

Texture Analysis

Computer Vision (CSCI 4420U)

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Today's lecture

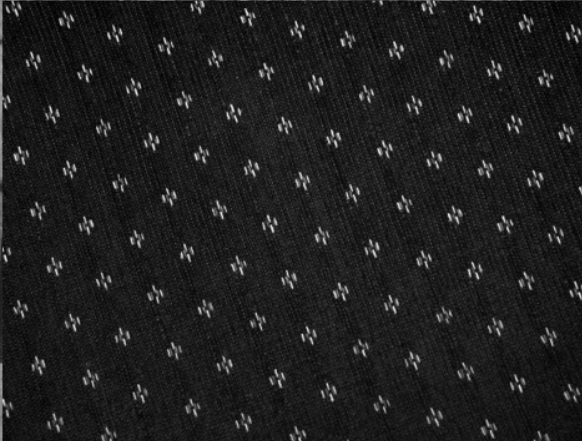
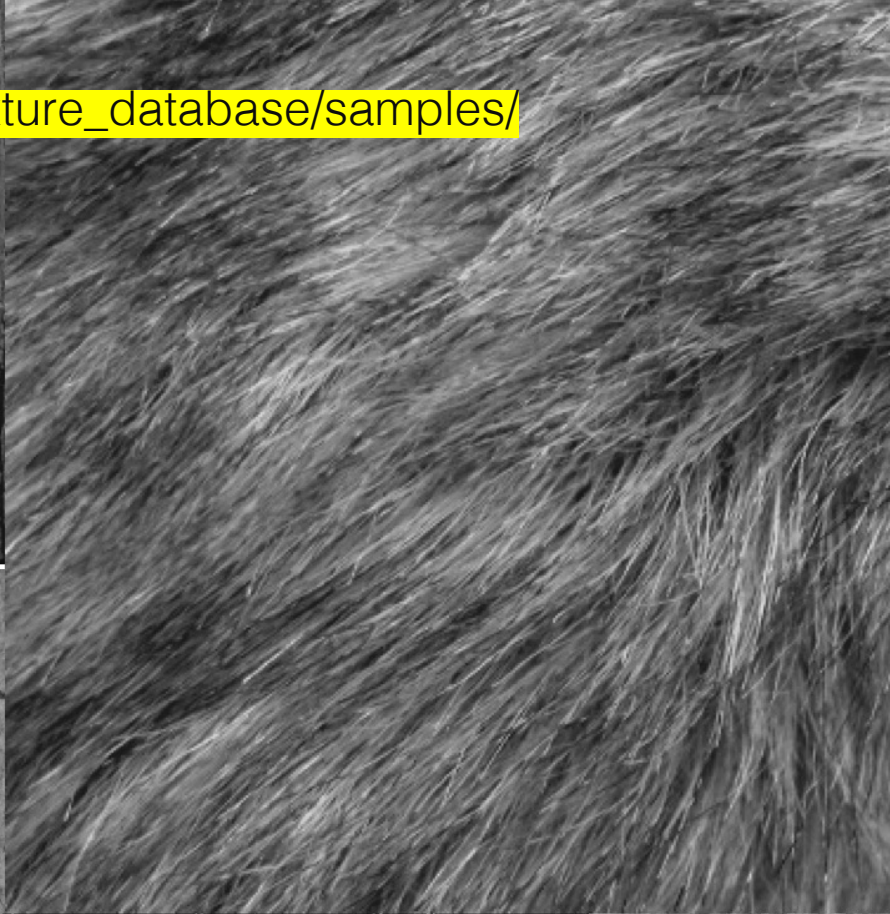
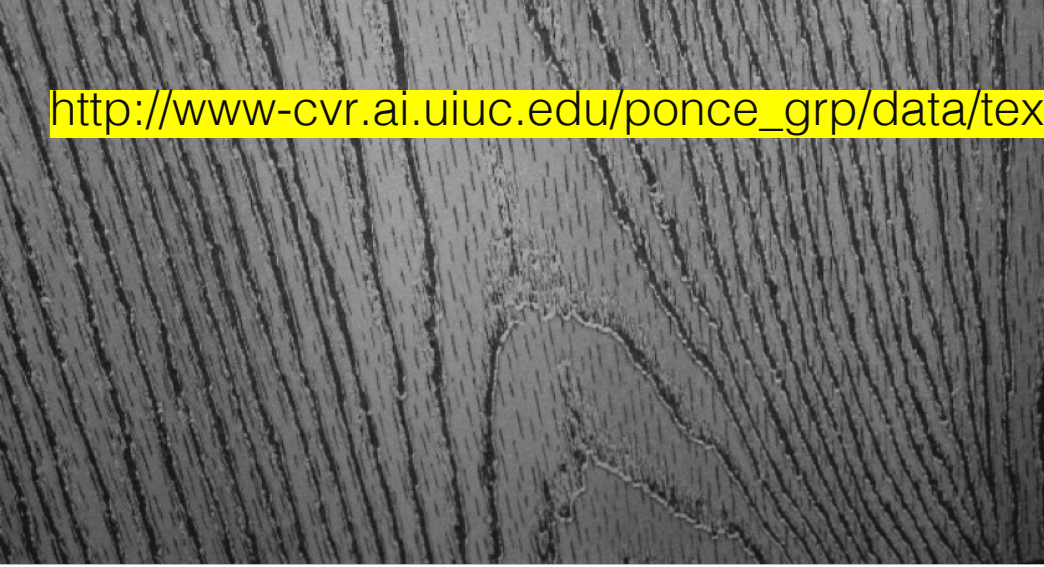
- Filter banks
- Leung-Malik (LM) Filter
 - Construction
- Schmid Filter Bank
- Maximum Response Filter Bank

- Accompanying notebook is available at
<http://csundergrad.science.uoit.ca/courses/cv-notes/notebooks/14-texture-analysis.html>
<http://csundergrad.science.uoit.ca/courses/cv-notes/notebooks/09-histograms.html>



Forsyth

http://www-cvr.ai.uiuc.edu/ponce_grp/data/texture_database/samples/



<http://www.ultimateupcycle.com/>



Texture representation

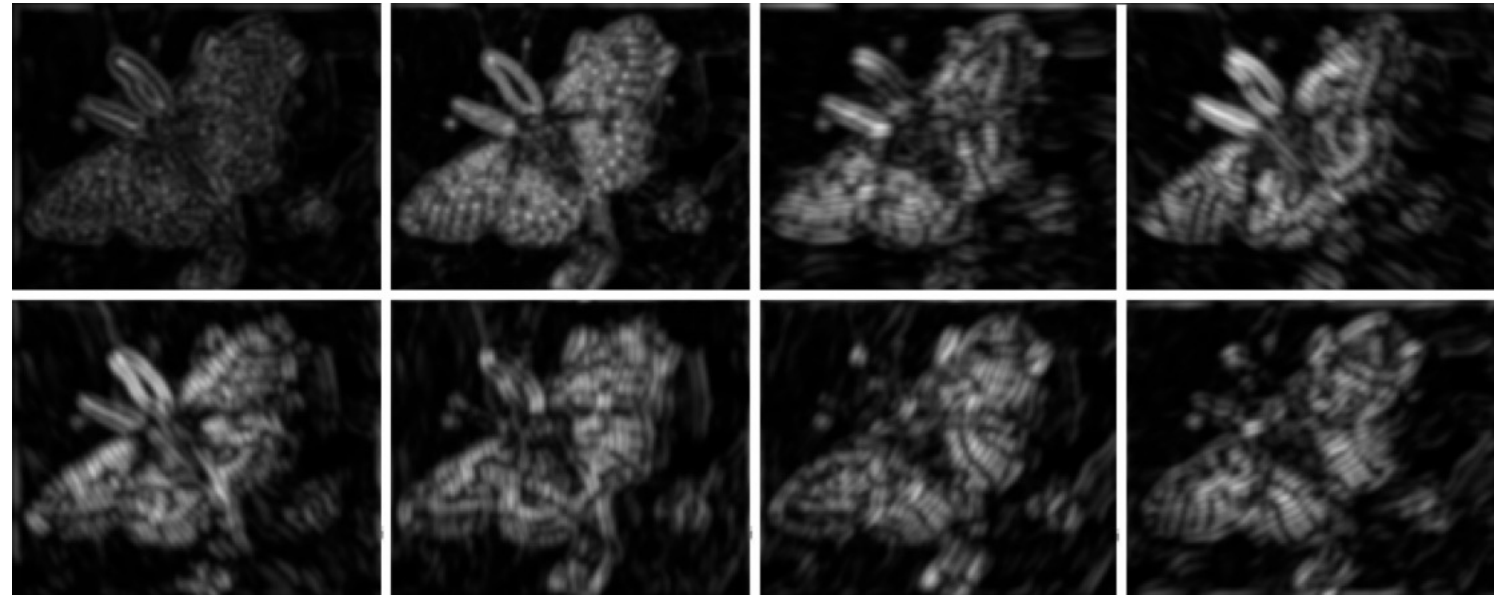
- Textures are regular or stochastic pattern caused by bumps, grooves, color changes
- How do we represent texture?

How do we capture texture?

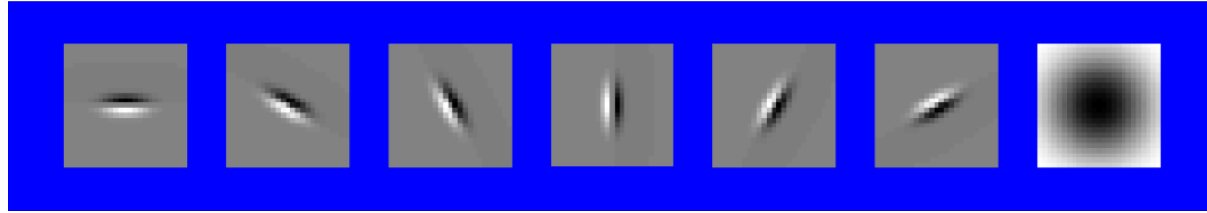
- Convolve image with each filter and record the responses
 - Compute responses of blobs and edge at various scales and orientations
 - Record simple statistics, e.g., mean, standard deviation etc.



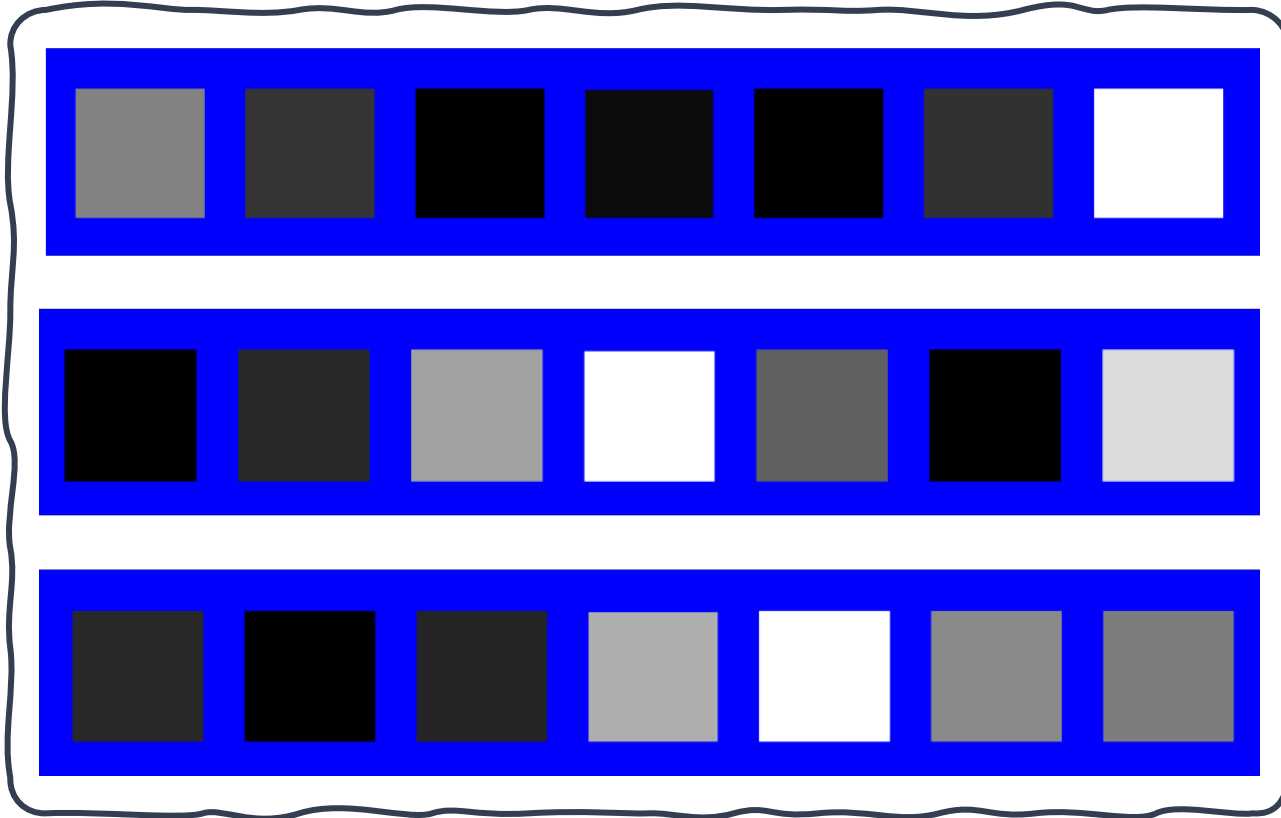
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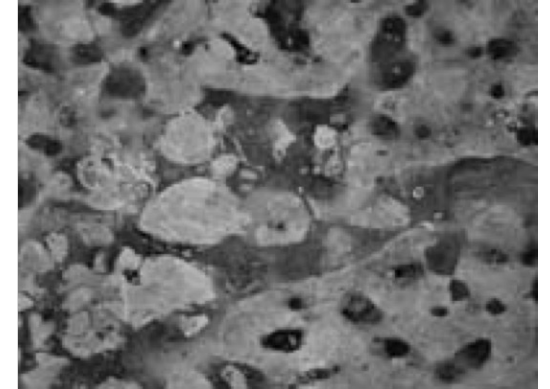
Filter bank



