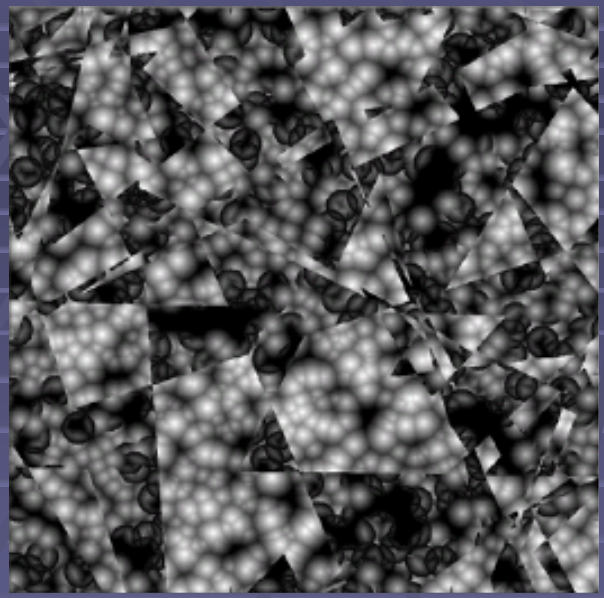
# Segmentation of random textures by morphological and linear operators

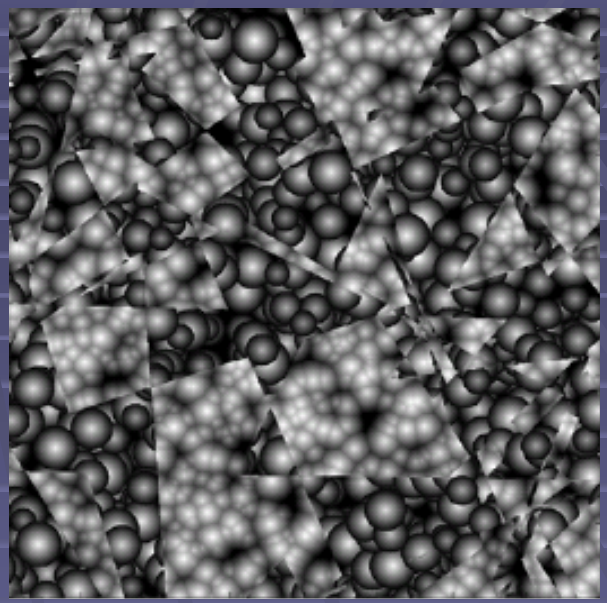
A. Cord, F. Bach and D. Jeulin

October 11th, 2007

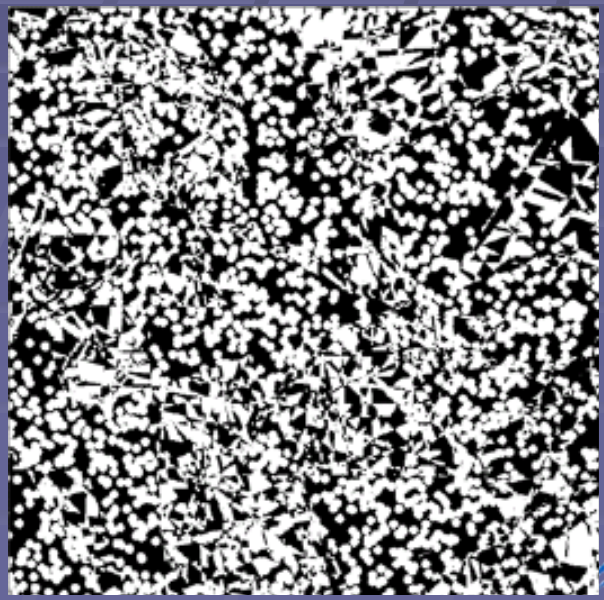


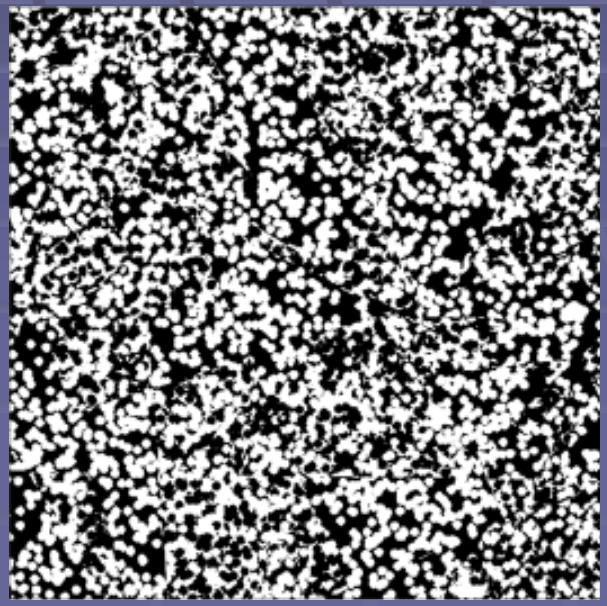
# Objectives





Segmentation of digital and binary random textures





Centre de Morphologie Mathématique

# Outline

1. Pixel texture description
2. Machine learning
3. Application
    1. Simulated random texture images
    2. Experiments

# Theoritical approach of random textures

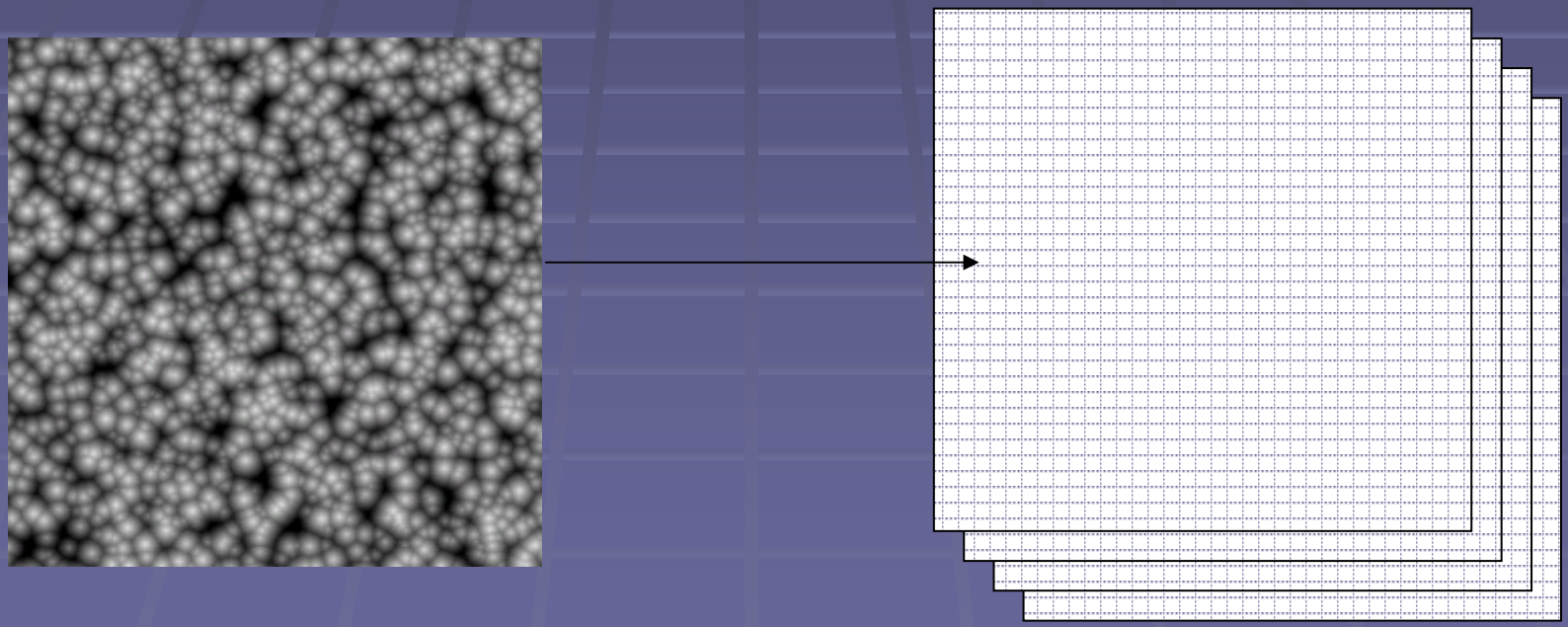
- Textures -> fluctuations at a small scale, uniformity at a large scale.
- It requires the use of a probabilistic approach
- A random texture is completely known from its Choquet capacity.
- Good candidates for texture descriptors can be provided by estimates of probabilities obtained after dilations (or erosions) by compact sets.

# Texture segmentation

- **From Image to pixels**
- **Classification of pixels into textures**: needs for a **local characterization** of textures
  - Transform the image by dilations, erosions (« pixel » approach), and generate a multispectral image from the collection of compact sets K
  - Use of the local estimates of *T(K), T(g)* inside a neighborhood *B(x)*, to generate a multispectral image
  - Use of measures $\mu_i$ with a compact support $K_i$ and estimate $\mu_i(A)$ , to generate a multispectral image; examples: linear filters, multiscale convolution, local measurement of Minkowski functionals of a RS,…

