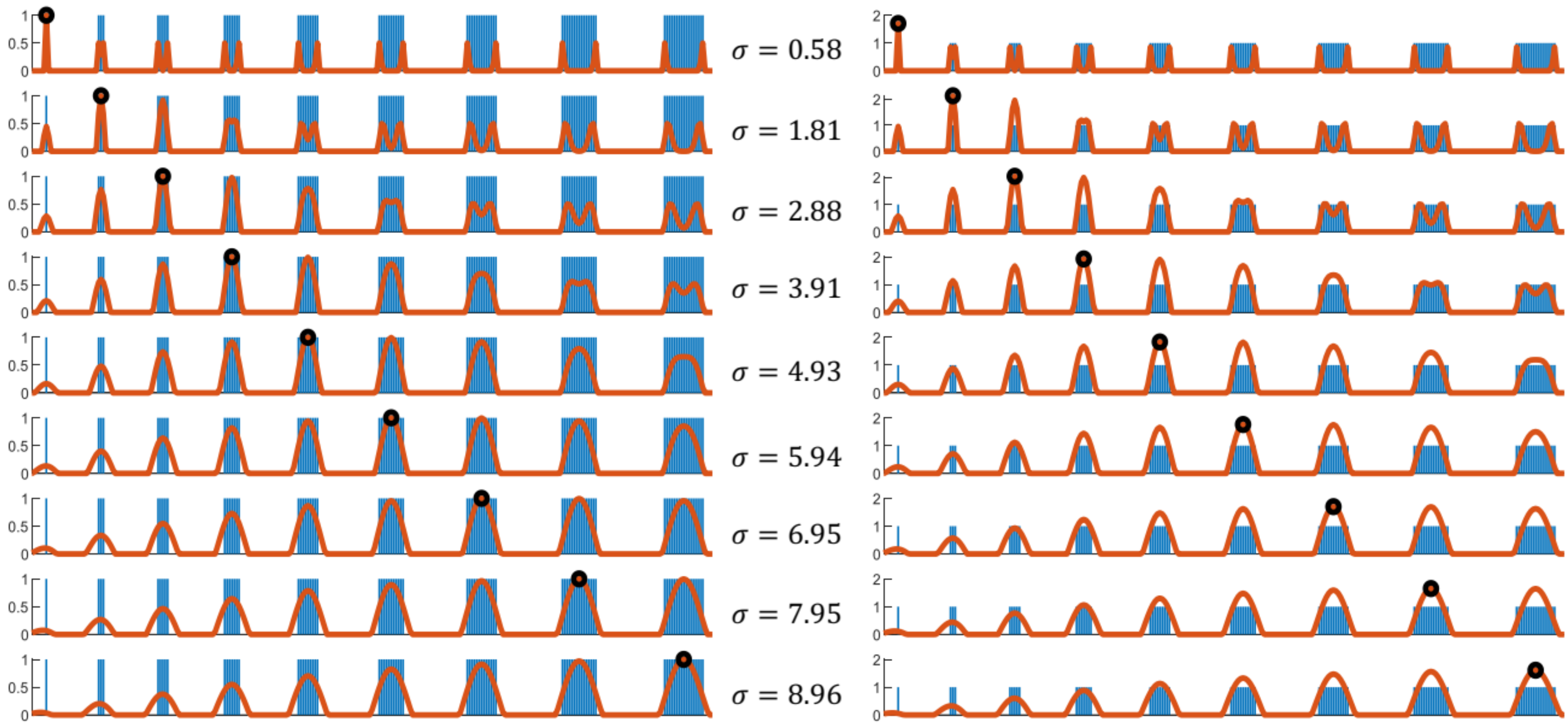
Transform the gaussian to piecewise continuous bi-Gaussian function

$$BG''(\sigma,\sigma_b,x)=\begin{cases} k\cdot G''(\sigma_b,x-\sigma_b+\sigma), & x\le -\sigma \\ G''(\sigma,x), & \|x\|<\sigma \\ k\cdot G''(\sigma_b,x+\sigma_b-\sigma), & x\ge \sigma \end{cases}.$$



Xiao, et al. "Multiscale bi-Gaussian filter for adjacent curvilinear structures detection with application to vasculature images." *IEEE TIP* 2012.