Responses (mean absolute values)



*



*

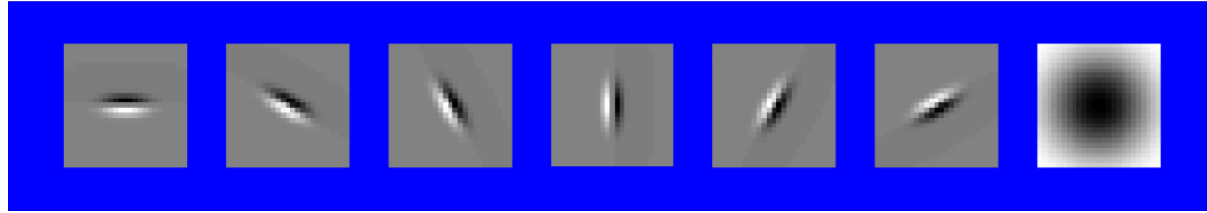


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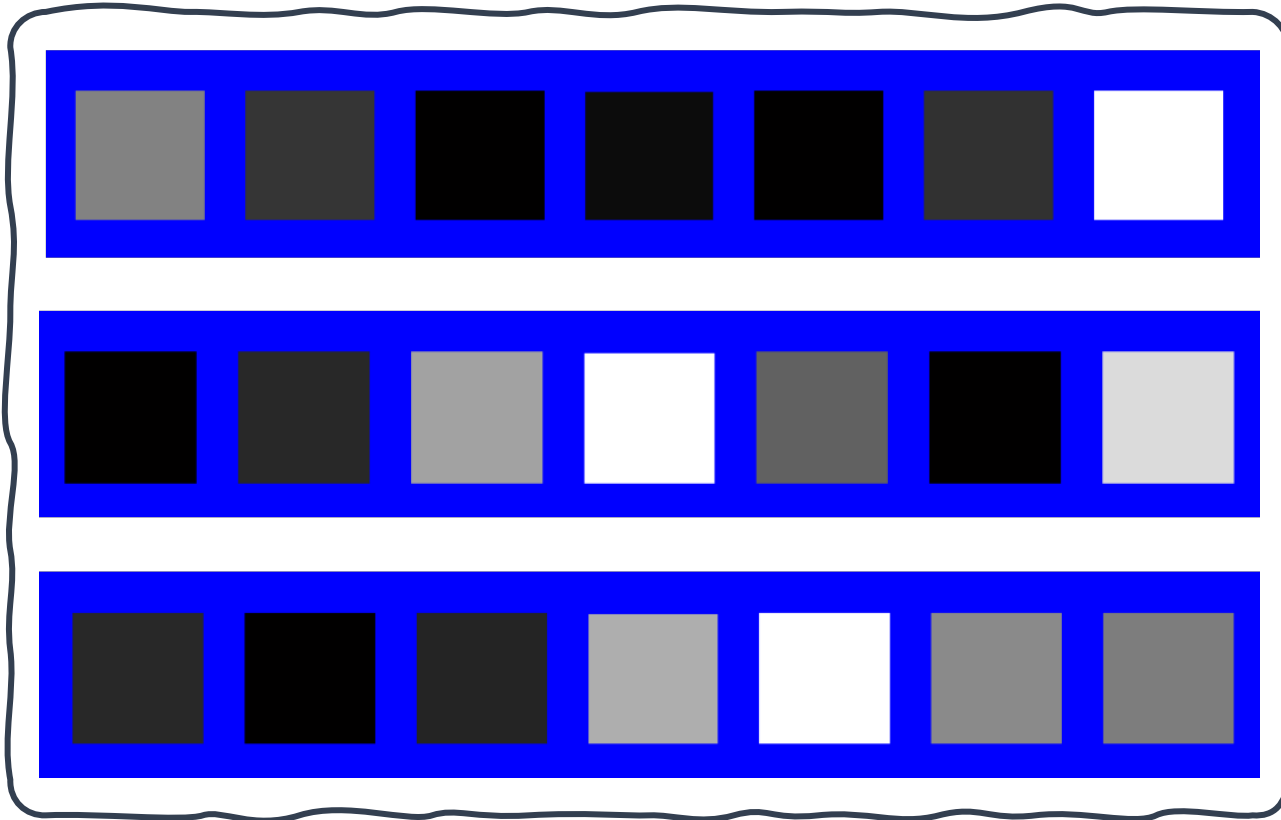


Images

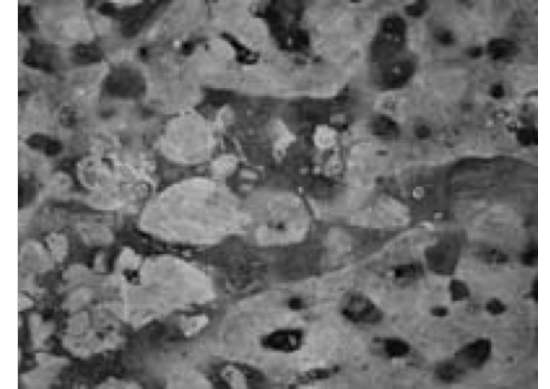
Filter bank



Responses (mean absolute values)



$\in \mathbb{R}^7$



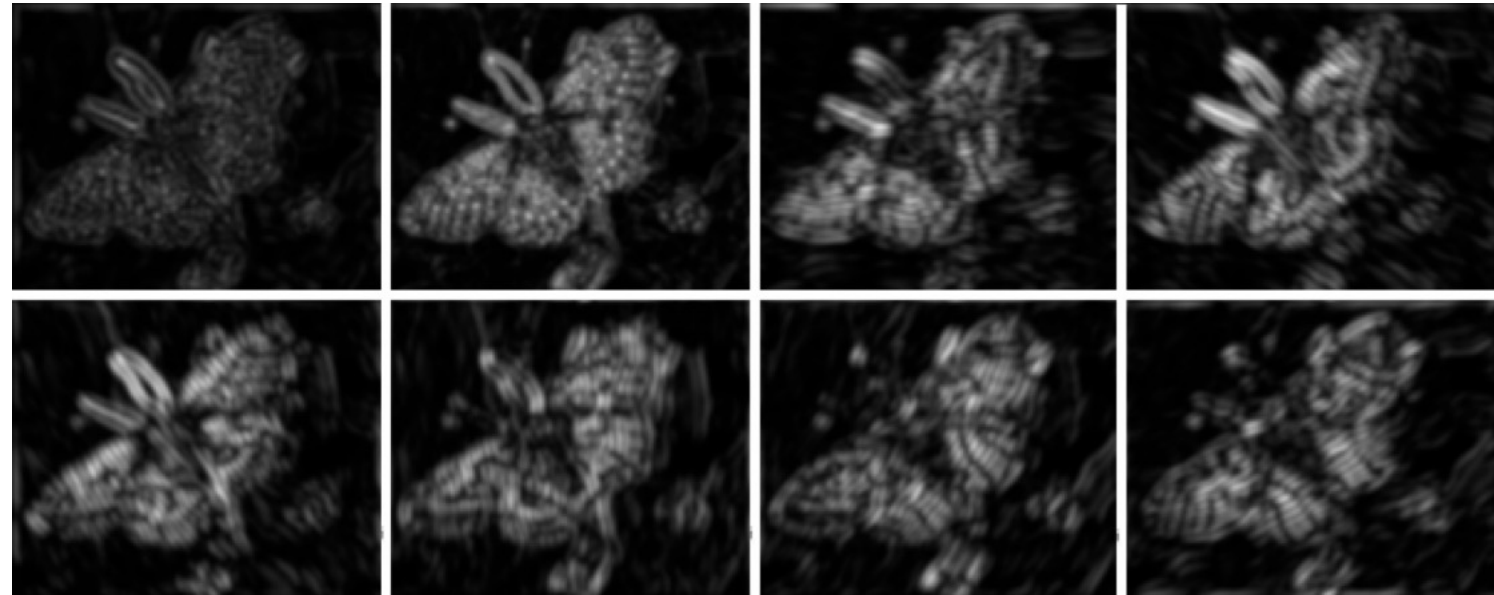
Images

How do we capture texture?

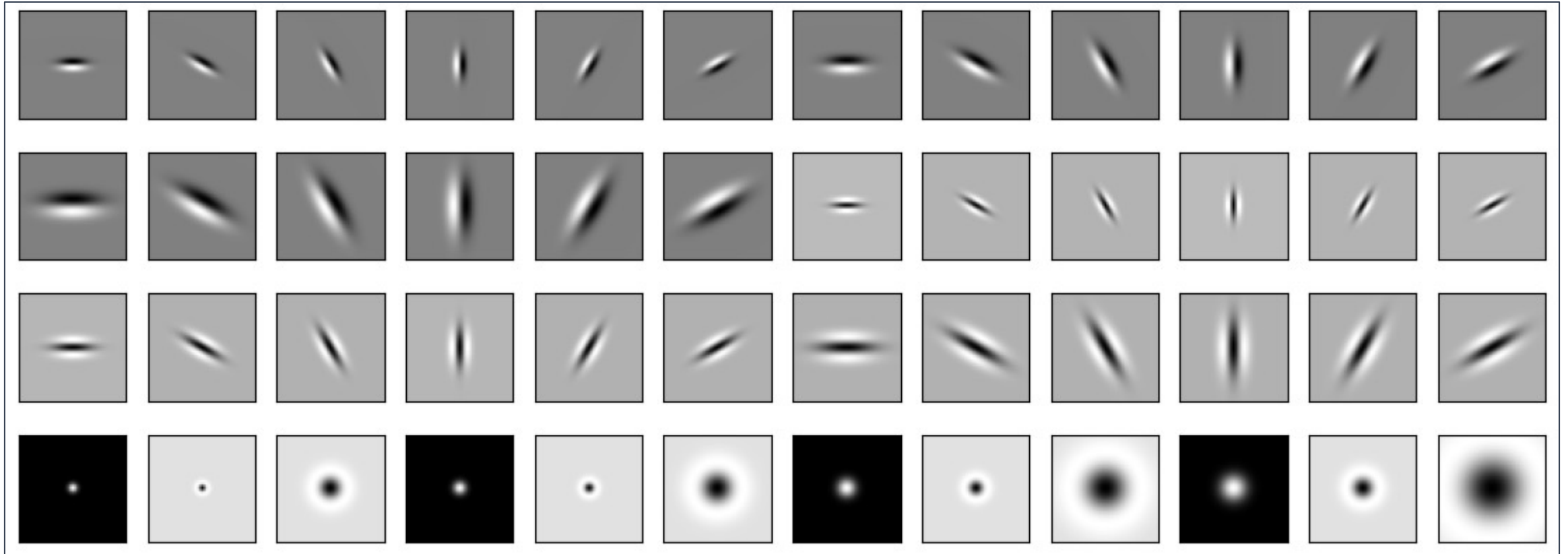
- Convolve image with each filter and record the responses
 - Compute responses of blobs and edge at various scales and orientations
 - Record simple statistics, e.g., mean, standard deviation etc.
 - Cluster filter responses, construct histograms, etc.