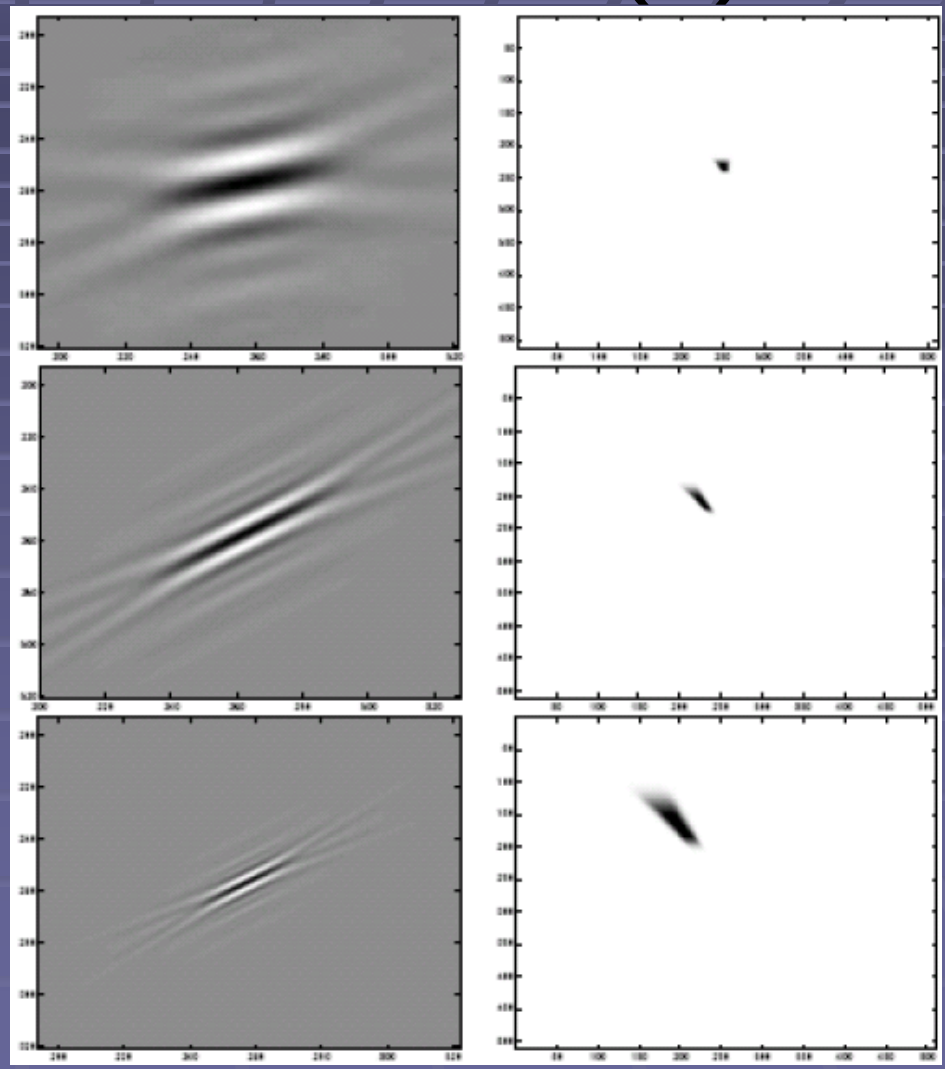
# Texture properties description

- Texture properties calculated for each pixel, accounting for local properties in neighborhoods with varying scales.

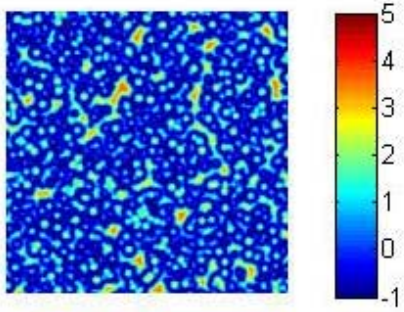


# Linear Filters : Curvelets (1)

- Directional and frequential filtering
- 4 frequencies
- 16 angles
- Descriptor dimension = 26

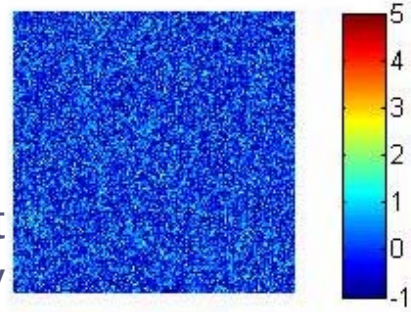


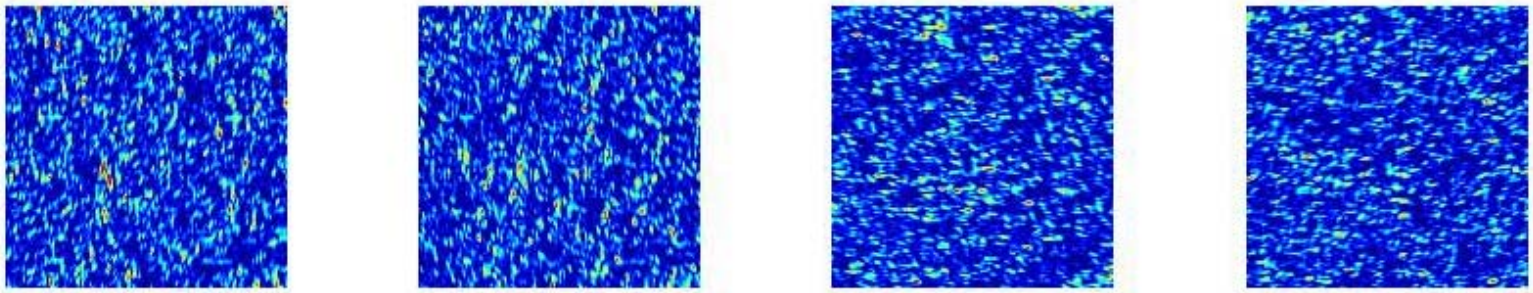
# Curvelets (2)



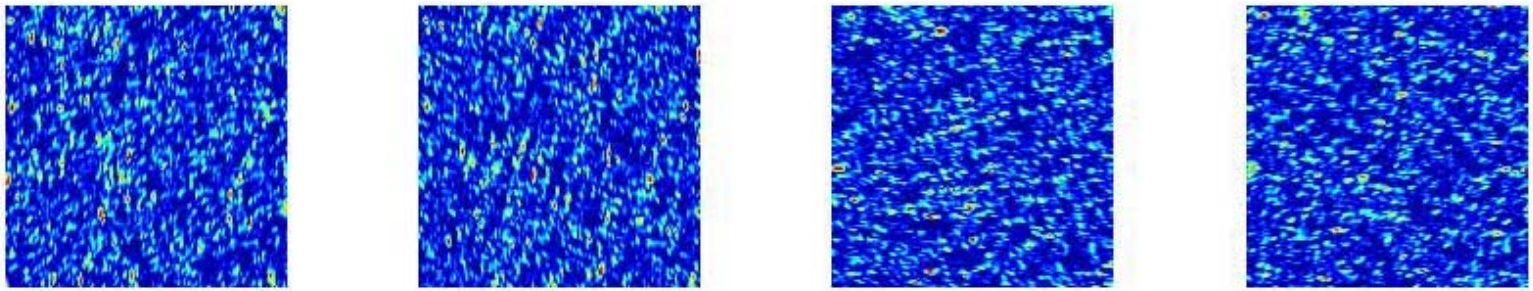

Lowest Frequency

Highest Frequency

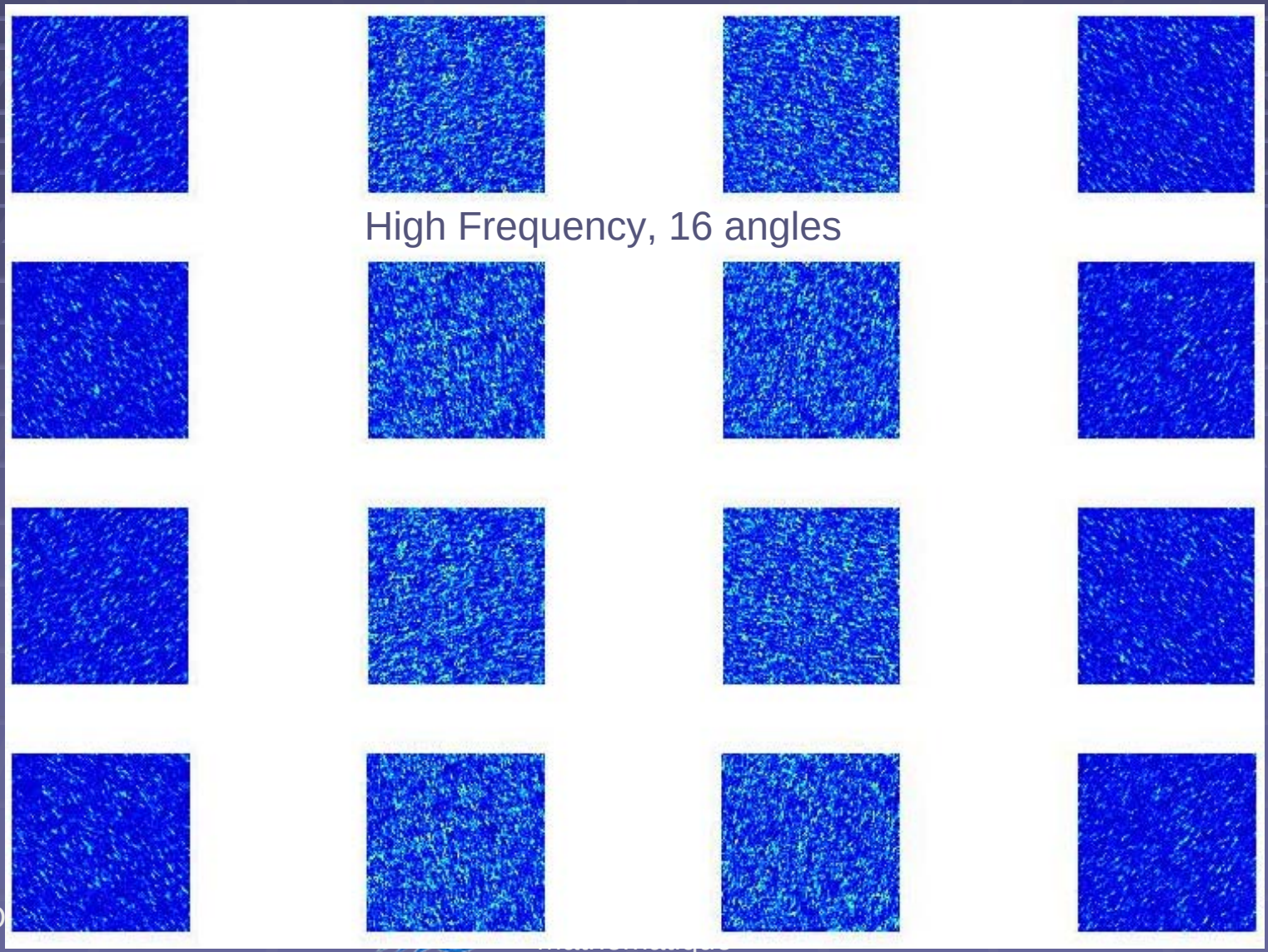


Low Frequency, 8 angles

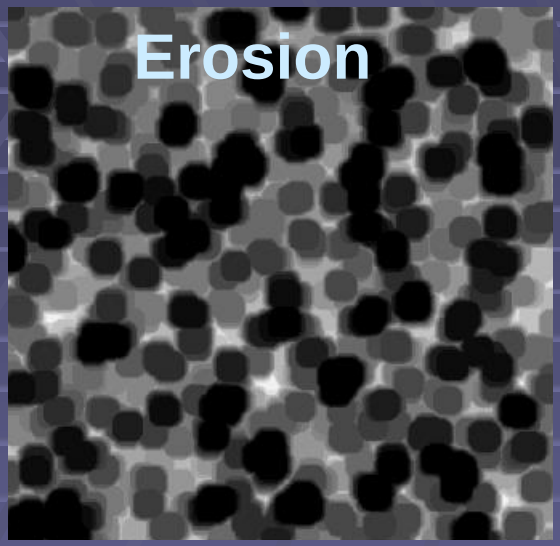


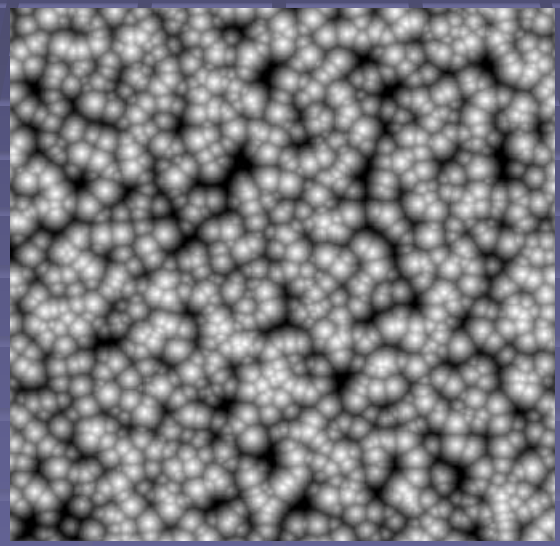
# Curvelets (3)