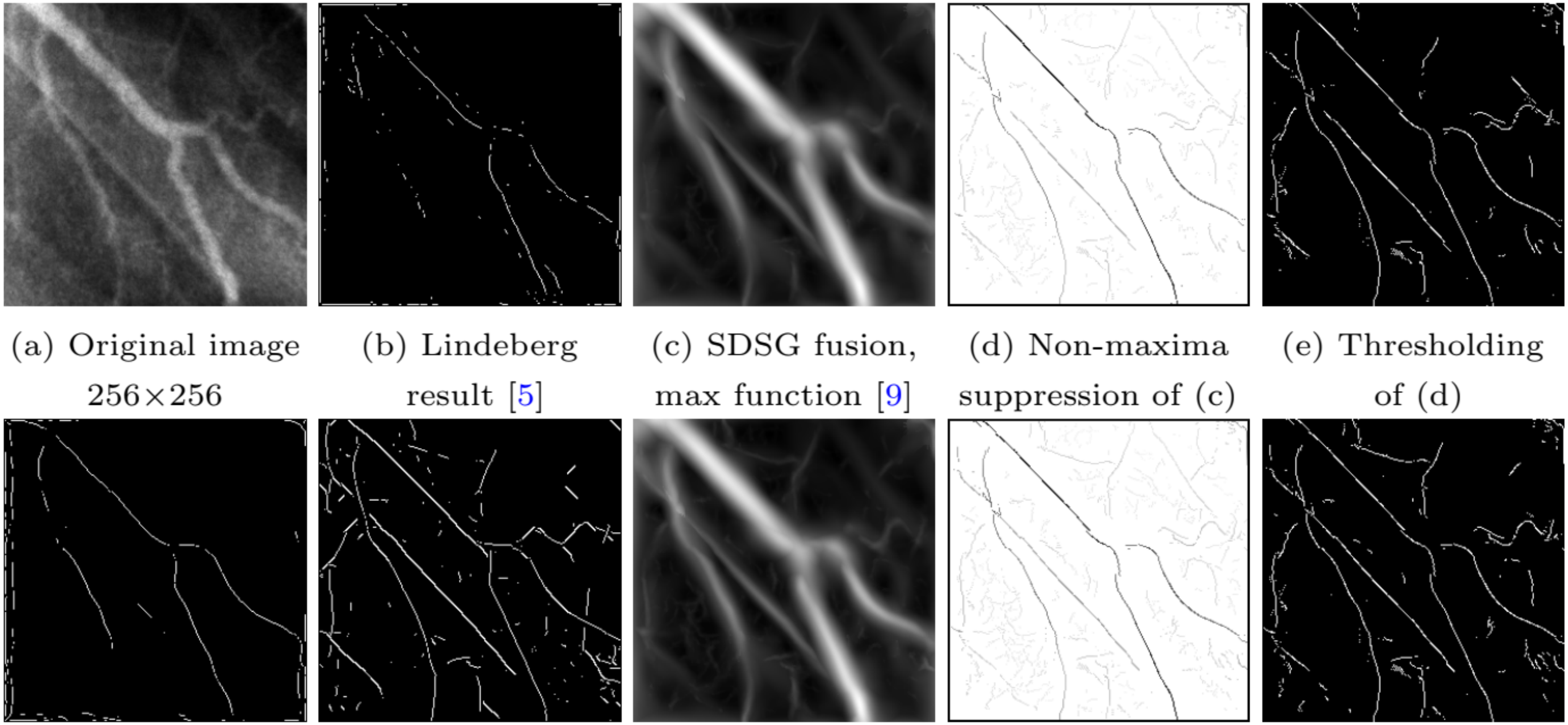
<u>Objectif numéro 2 :</u> Calculer la fonction de normalisation en multi-échelle (Python ou Matlab).



(b) Convolution of the signal with the second derivatives of the Gaussian on the left (without normalization)

(c) Convolution of the signal with the second derivatives of the Gaussian on the left (with normalization)

SCALE FUSION OF THE SDSG



(a) Original image 256×256 (b) Lindeberg result [5] (c) SDSG fusion, max function [9] (d) Non-maxima suppression of (c) (e) Thresholding of (d)

(f) Multi-scale result [1] (g) Multi-scale SOAGK result [6] (h) SDSG fusion, with Eq. 3 (i) Non-maxima suppression of (h) (j) Thresholding of (i)