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Leung-Malik Filter Bank

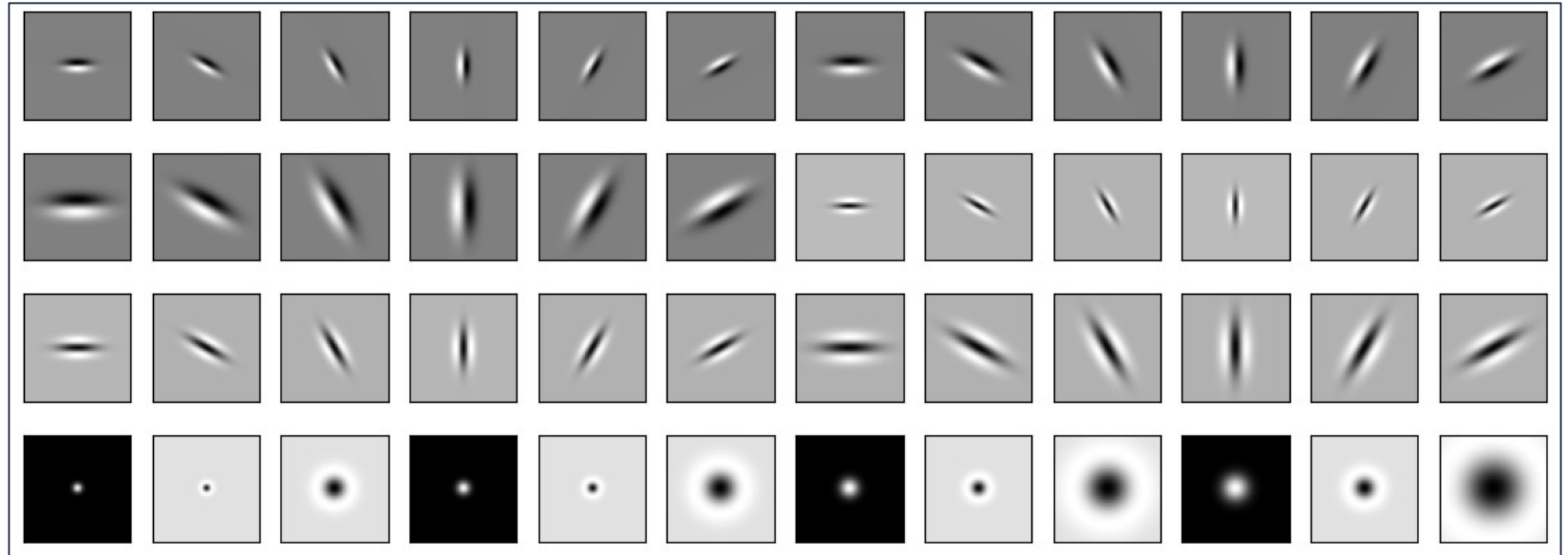


Leung-Malik Filter Bank

- The LM set is a multi-scale, multi-orientation filter bank with 48 filters.
 - 36 first and second derivatives of Gaussians at 6 orientations and 3 scales
 - 8 Laplacian of Gaussian (LOG) filters
 - 4 Gaussians.
- LM Small (LMS) filters occur at scales $\sigma = \{1, \sqrt{2}, 2, 2\sqrt{2}\}$
- LM Large (LML) filters occur at scales $\sigma = \{\sqrt{2}, 2, 2\sqrt{2}, 4\}$
- The first and second derivatives occur at the first three scales with an elongation factor of 3 (i.e., $\sigma_x = \sigma$ and $\sigma_y = 3\sigma$).
- The Gaussians occur at four basic scales.
- The 8 LOG occur at σ and 3σ .