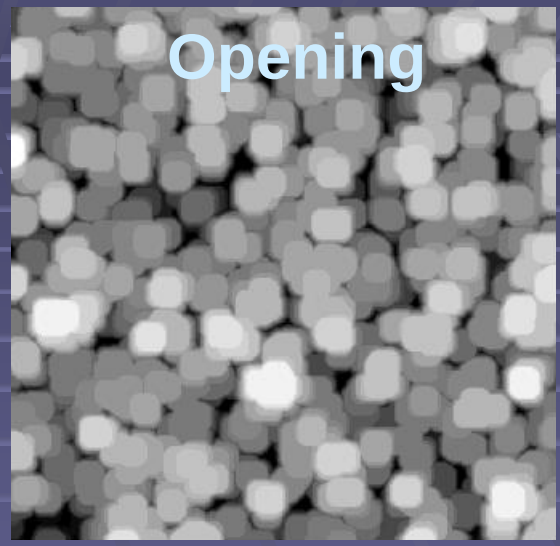


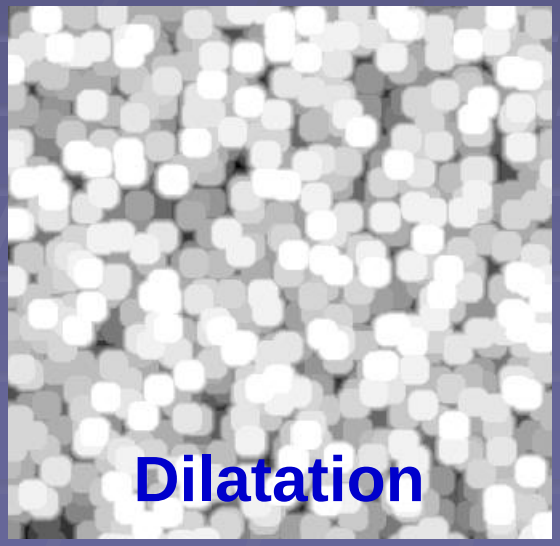
High Frequency, 16 angles

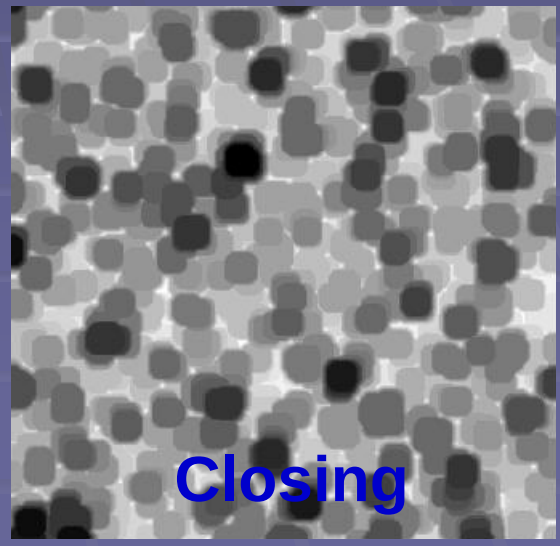
# Morphological description (1)





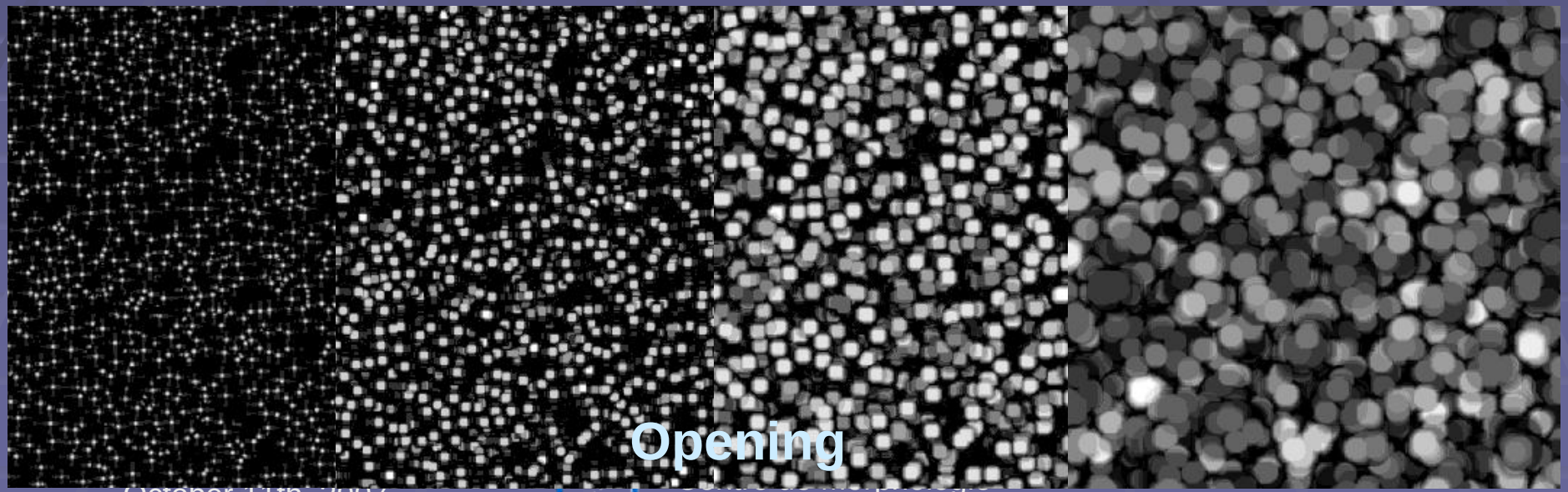




Centre de Morphologie Mathématique

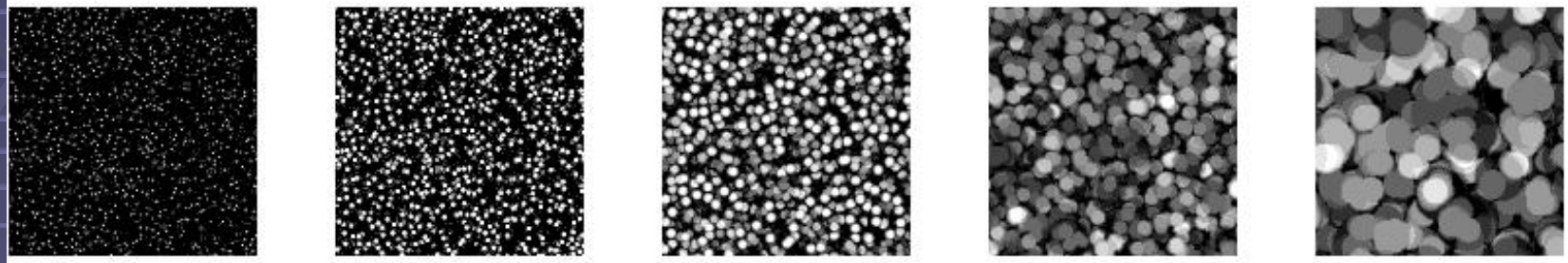
# Morphological Descriptors (2)

- Succession of openings and closings by structuring elements (disk, segment) of increasing sizes.
- Differences between the two sucessive operations