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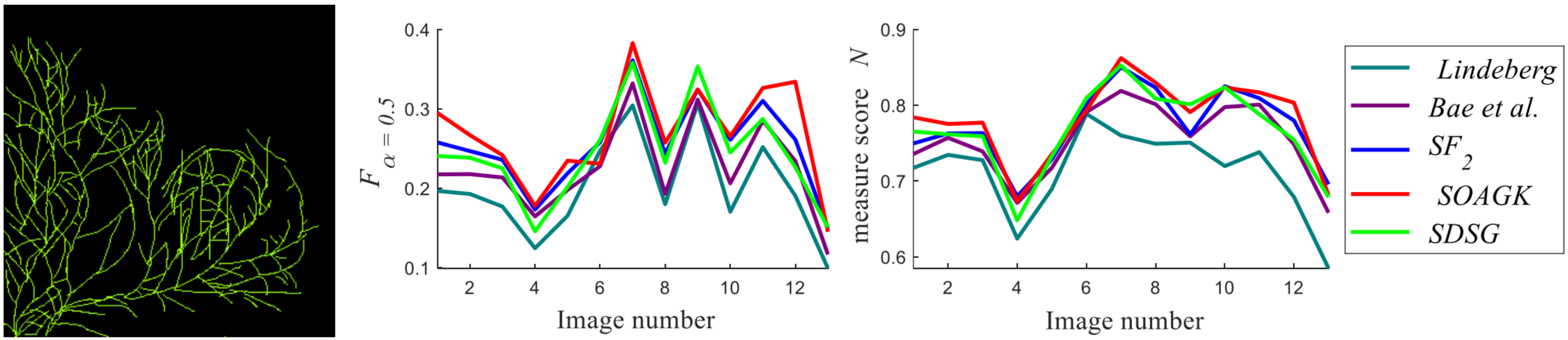
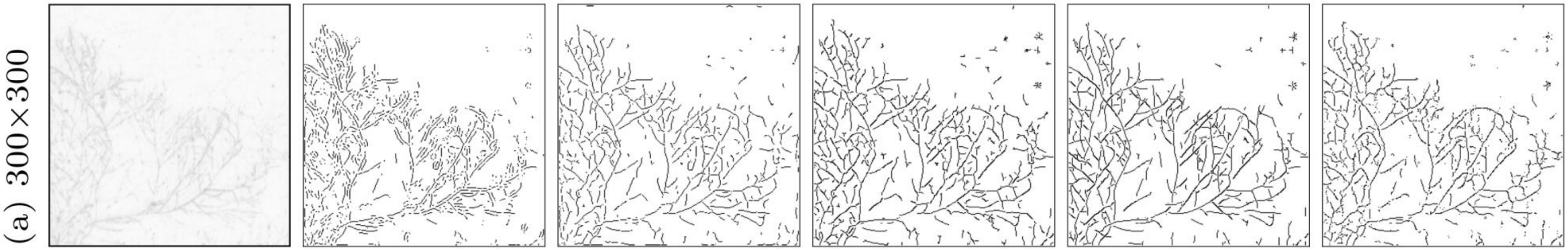
EDGE DETECTION ASSESSMENT

- Evaluation d’une bonne détection de la méthode **sur images synthétiques et réelles** (Matlab)
- Evaluation de la bonne échelle
- Rédaction du rapport sous forme d’article scientifique en anglais (**publication avec le doctorant en février**)



(a) Image annotated by hand (b) F_α measure, tied to *TP, FP*, and *FN* (c) Edge detection evaluation N (d) Legend