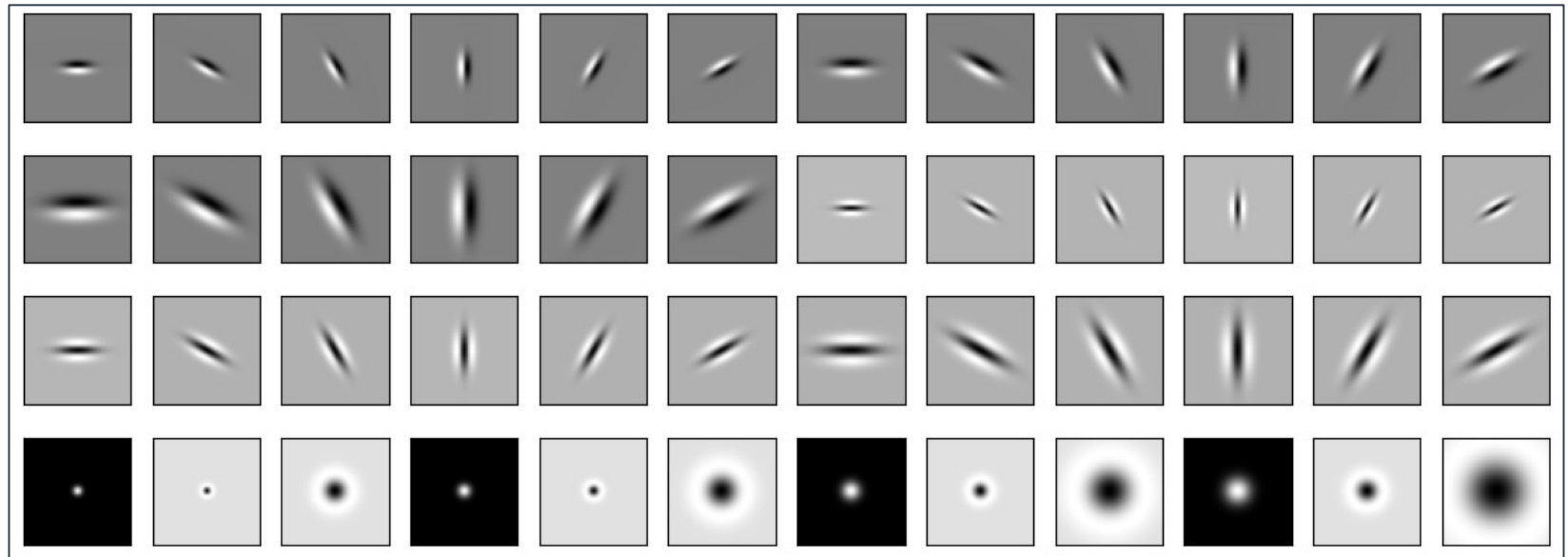


LM Filters

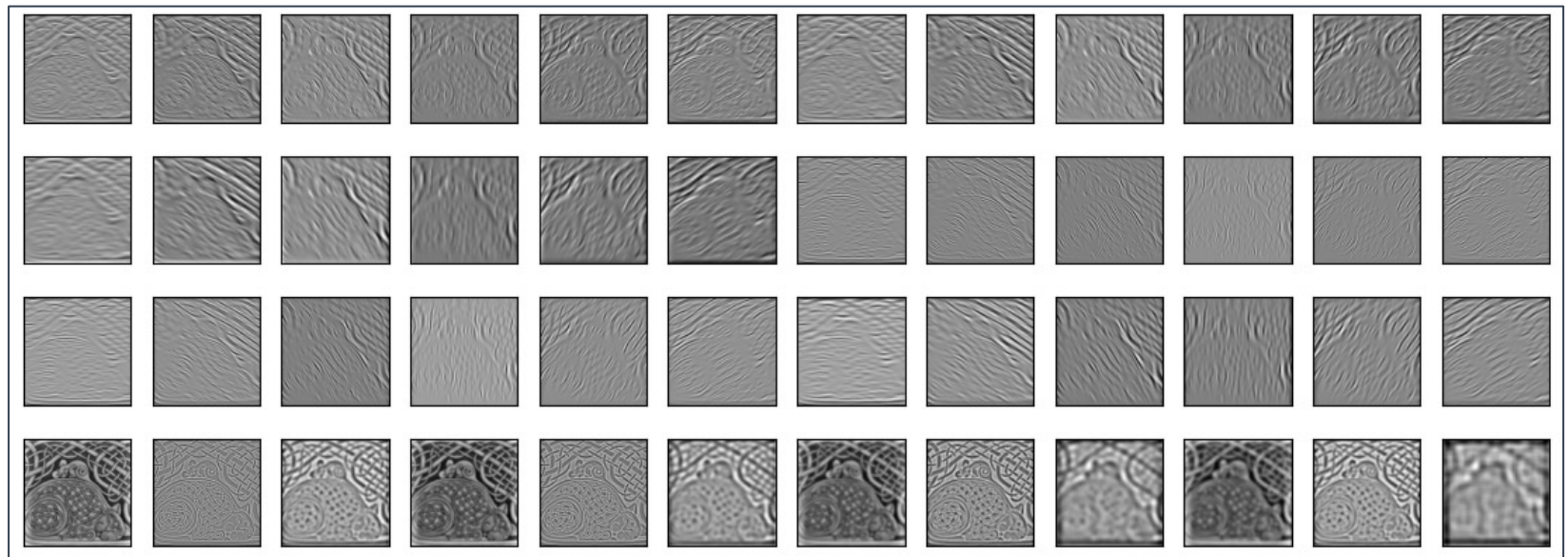




LM Filters

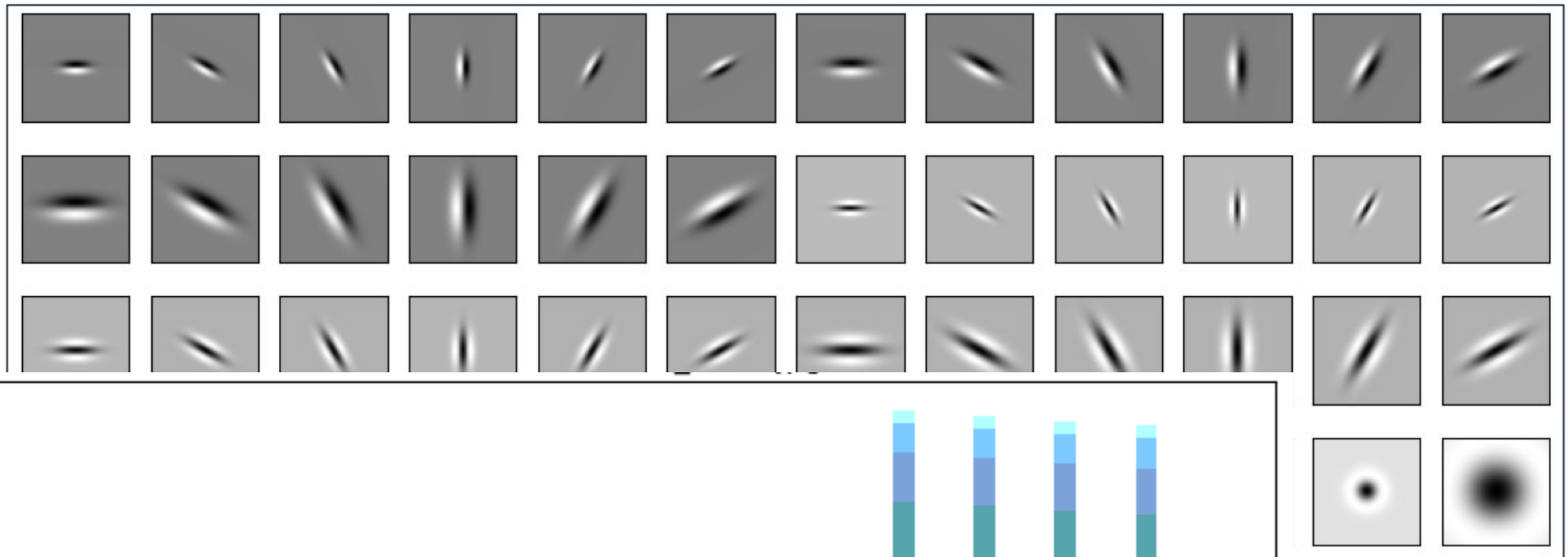


Response

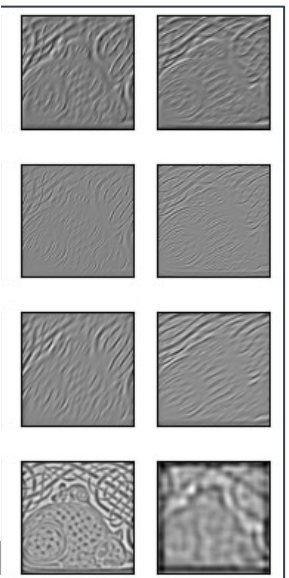
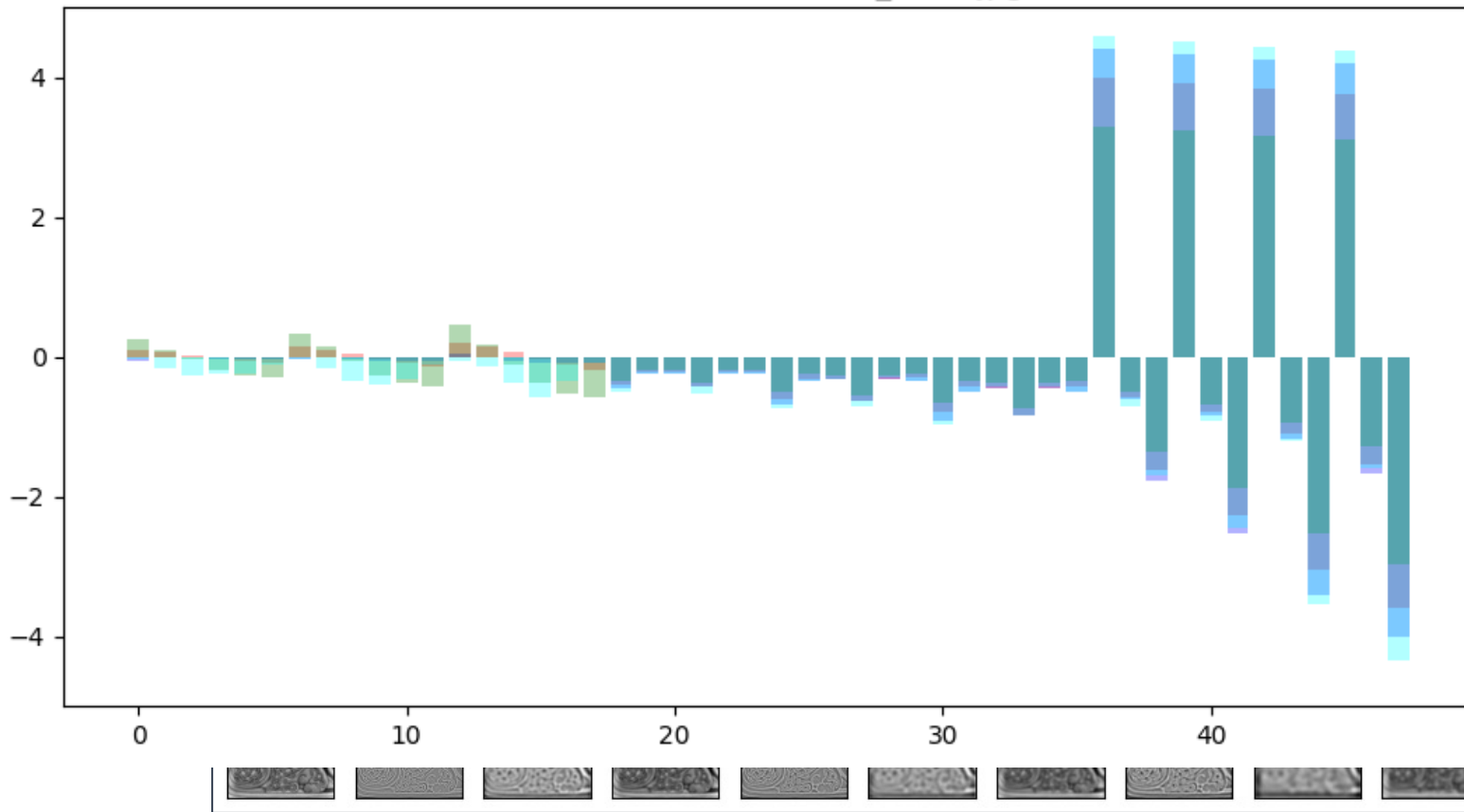




LM Filters

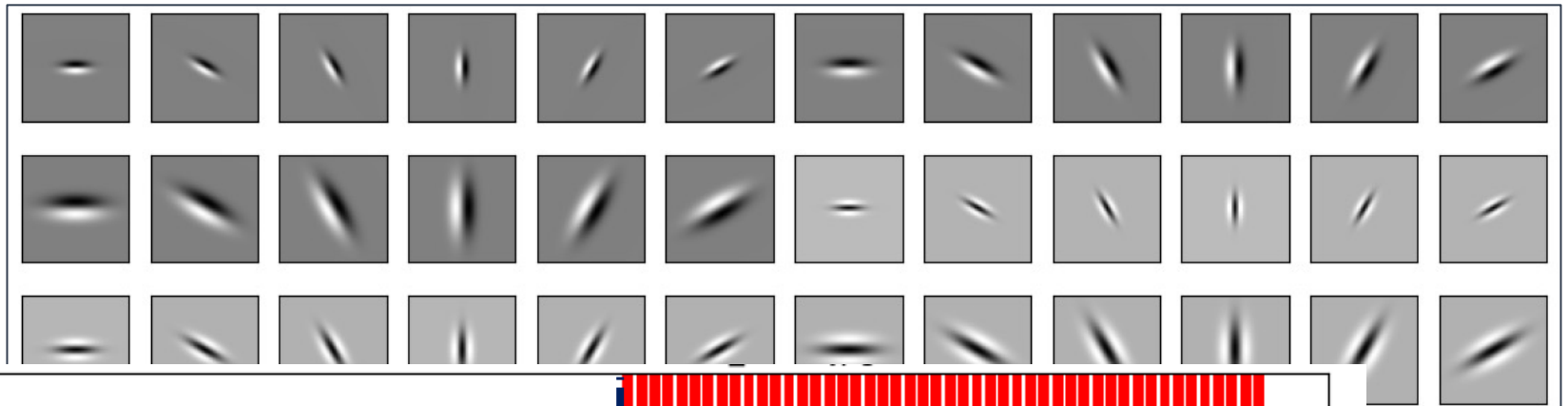


LM Filter Response
(mean values)

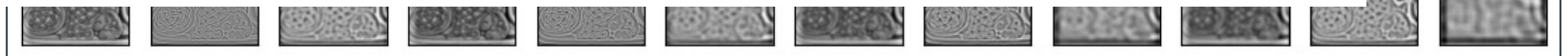
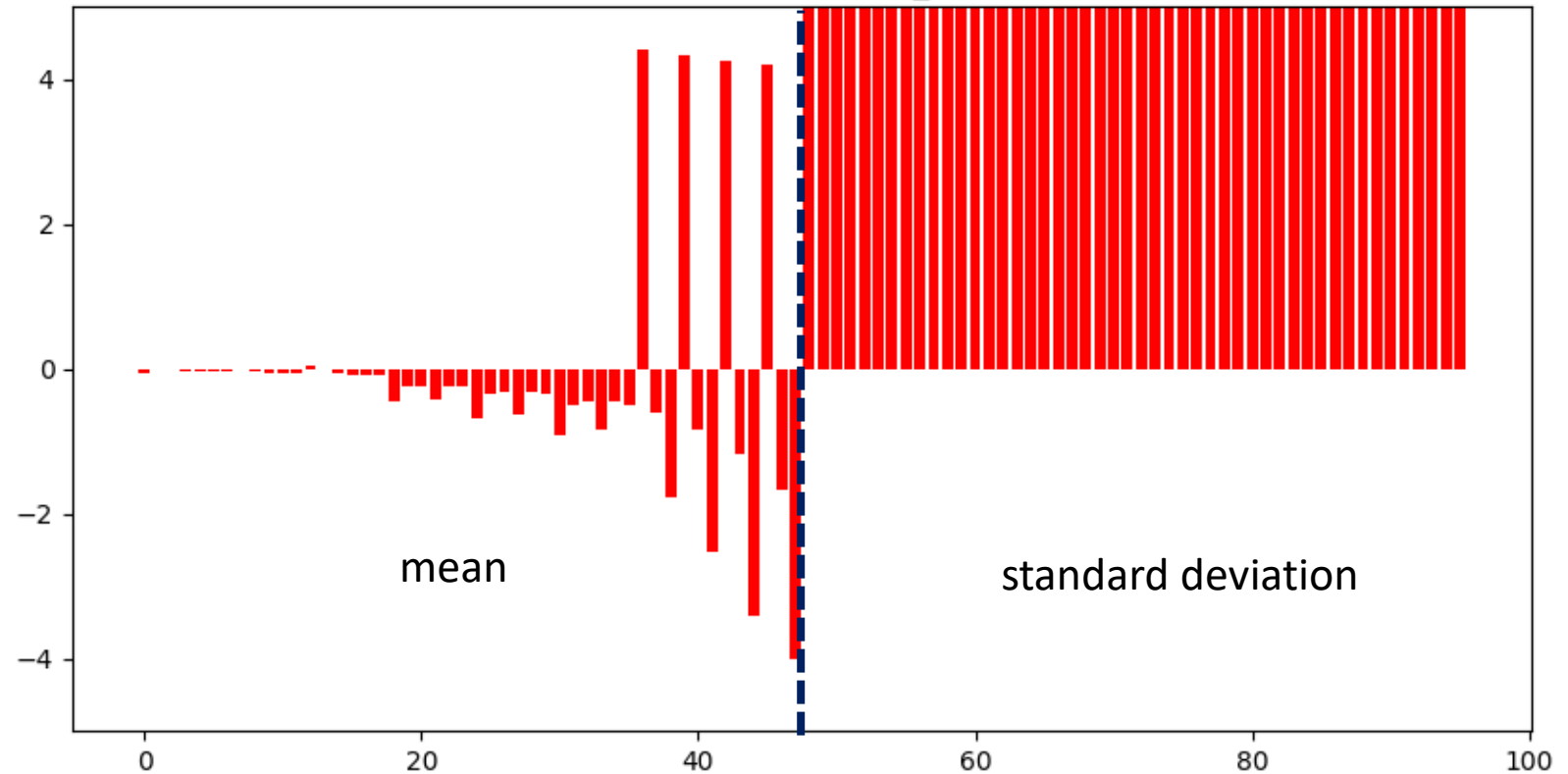