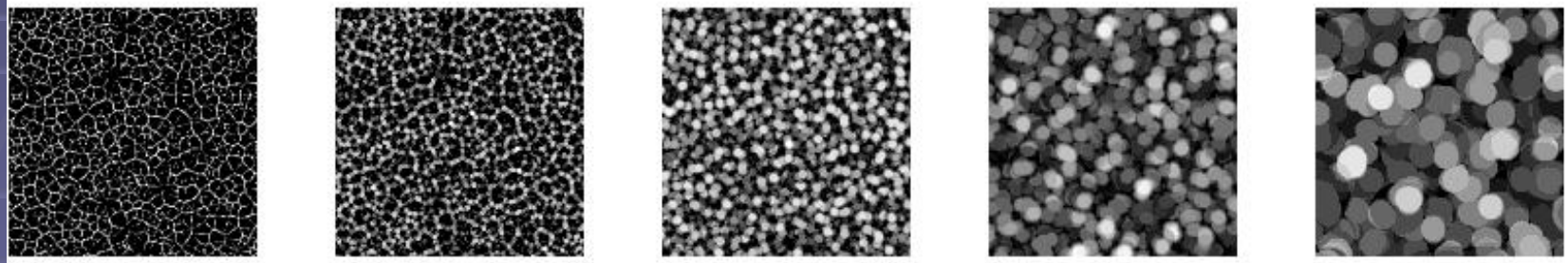


# Morphological Descriptors (2)

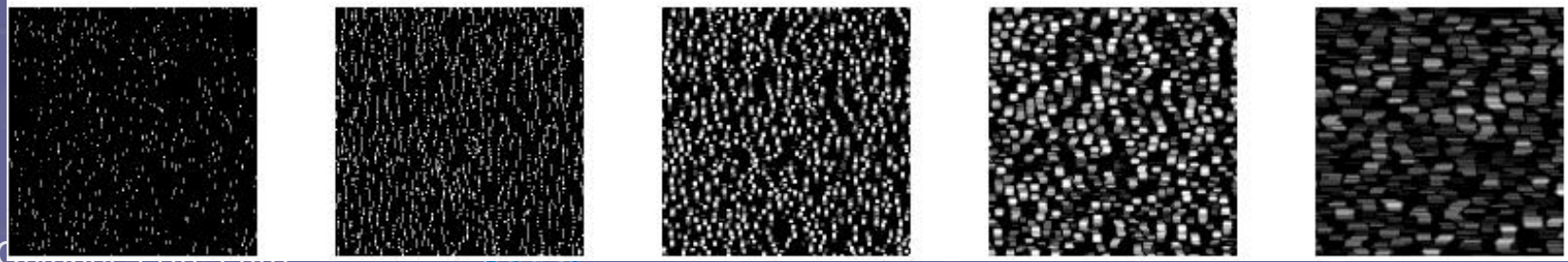
Open Disk



Close Disk



Open H line

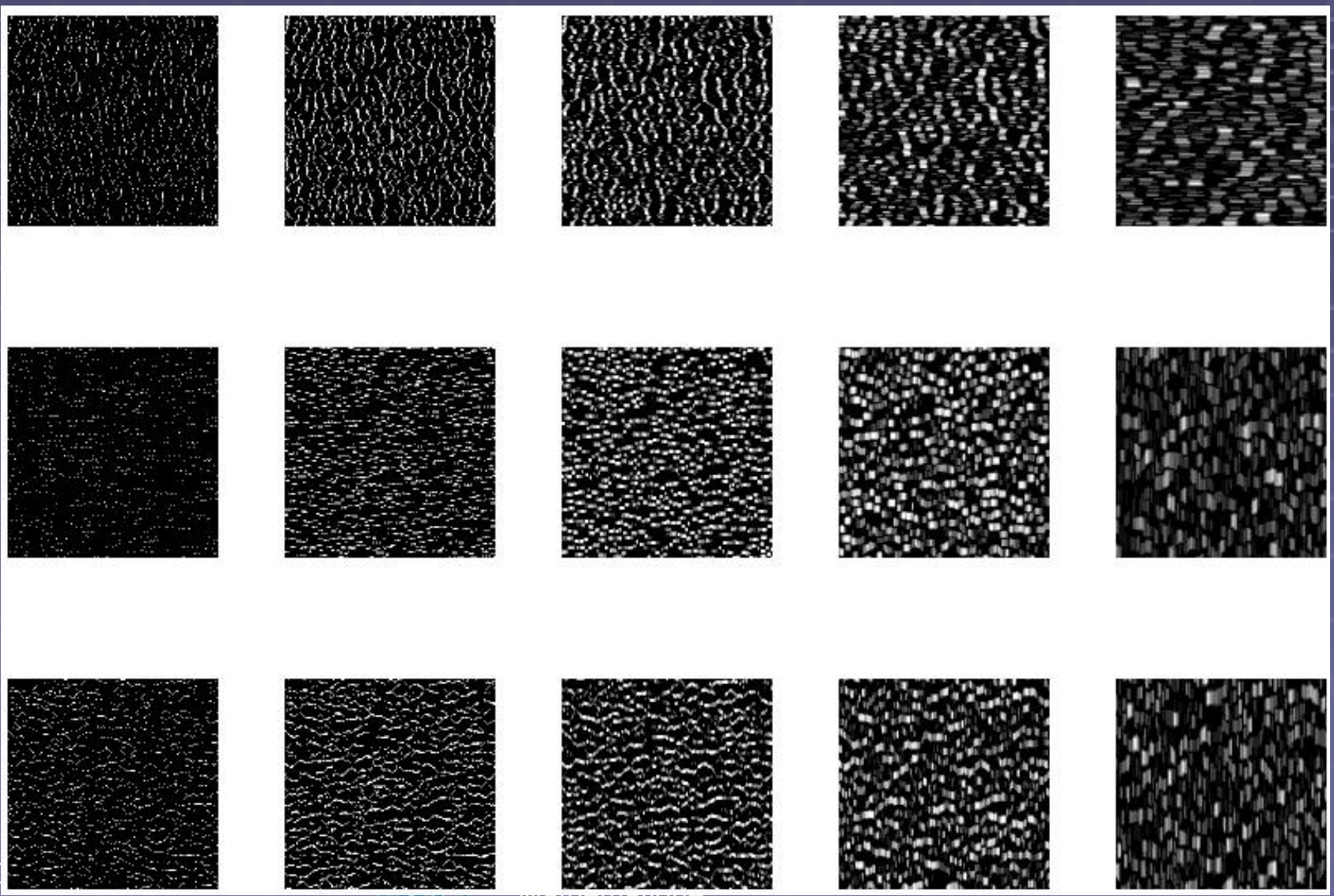


# Morphological Descriptors(3)

Close H line

Open V line

Close V line



# Texture descriptors

The texture descriptors is a combination of:

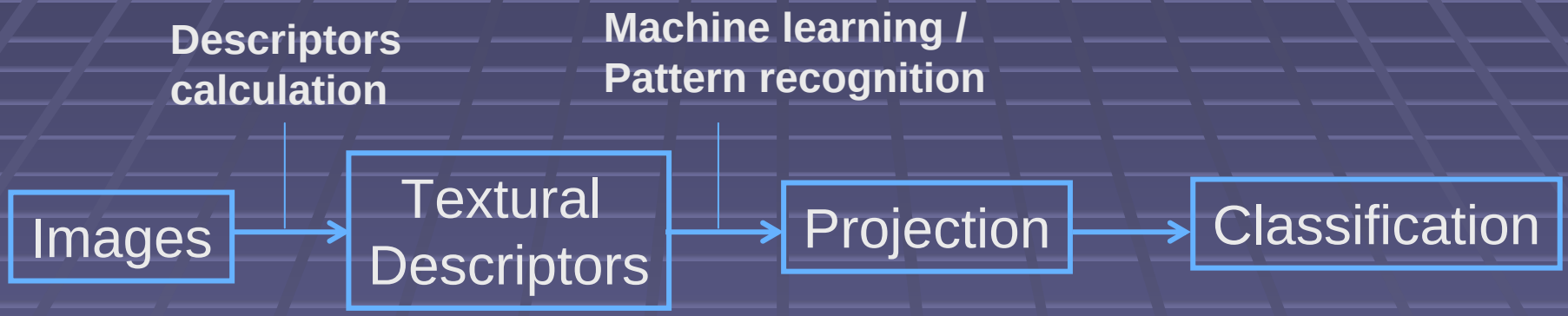
- 26 curvelets, combining 4 frequencies and 16 directions
- 126 morphological operations, with disks, vertical and horizontal lines as structuring elements and the series of sizes :
  - Opening/Closing, [2, 4, 8, 16, 32] x 2 +1 pixels.
  - Opening/Closing, [1, 2, 3, 4, 5, 7, 9, 12] x 2 +1 pixels.
  - Erosion/Dilatation, [1, 2, 3, 4, 5, 7, 9, 12] x 2 +1 pixels.

Each descriptor is averaged in a window sizing between 1x1 and 60x60.

# Outline

1. Pixel texture description
2. Machine learning
3. Application
    1. Simulated random texture images
    2. Experiments

# Methodology




Find the best descriptor projection to separate classes

# Linear Discriminant Analysis (LDA)

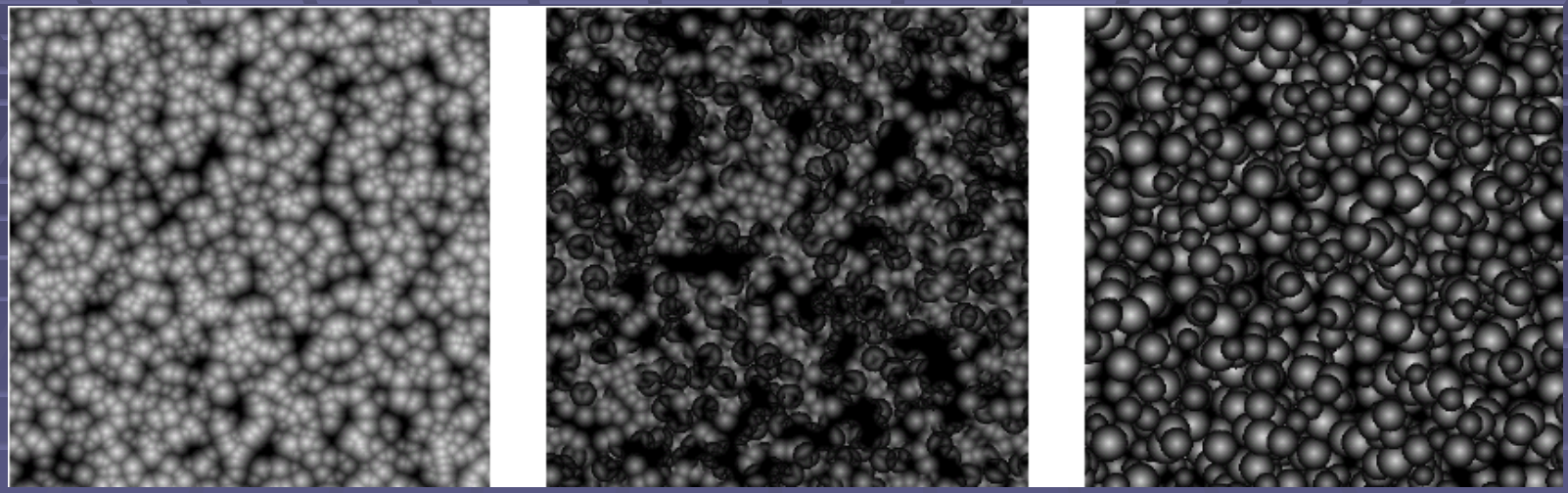
- Discriminant Analysis: to classify objects into one of two or more groups based on a set of features describing the objects (e.g. Texture properties.)
- Supervised learning method: it needs that each object owns an identified label.
- Produces new variables, as a linear combinations of the initial descriptors that are effective to separate classes
- Use of independent training and testing pixels to evaluate errors with a good accuracy.