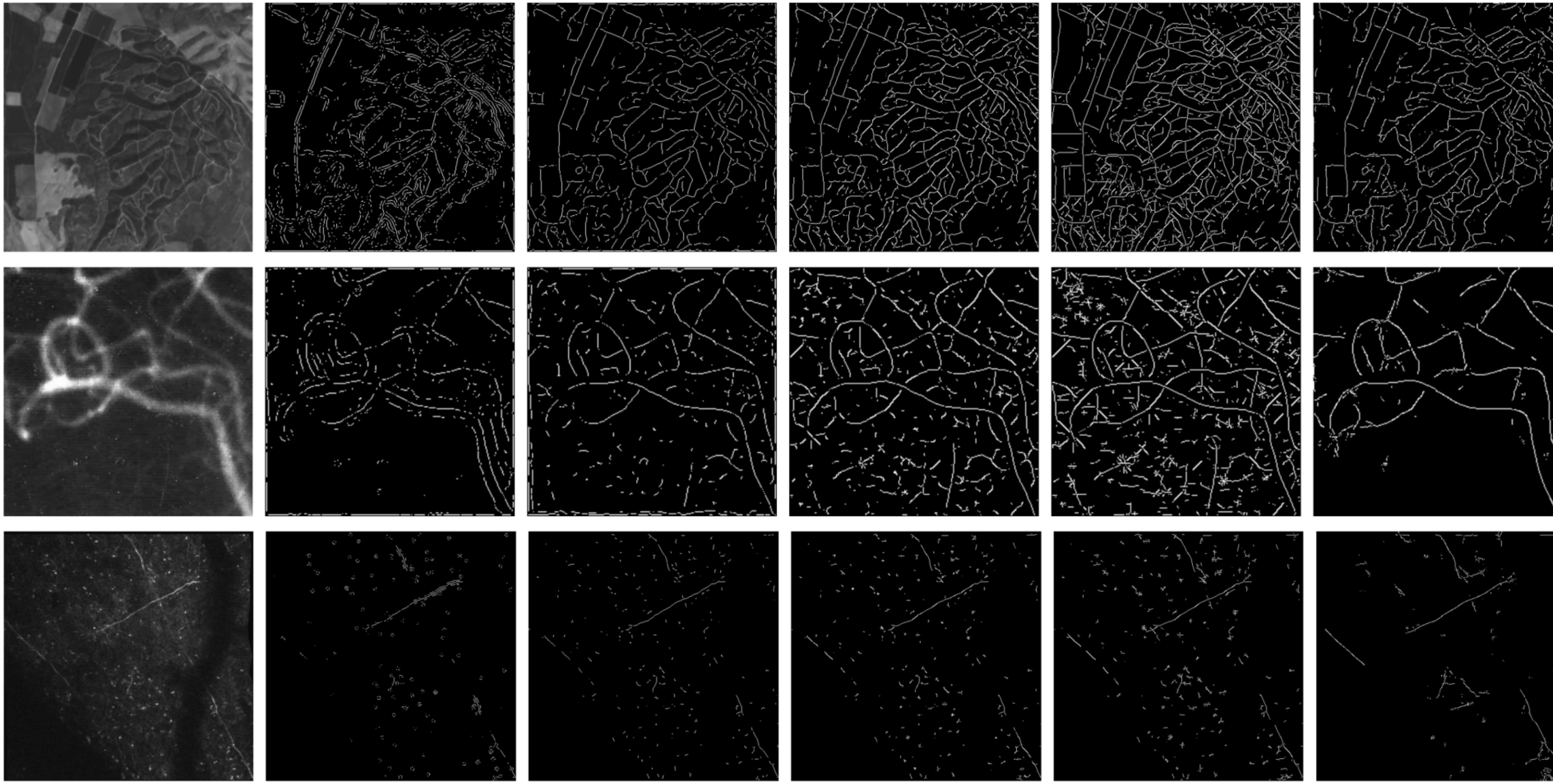
Original Lindeberg[5] Bae *et al.*[1] SF_2 [3] SOAGK [6] SDSG

RESULTS

(c) 400×400

(d) 256×256

(f) 512×512

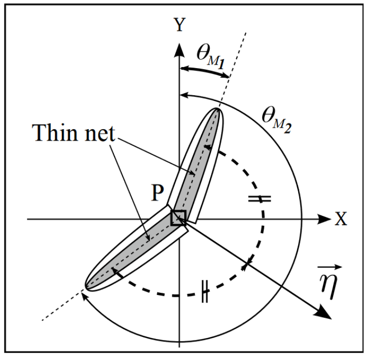


Original | Lindeberg[5] | Bae *et al.*[1] | SF_2 [3] | SOAGK [6] | SDSG

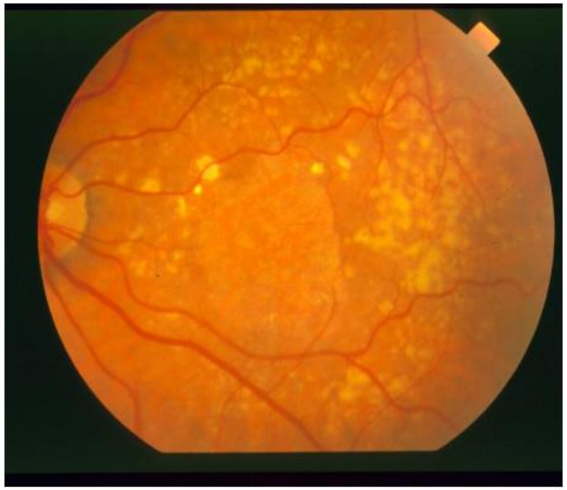
CONCLUSION

- A multi-scale filtering approach for line feature detection.
  - → build a new filter
  - → compute the multiscale normalization
  - → evaluation (precision + scale)
- Adapted to noisy environments