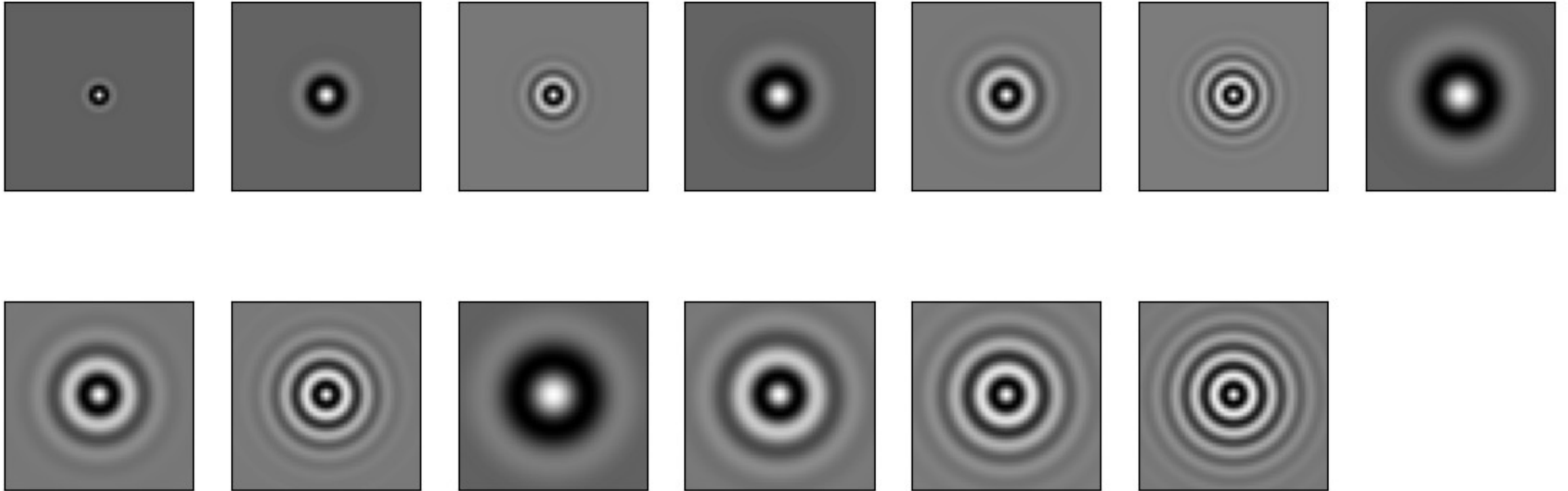
LM Filters



LM Filter Response



Schmid Filter Bank



Schmid Filter Bank

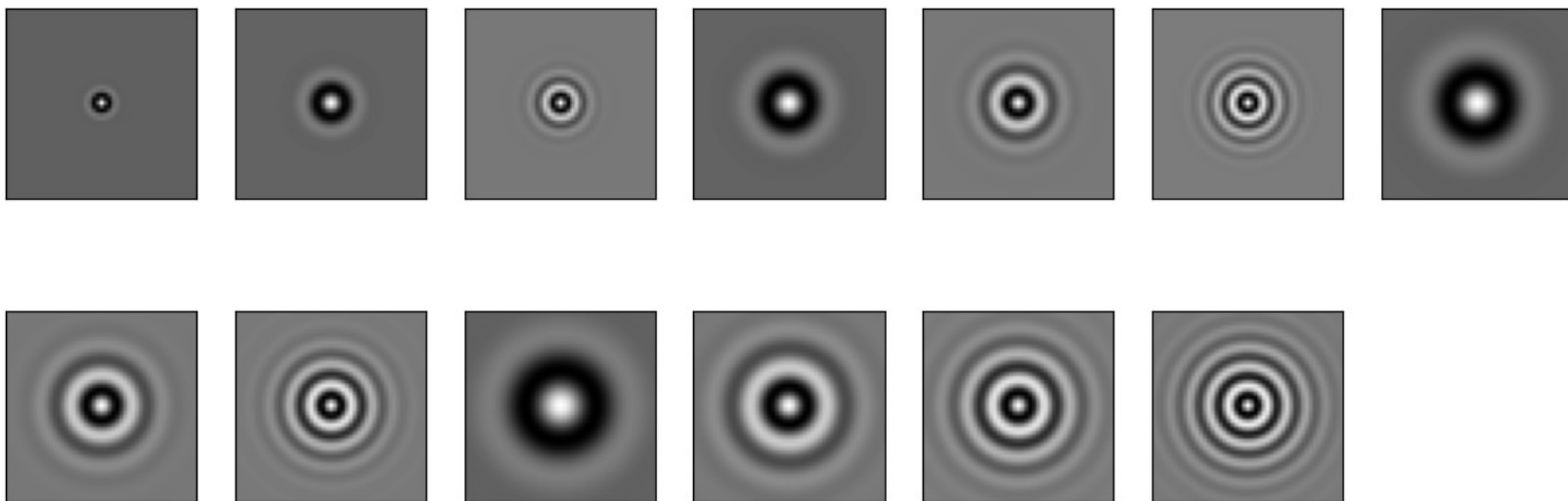
- 13 rotationally invariant filters of the form

$$F(r, \sigma, \tau) = F_0(\sigma, r) + \cos\left(\frac{\pi\tau r}{\sigma}\right) e^{-\frac{r^2}{2\sigma^2}}$$

- Schmid Filter Bank equation where F_0 is added to obtain a zero DC component
- (σ, τ) pair takes the following values:
(2,1), (4,1), (4,2), (6,1), (6,2), (6,3), (8,1), (8,2), (8,3), (10,1), (10,2), (10,3), (10,4)
- These filters have rotational symmetry

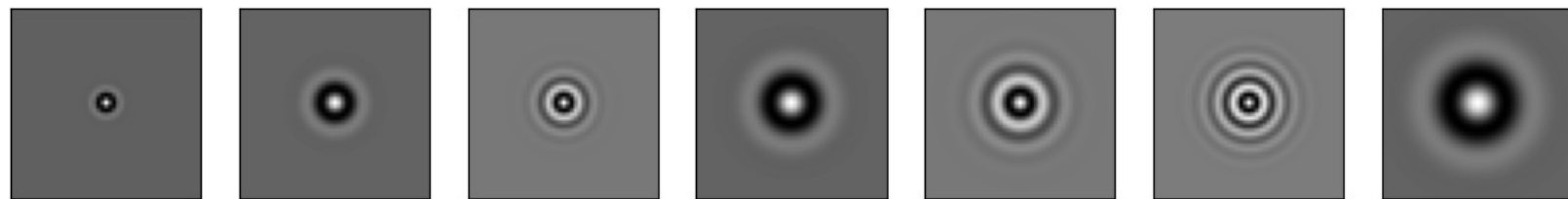


Schmid Filter Bank

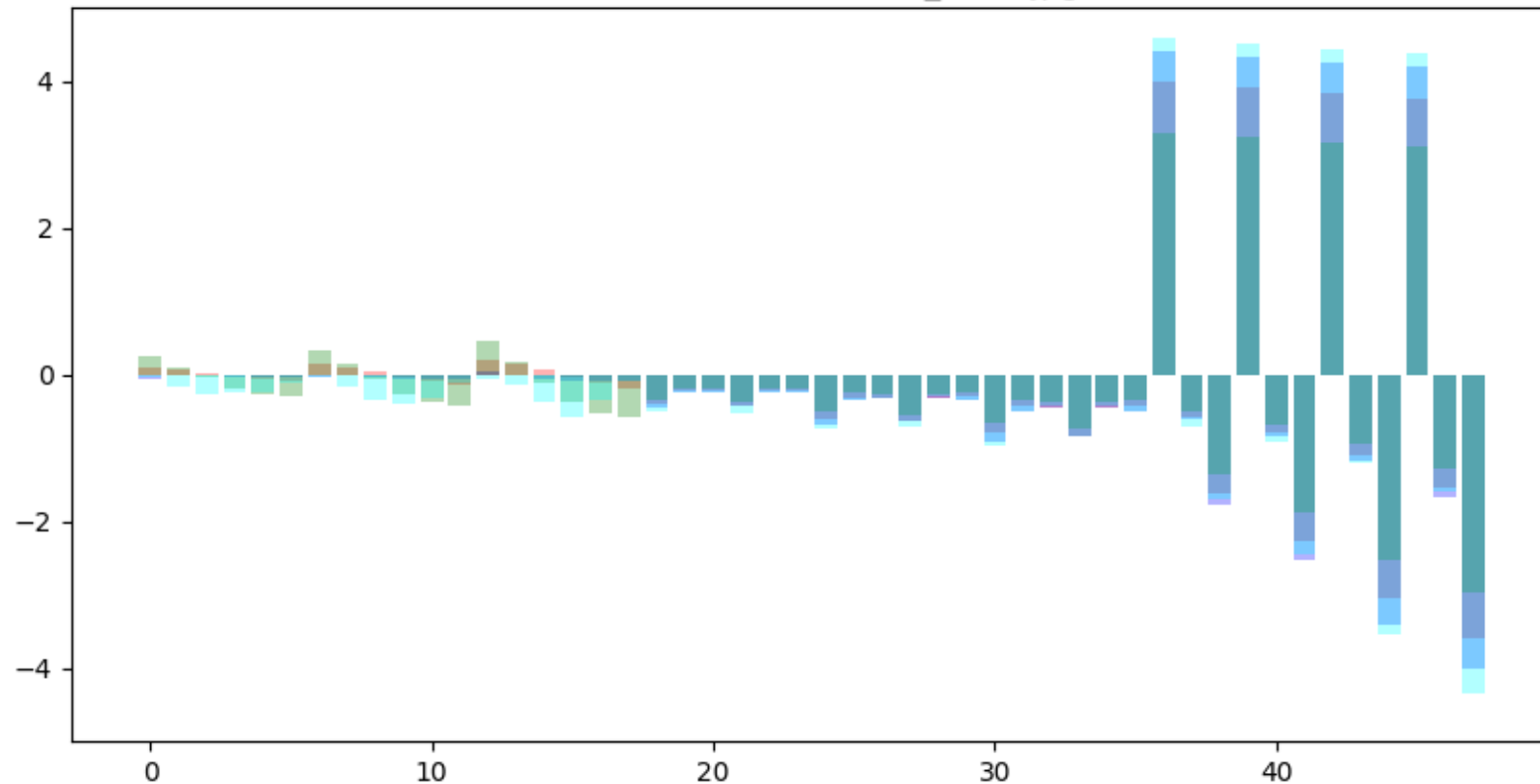




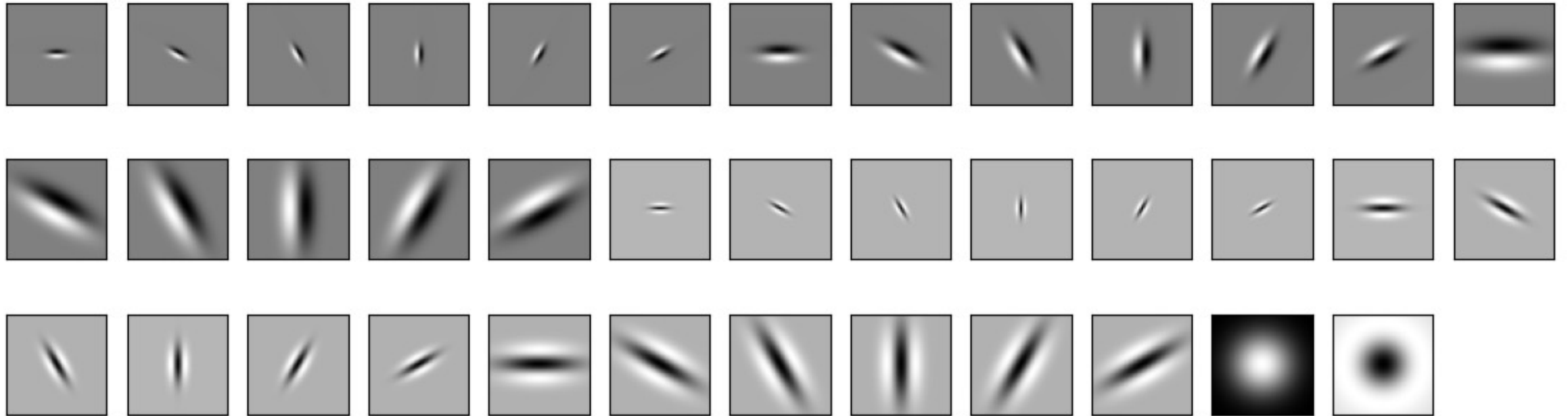
Schmid Filter Bank



S Filter Response



Maximum-Response Filter Bank

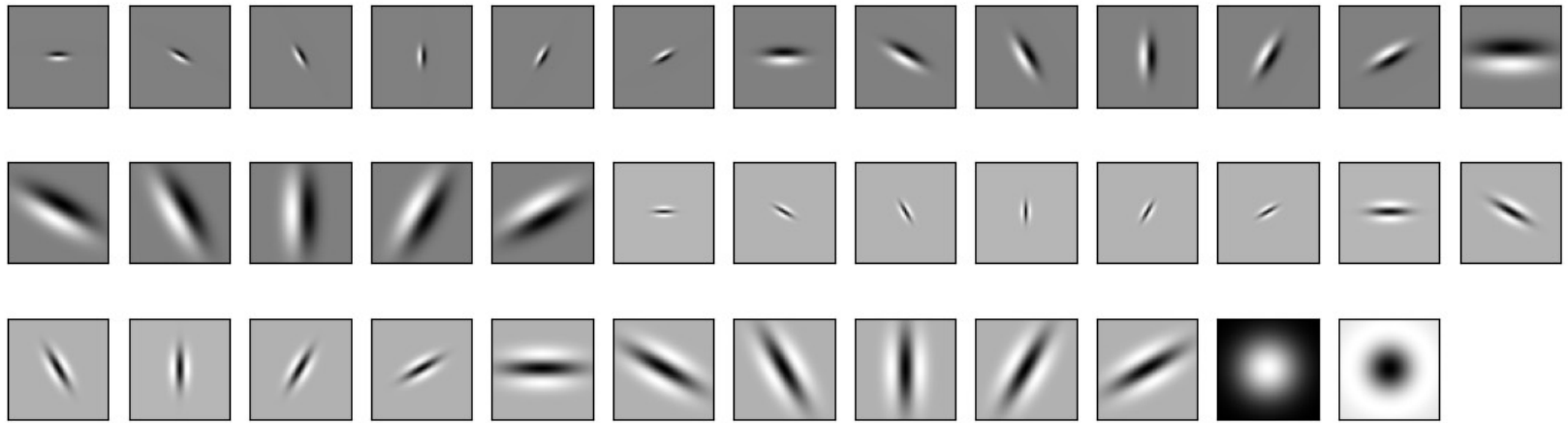


Maximum-Response Filter Bank

- Derived from a common Root Filter Set (RFS), which consists of 38 filters (very similar to LM filters).
 - Gaussian and Laplacian of Gaussian with $\sigma = 10$
 - Edge filter 3 scales: (1,3), (2,6), and (4,12)
 - 6 orientations
 - Bar filter at 3 scales
 - 6 orientations