# Outline

1. Pixel texture description
2. Machine learning
3. Application
    1. Simulated random texture images
    2. Experiments



# Simulated random textures



Boolean RF

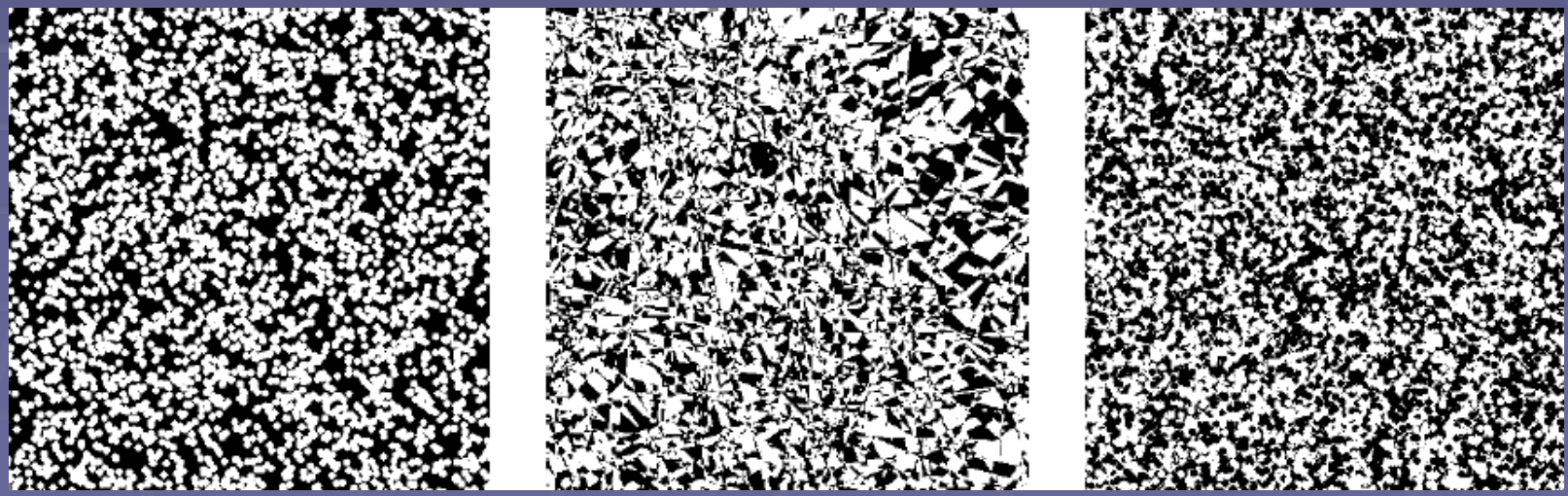
Sequential Alternate RF

Dead leaves RF

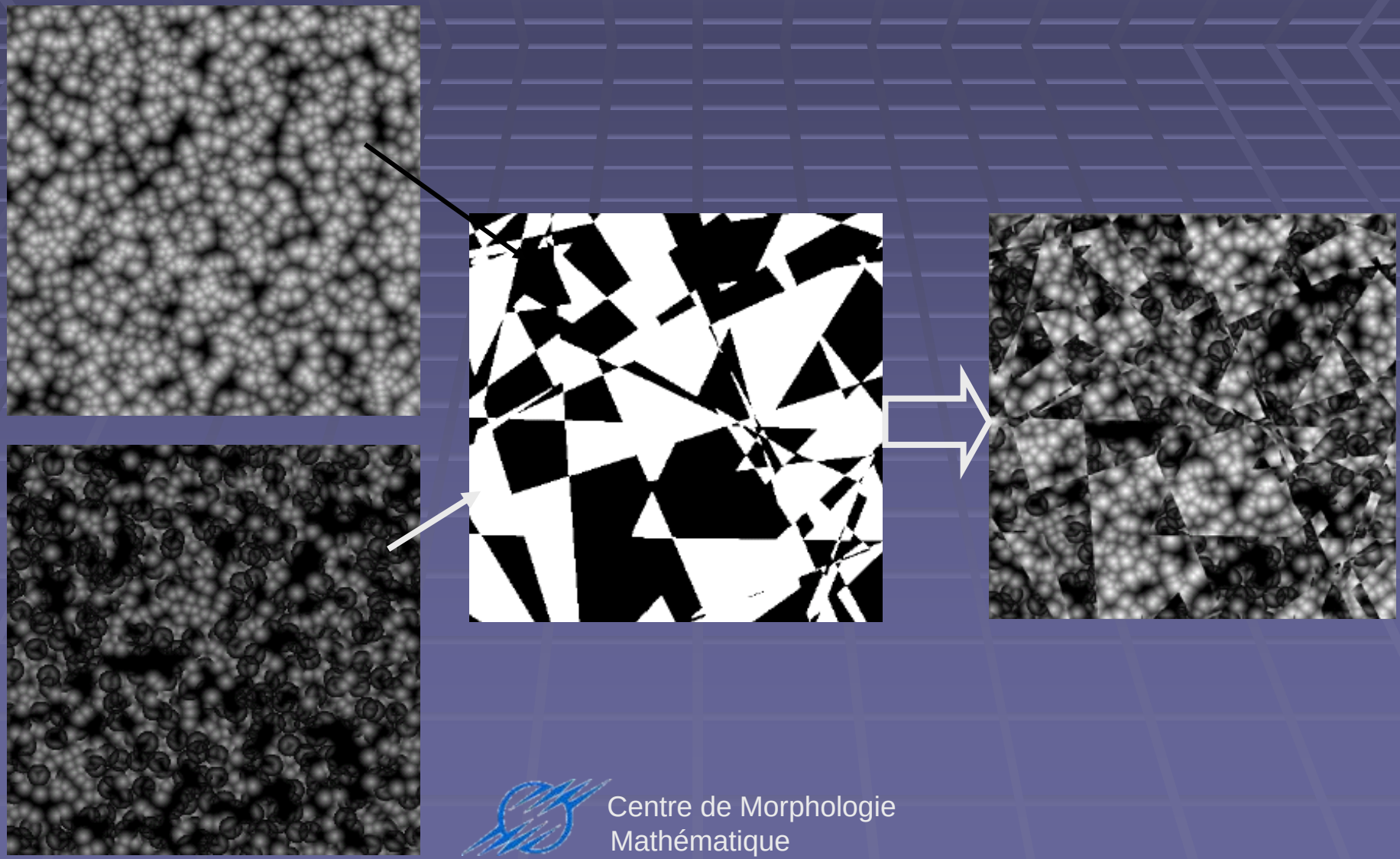
Boolean RS

Poisson mosaic RS

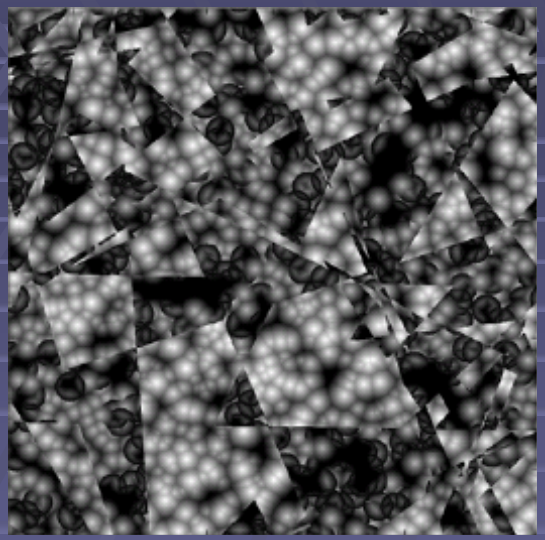
Binary dead leaves RS

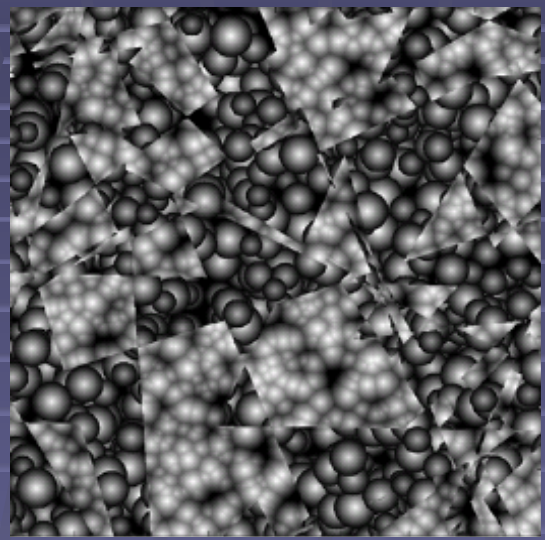


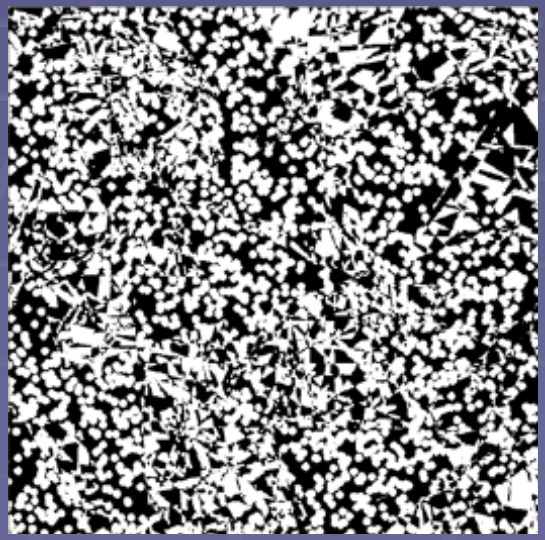
# Patchwork images (1)

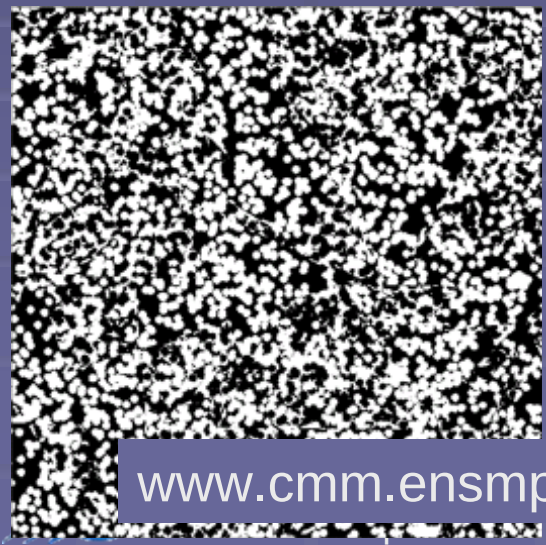


# Patchwork images (2)









4 images.

Very small areas with different textures compared to the size of the primary grain.