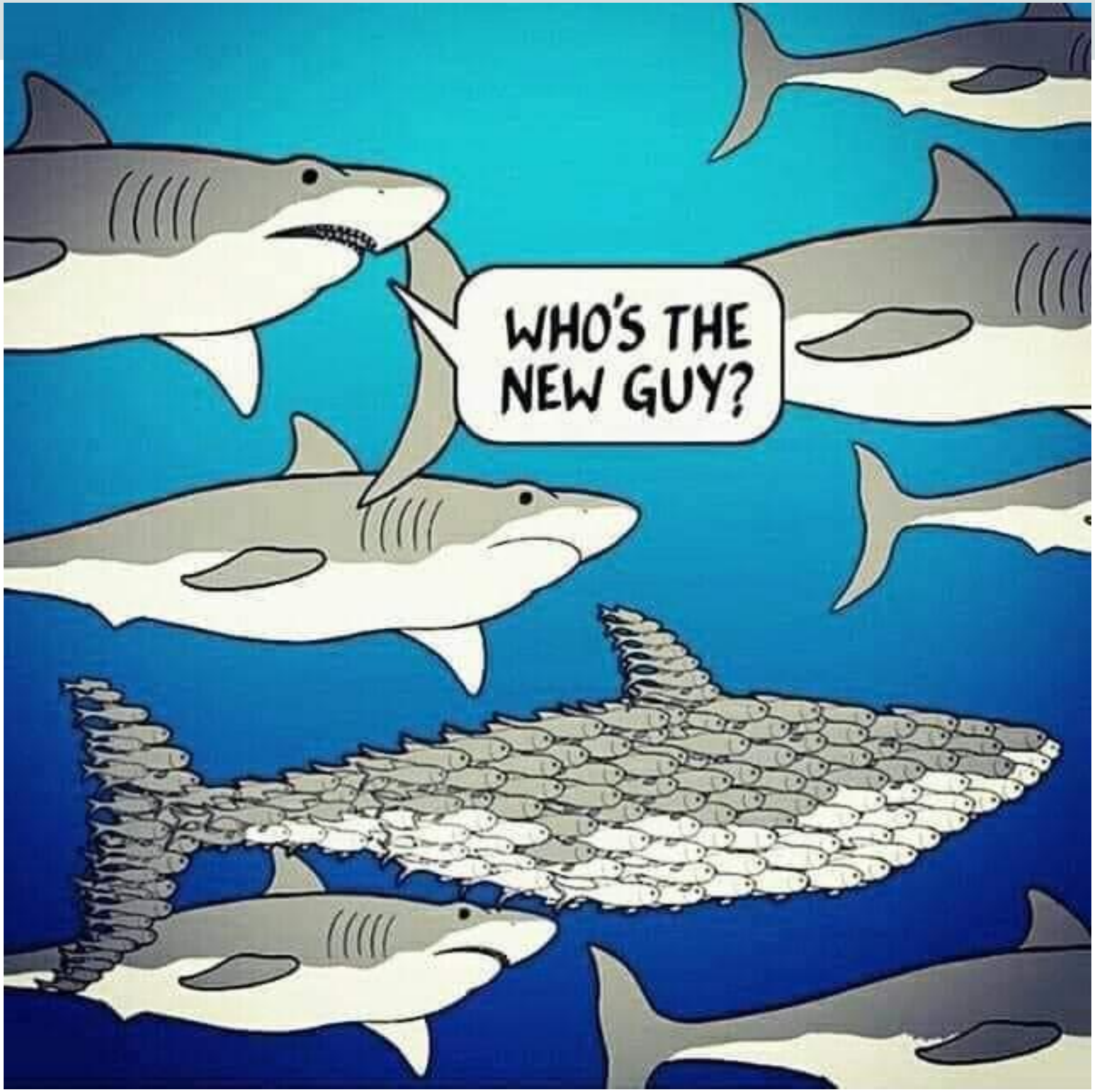
(a) $\theta = 0°$



Application : Test et évaluation sur BDD de fond d'oeil



QUESTIONS ???



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