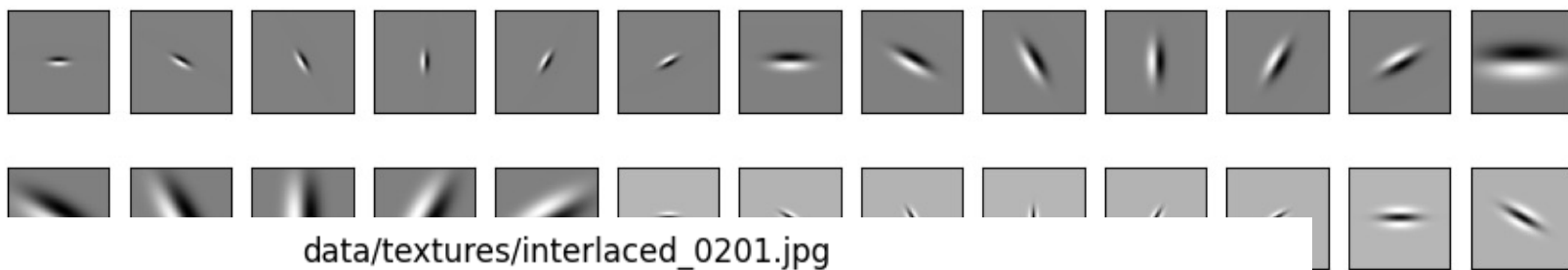


Maximum Response Filter Bank

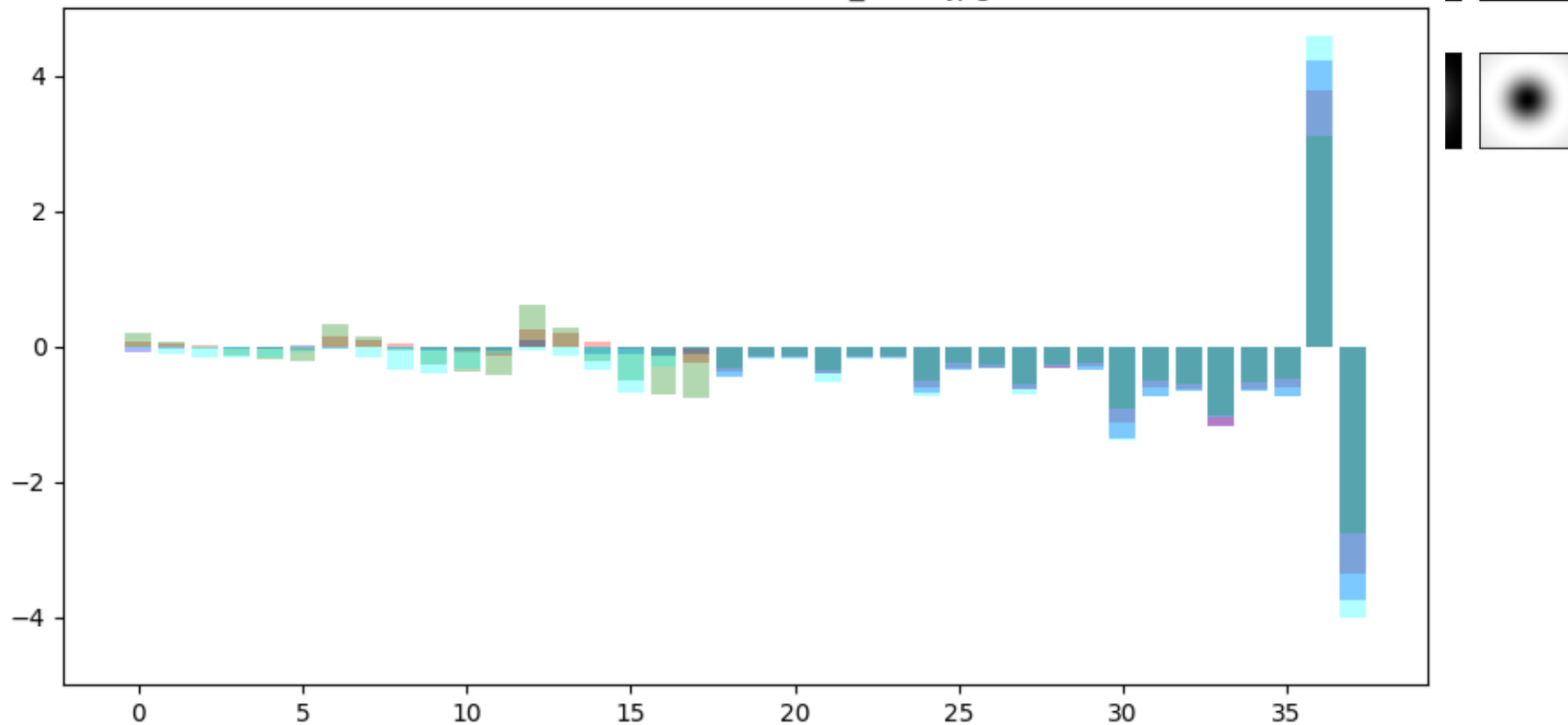




Maximum Response Filter Bank



MR Filter Response



Texture analysis and synthesis

- Computational photography
 - Repair defects, e.g., fill holes
 - Generate non-photorealistic painterly renderings



(Bertalmio, Sapiro et al. 2000) © 2000 ACM;



(Criminisi, Pérez, and Toyama 2004)

Texture analysis and synthesis

- Computational photography
 - Repair defects, e.g., fill holes
 - Generate non-photorealistic painterly renderings



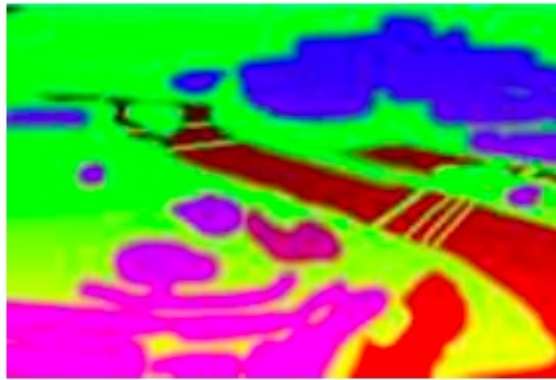
(Hertzmann, Jacobs et al. 2001)

Texture analysis and synthesis

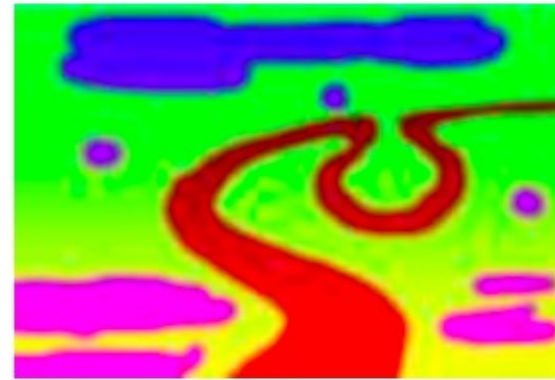
- Computational photography
 - Repair defects, e.g., fill holes
 - Generate non-photorealistic painterly renderings



Original A'



Painted A



Novel painted B



Novel textured B'

(Hertzmann, Jacobs et al. 2001)