Avalaible on the internet

www.cmm.ensmp.fr/~cord/Synthetik_Texture/

# Outline

1. Pixel texture description
2. Machine learning
3. Application
    1. Simulated random texture images
    2. Experiments



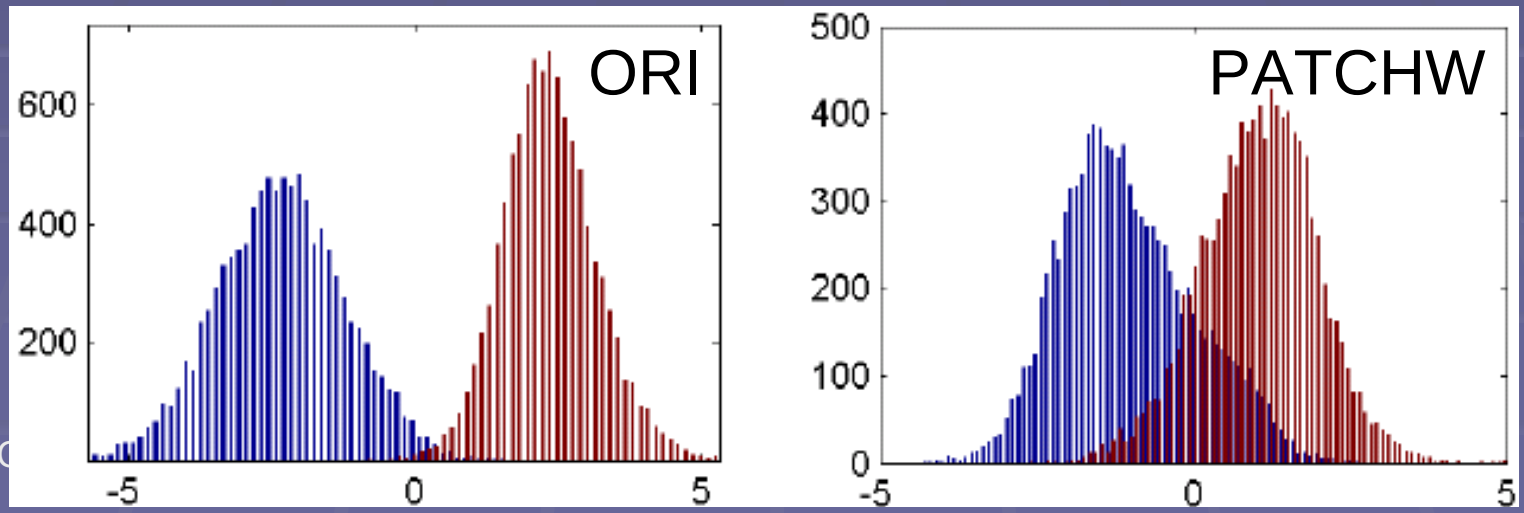
# Learning Procedures

1. Learning from original images « ORI »

   Best separation of the two textures

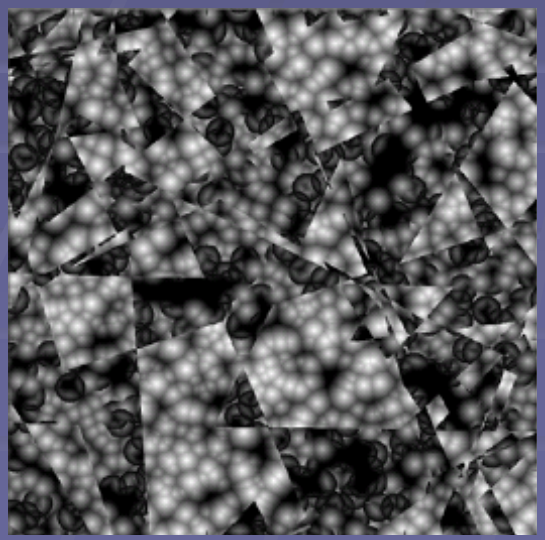
2. Learning from patchwork images « PATCHW »

   Best separation even on border areas



# Misclassification error

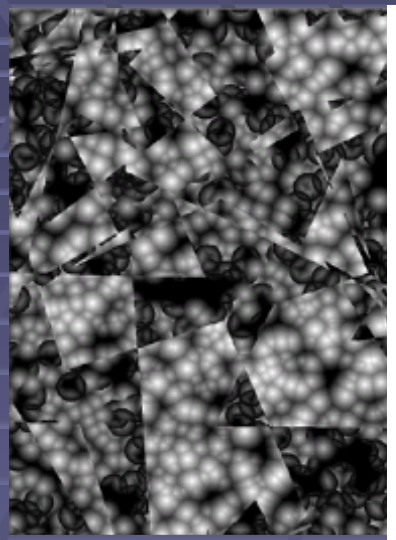
- All pixels of patchwork image are projected on the first LDA axis and classified.
- Using the knowledge of the mask, the misclassification error is evaluated.

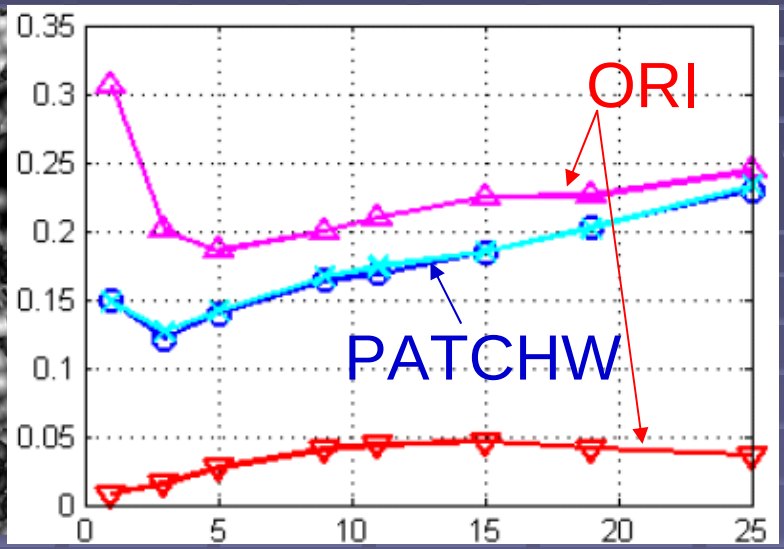


| | ORI | PATCHW |
|---|---|---|
| Learning test error | 1.0 | 15.5 |
| Misclassification error | **29.5** | **15.7** |

Centre de Morphologie Mathématique

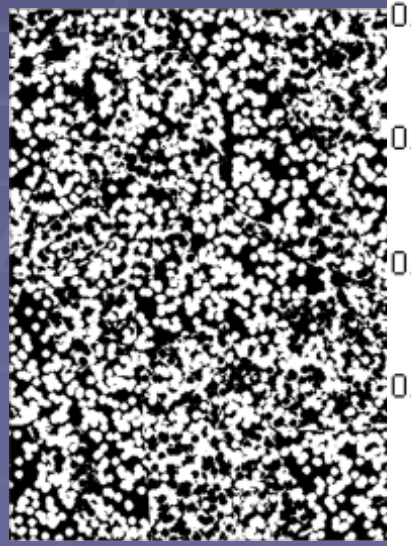
# Averaging window sizes

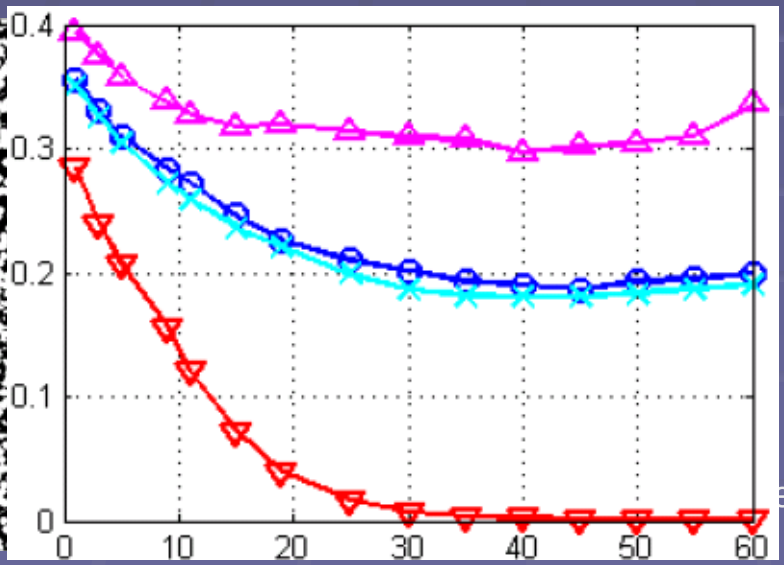





Only a small box 3x3 slightly improves the results

Descriptor sizes well adapted

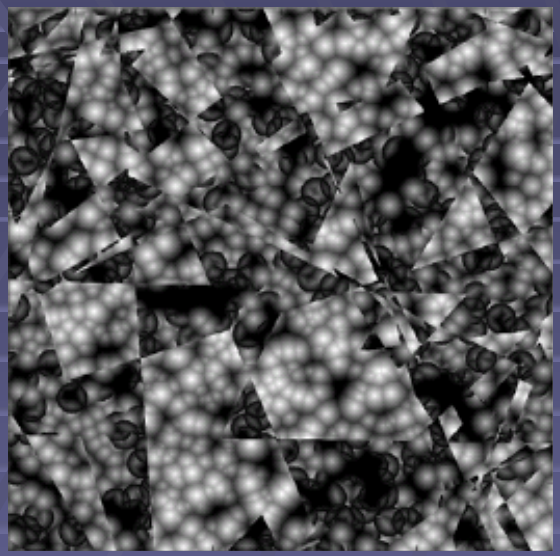


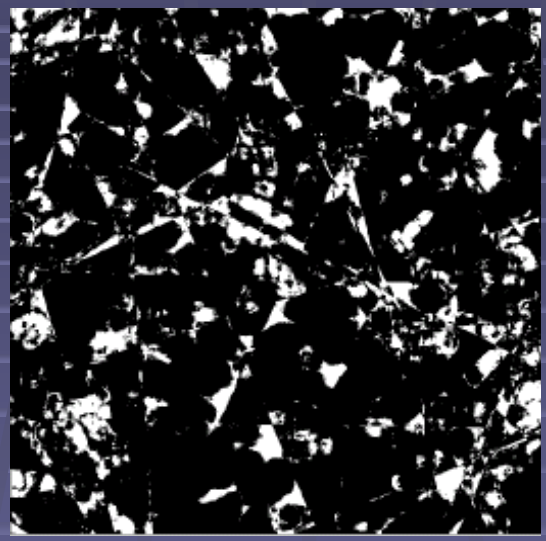


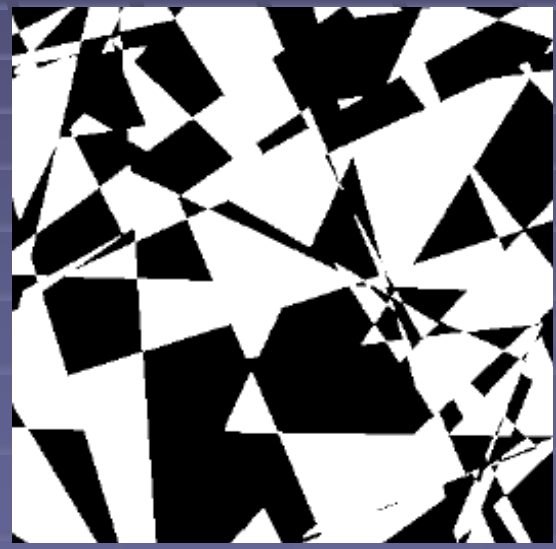

It need a 35x35 averaging window.