Boundary detection

- An interplay of textures



Boundary detection

- An interplay of textures



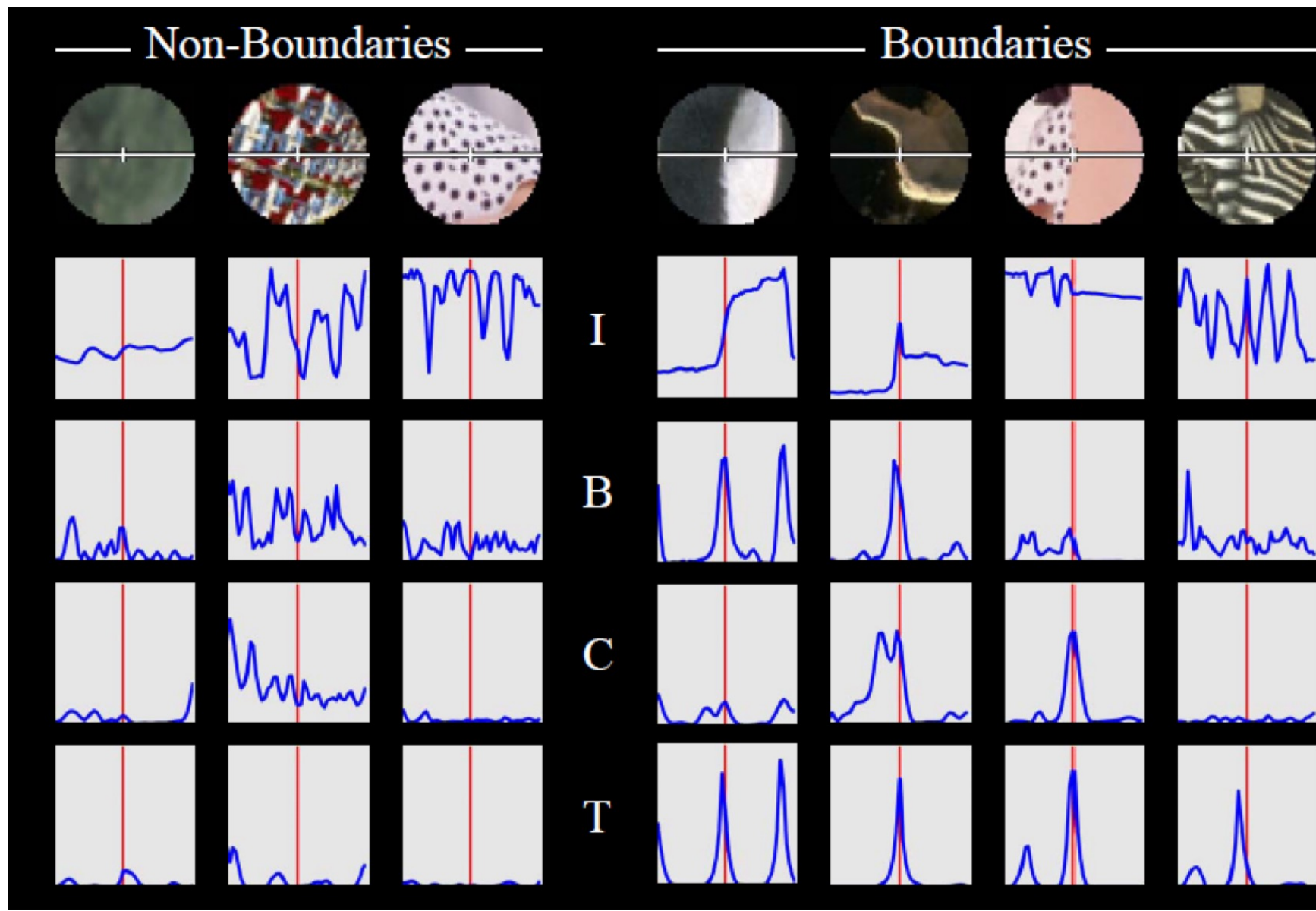
Boundary detection

- An interplay of textures



pB Boundary Detector

- Martin, Fowlkes, and Malik, 2004



pB Boundary Detector

Brightness

Color

Texture

Combined

Human

Image

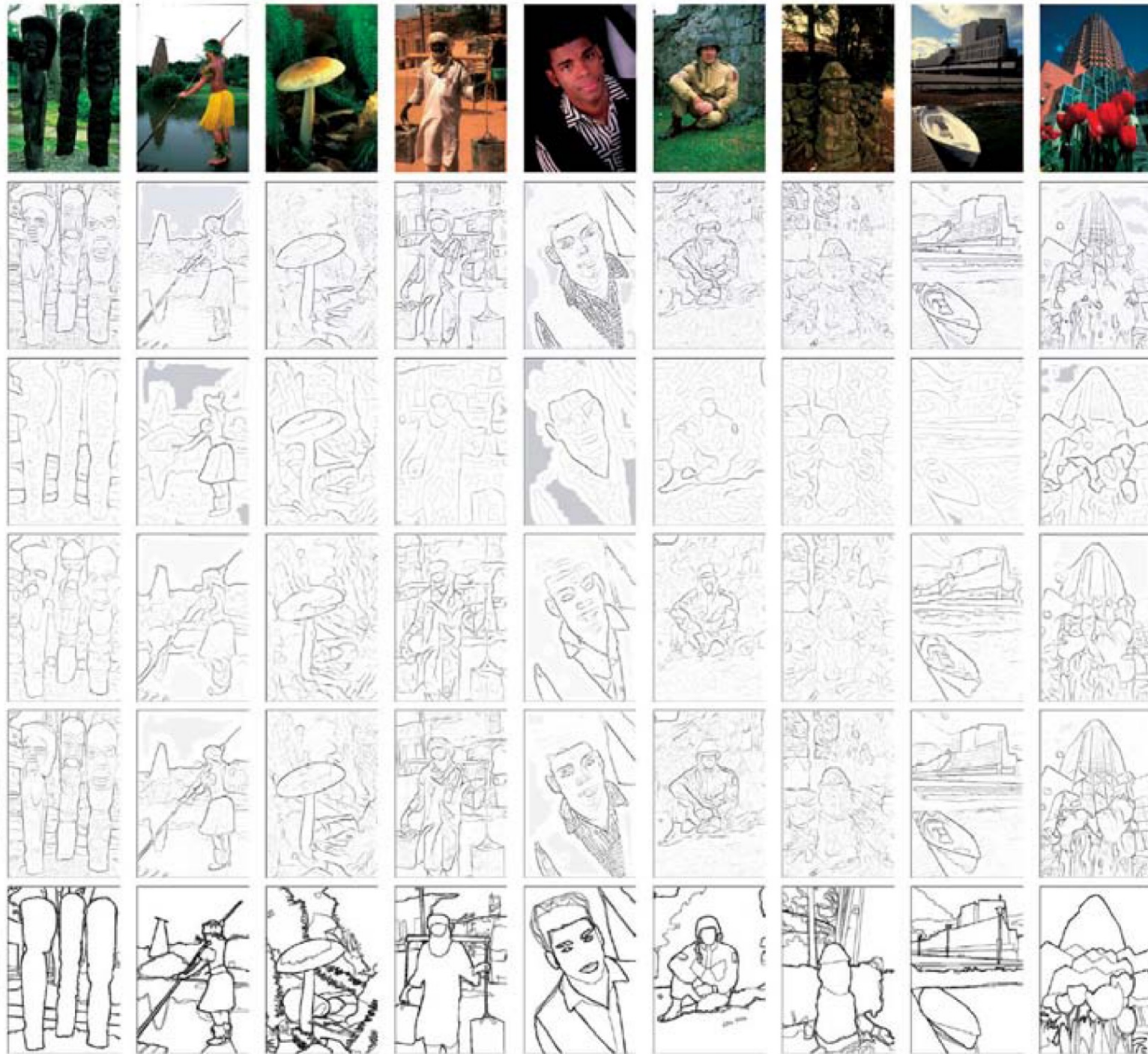
BG

CG

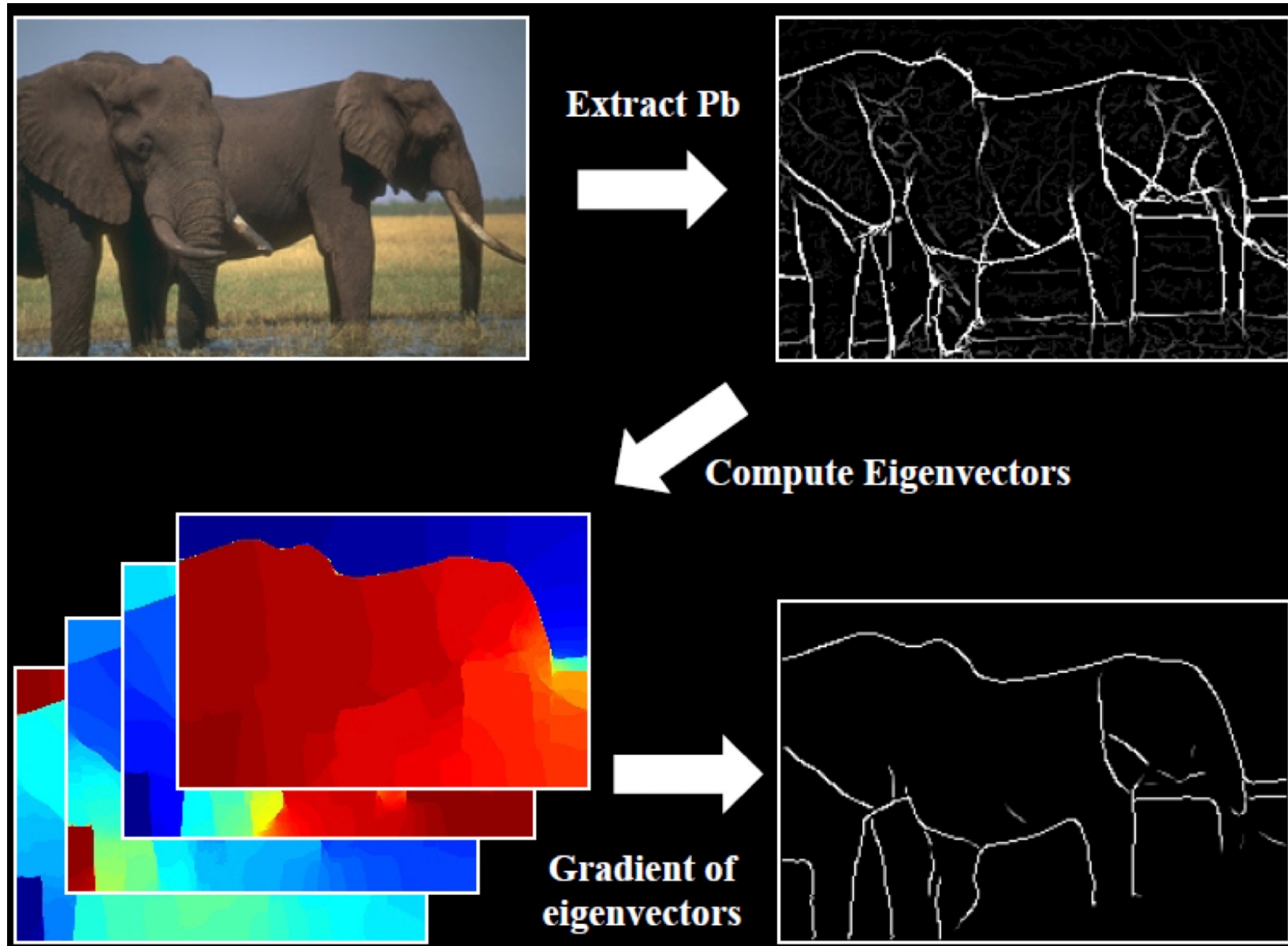
TG

BG+CG+TG

Human

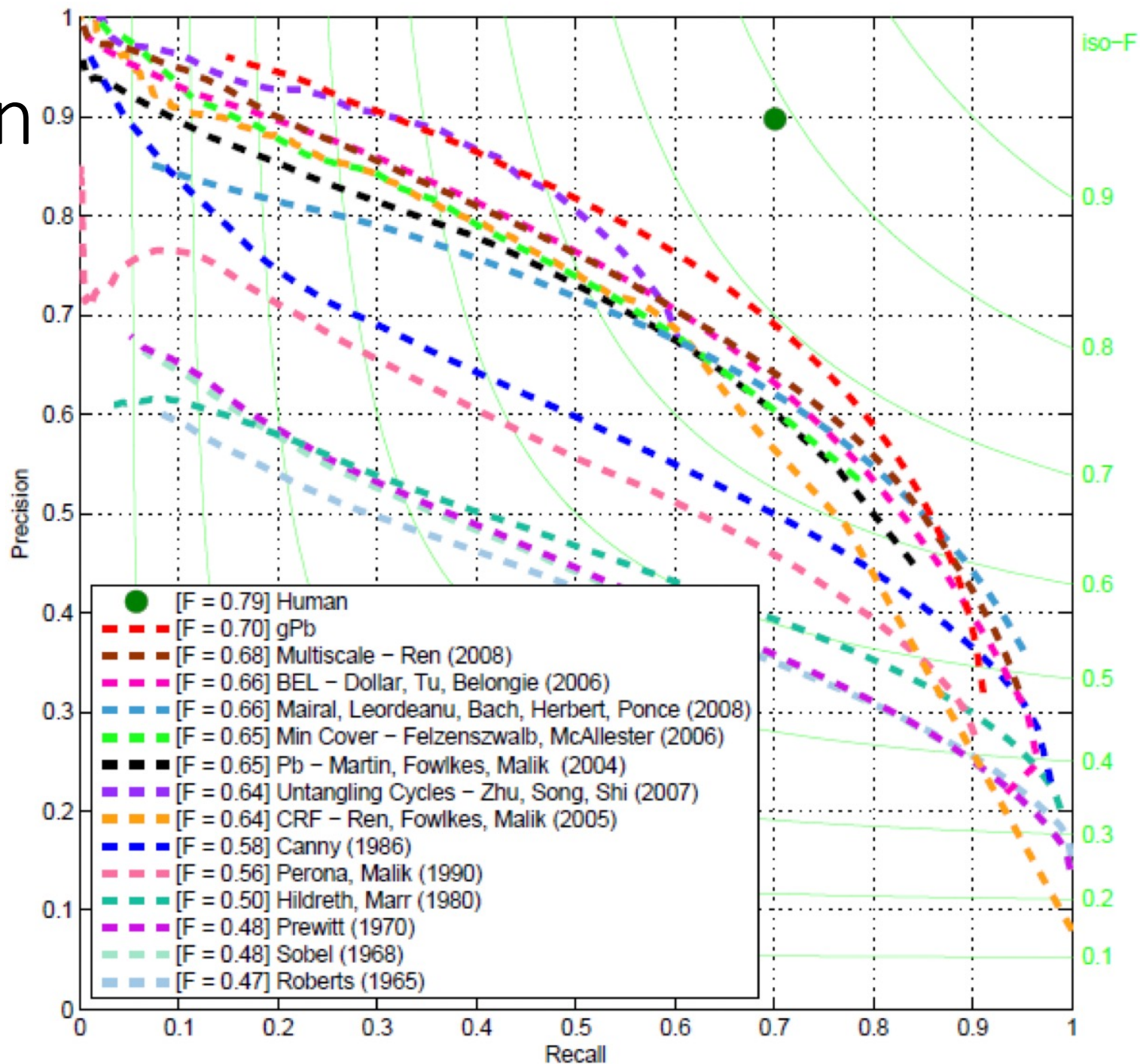


Global pB Boundary Detector



Boundary Detection

Before deep learning



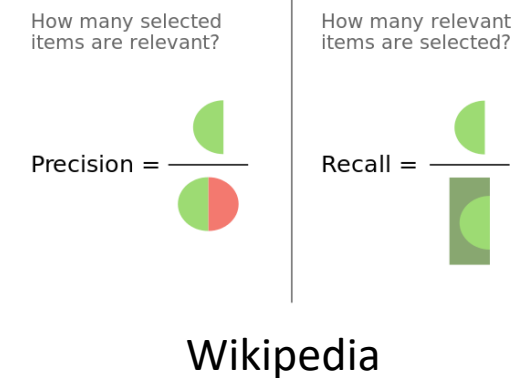
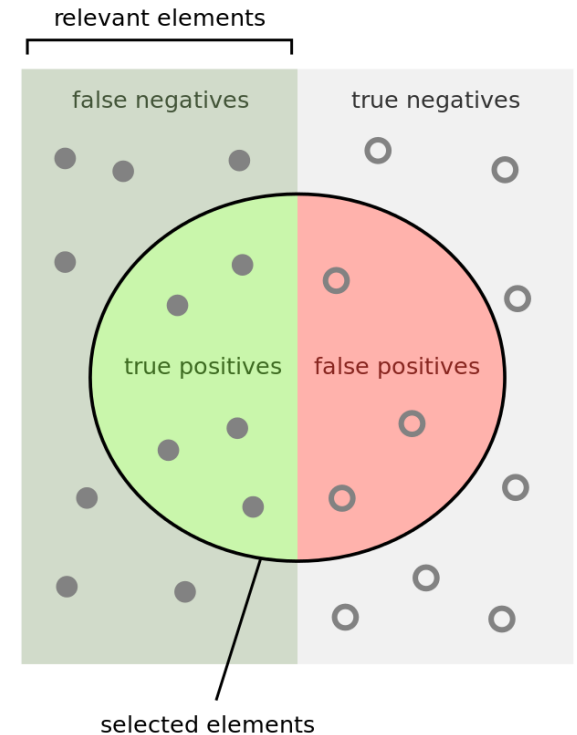
Metrics

- Precision (positive predictive value)
 - Fraction of relevant instances during retrieval

$$\text{Precision} = \frac{TP}{TP + FP}$$

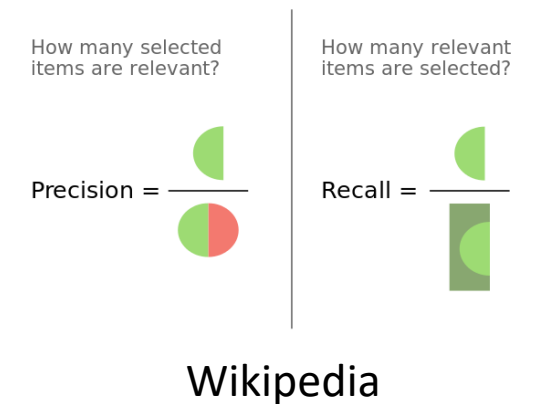
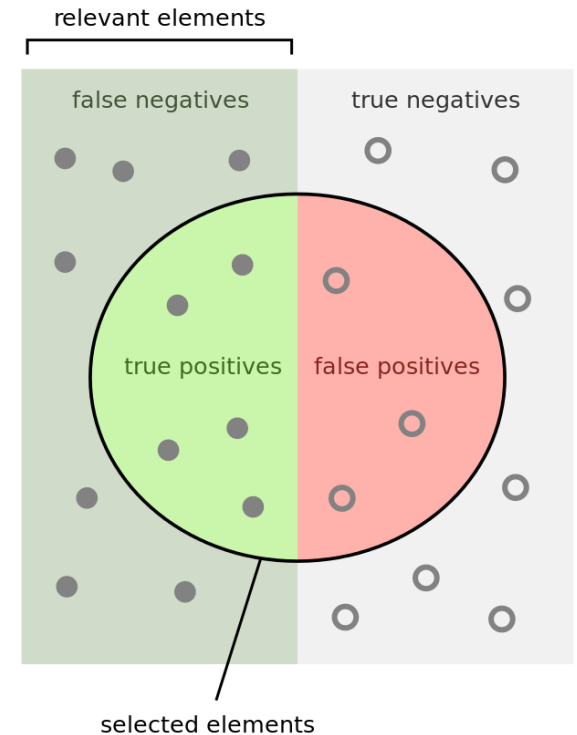
- Recall (true positive rate or sensitivity)
 - Fraction of relevant instances that have been retrieved over the total number of relevant instances

$$\text{Recall} = \frac{TP}{TP + FN}$$



Precision vs. recall

- High precision means that an algorithm returned substantially more relevant results than irrelevant ones, while high recall means that an algorithm returned most of the relevant results.



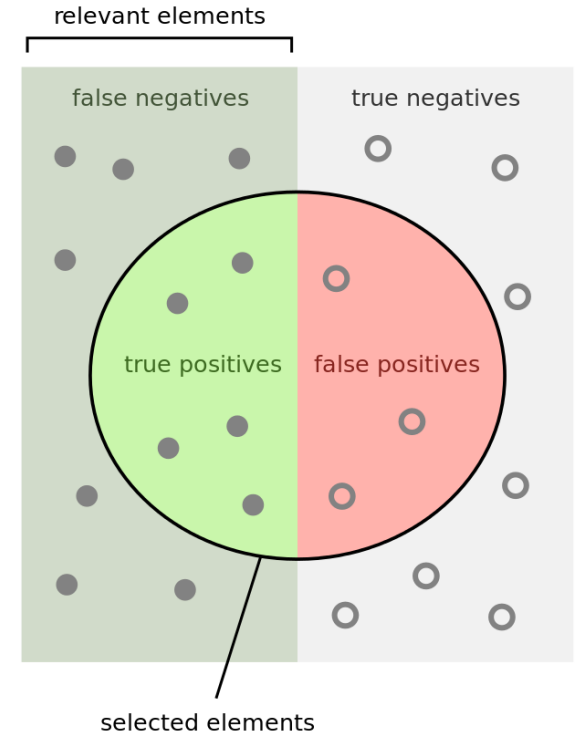
Specificity and accuracy

- Specificity
 - True negative rate

$$\text{Specificity} = \frac{TN}{TN + FP}$$

- Accuracy

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$



Wikipedia

Deep learning approaches

<https://paperswithcode.com/task/boundary-detection>

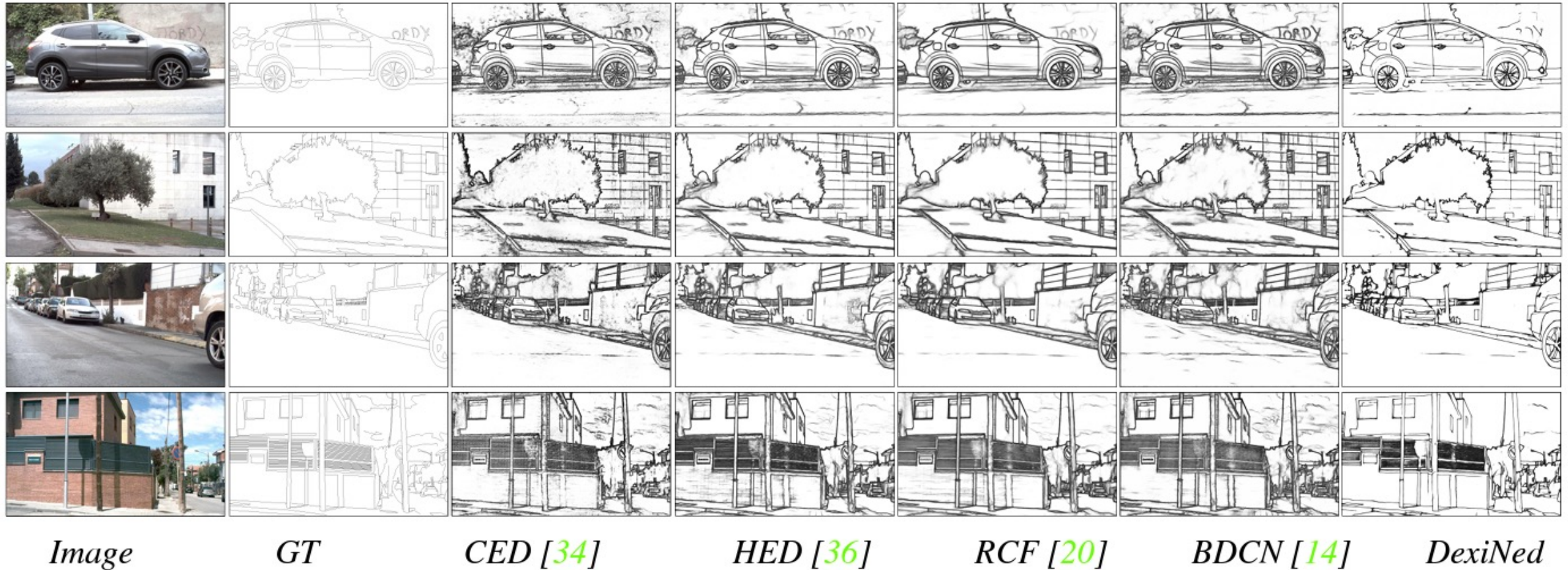


Figure 7. Results from different edge detection algorithms trained and evaluated in BIPED dataset.

Soria et al. 2020

[Dense Extreme Inception Network: Towards a Robust CNN Model for Edge Detection](#)

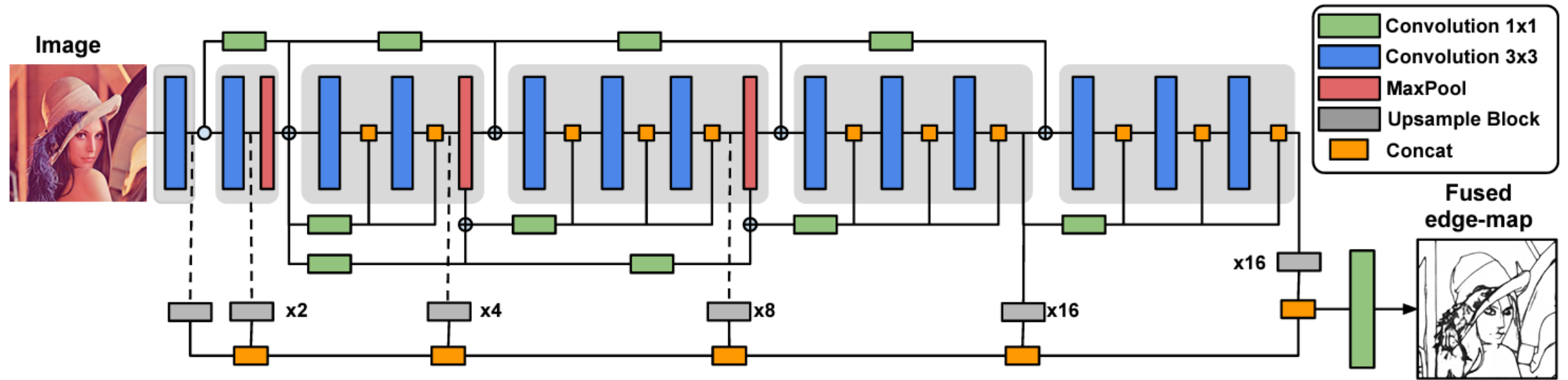


Figure 3. Proposed architecture: Dense Extreme Inception Network, consists of an encoder composed by six main blocks (showed in light gray). The main blocks are connected between them through 1x1 convolutional blocks. Each of the main blocks is composed by sub-blocks that are densely interconnected by the output of the previous main block. The output from each of the main blocks is fed to an upsampling block that produces an intermediate edge-map in order to build a Scale Space Volume, which is used to compose a final fused edge-map. More details are given in Sec. 3.

Summary

- Texture analysis
 - Description
- Filter banks
 - LM
 - S
 - MR
- Texture analysis and synthesis in computational photography
- The role of texture in boundary detection
- Metrics
 - Precision and recall