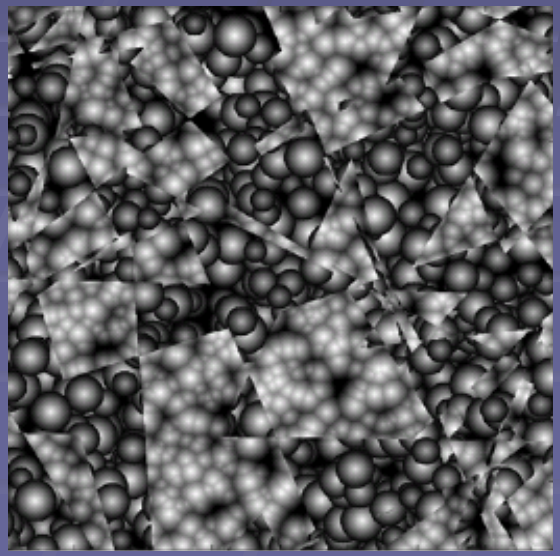
Textural motif are larger for binary images

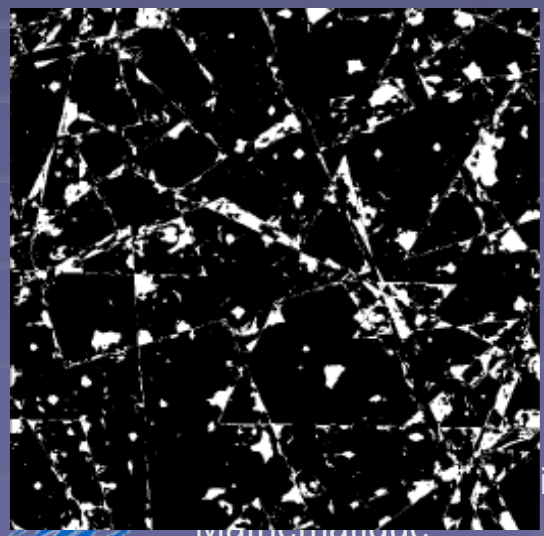
# Localization of misclassified pixels







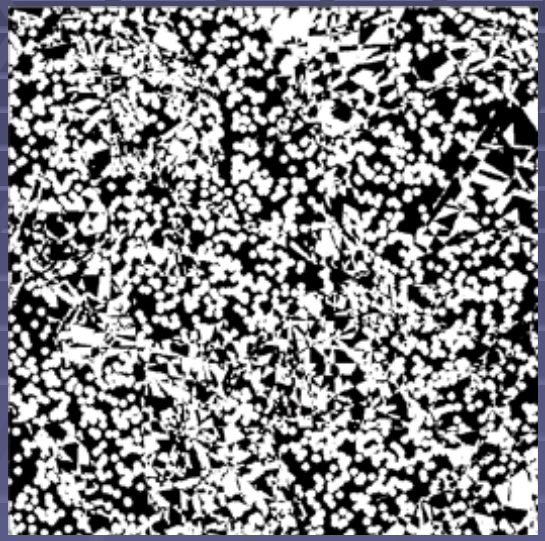


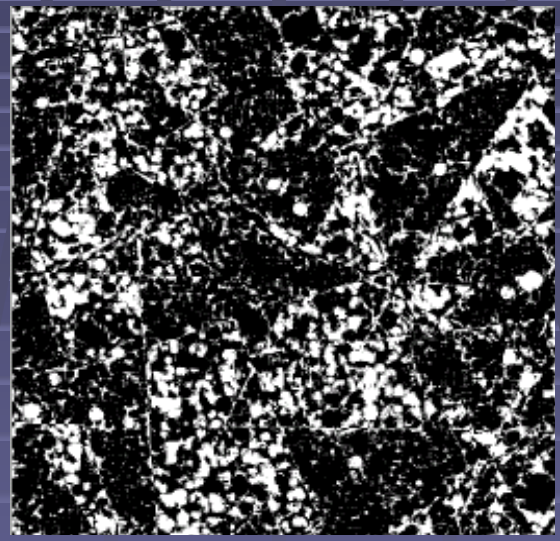


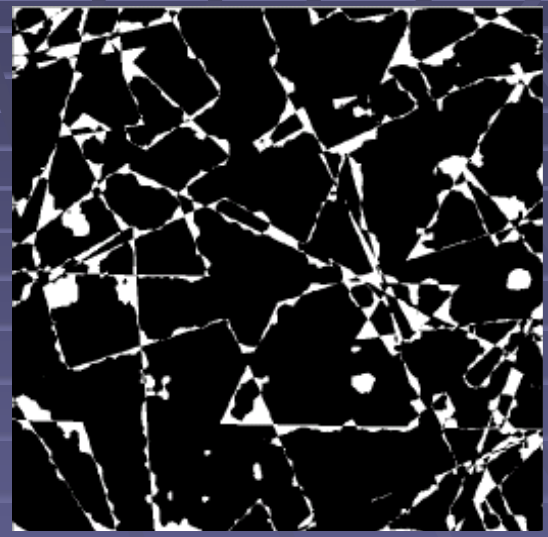
# Localization of misclassified pixels

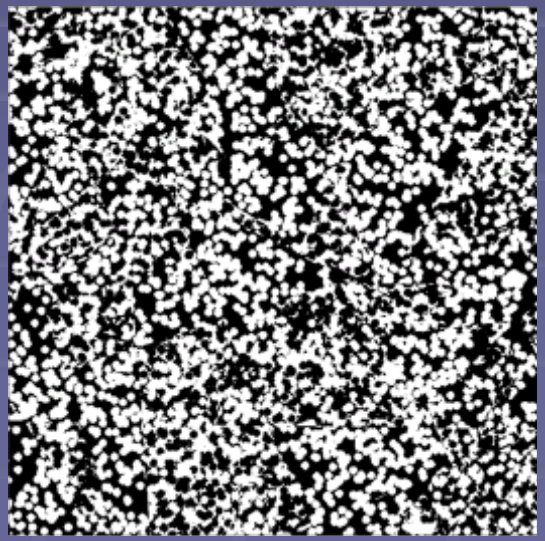
Without averaging

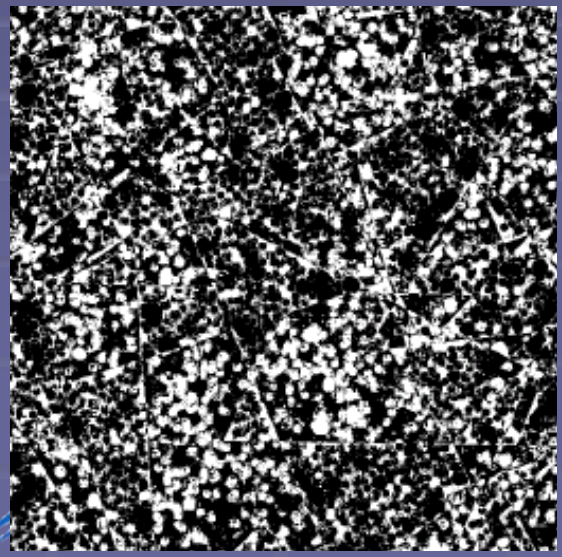
With 35x35 averaging

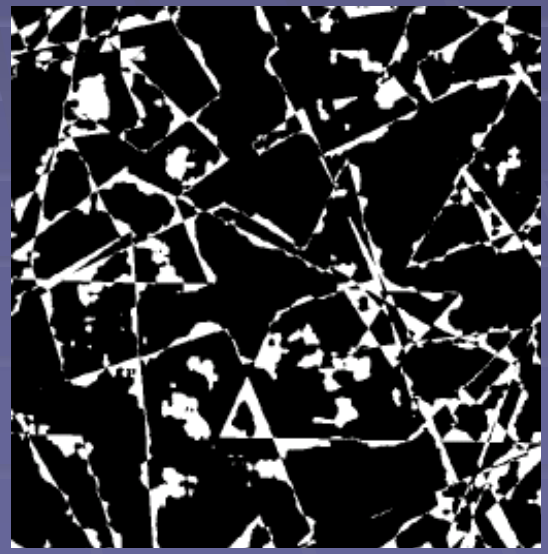






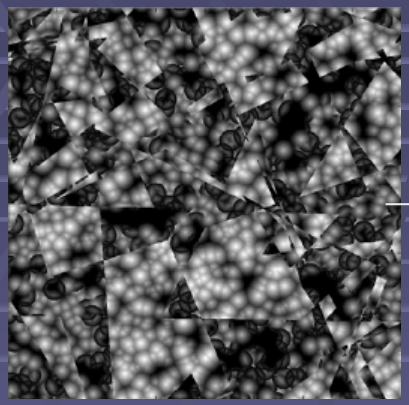


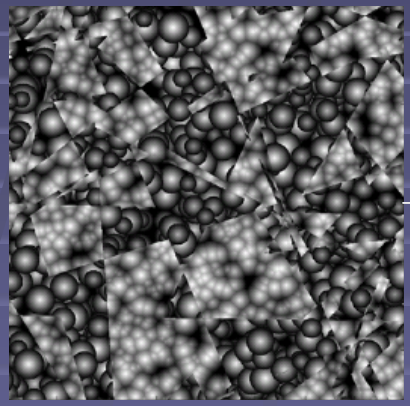


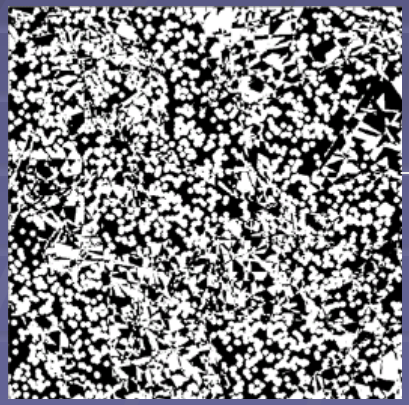


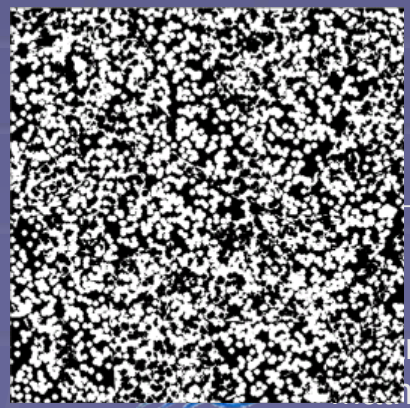
# Final classification errors

## LDA vs SVM







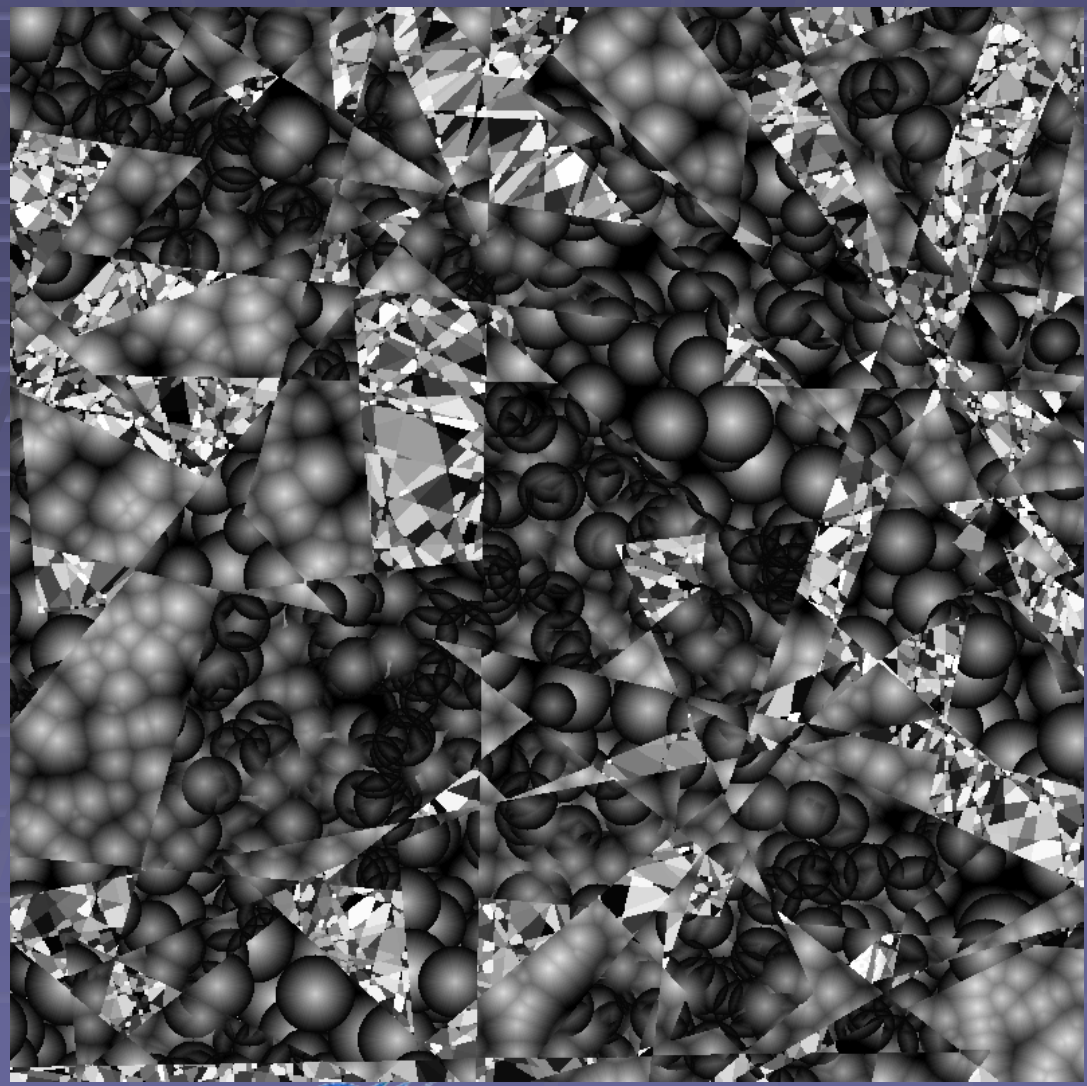


| LDA | SVM |
|---|---|
| 15.7 % | 9.7 % |
| 14.8 % | 9.4 % |
| 13.5 % | 12.1 % |
| 18.1 % | 19.3 % |

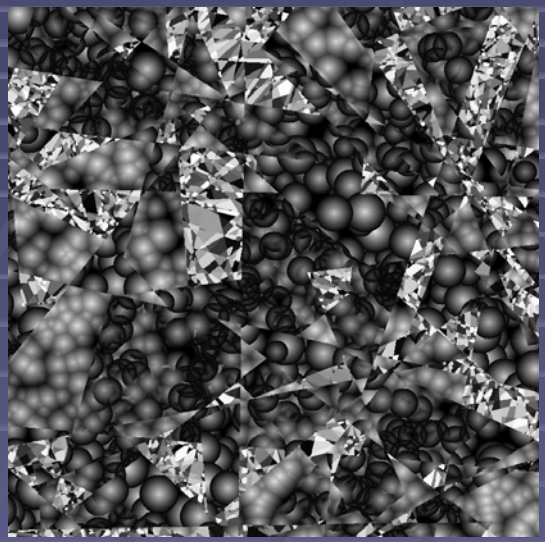
# Efficiency of descriptors

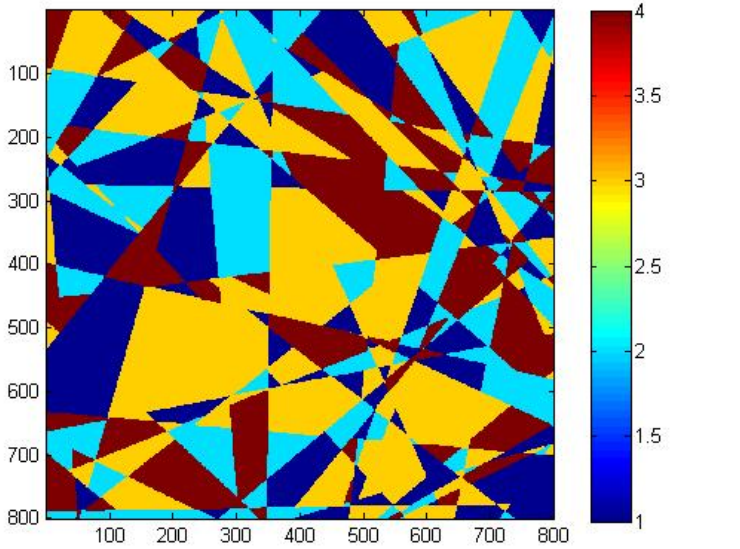
- Larger contribution to the LDA projection: disk structuring element (isotropic textures)
- Erosions-Dilations most relevant for binary images
- Opening/closing most relevant for grey level images
- Curvelets more relevant for binary images
- Large scale structuring elements irrelevant here

# Extension to more textures (4)

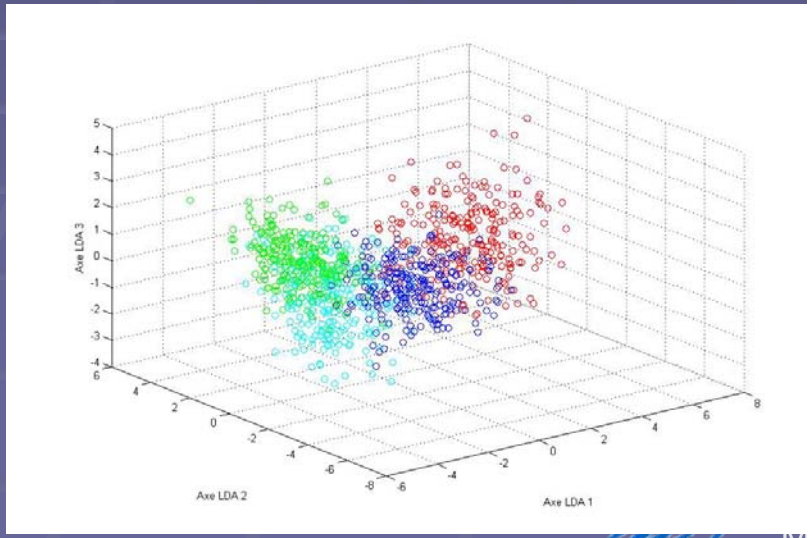


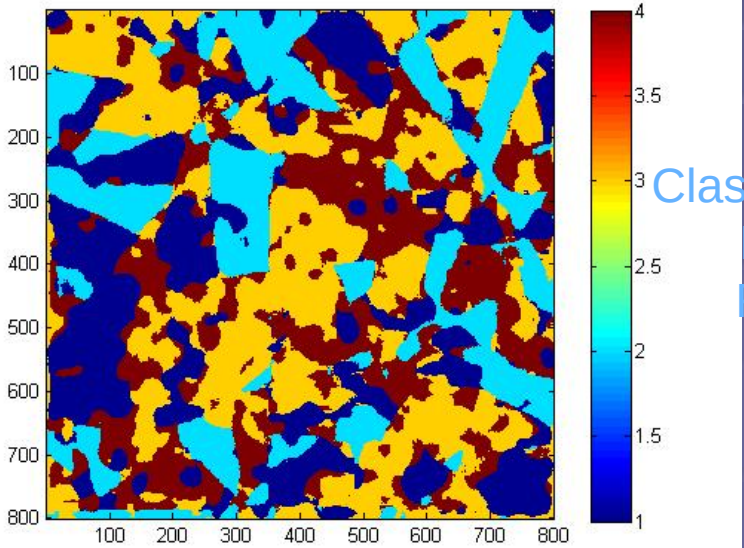
# Extension to more textures






mask




Classification Error Rate: 28%

# Conclusion

- Basic morphological image transformations and curvelets provide efficient texture descriptors at the pixel scale
- This description combined with statistical learning method is efficient for the segmentation according to the local texture.
- The training procedure has to be made on a selection of pixels from the patchwork image in order to minimize the boundary effect.
- Successful application of the methodology to texture extraction on steel plates