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## Pixel Classification using General Adaptive Neighborhood-based Features

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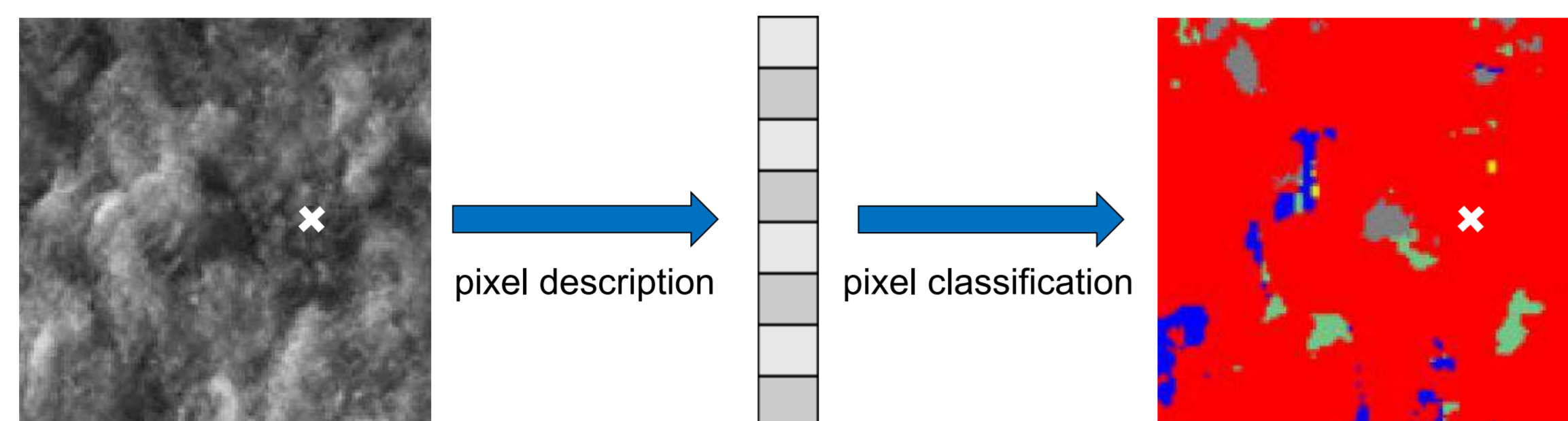
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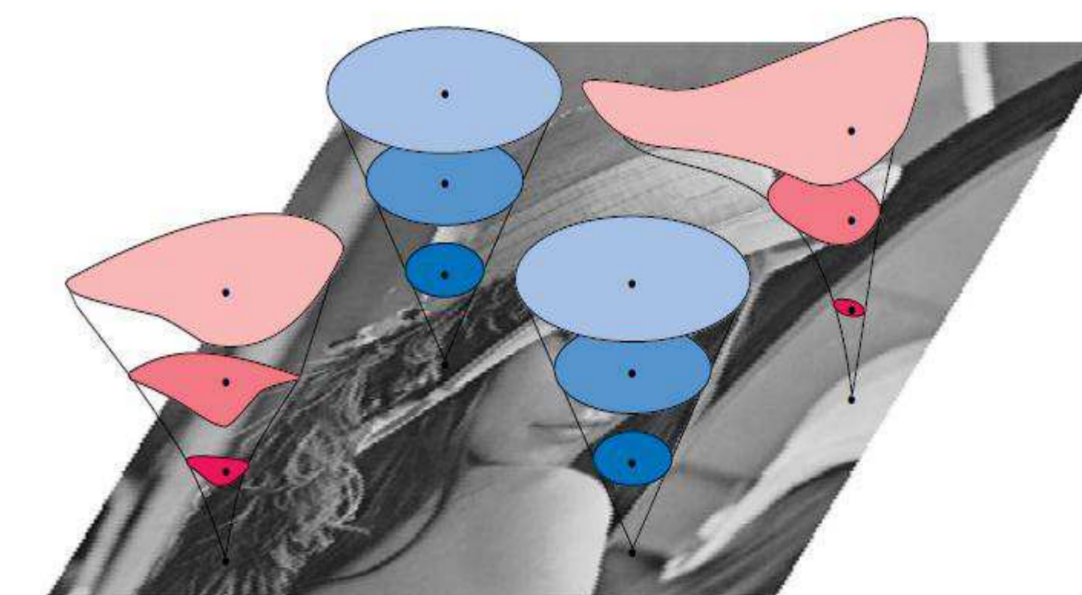
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## Context



Grey-level pixel classification



Local features extracted from adaptive neighborhoods

## General Adaptive Neighborhoods (GANs)

A **GAN** is a spatial neighborhood whose size and shape is adapted to the local features of the image

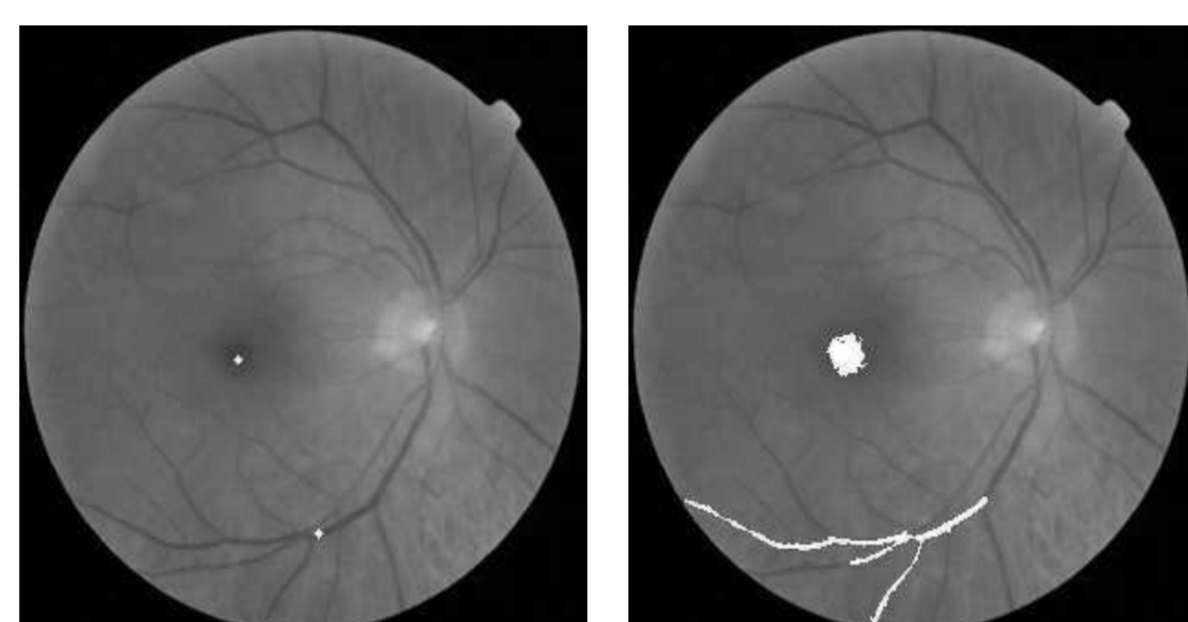
### Conditions

- Measurement of the **criterion mapping** of its points (i.e. intensity) **close** to the one on the origin.
- The GAN is a **path connected** set.

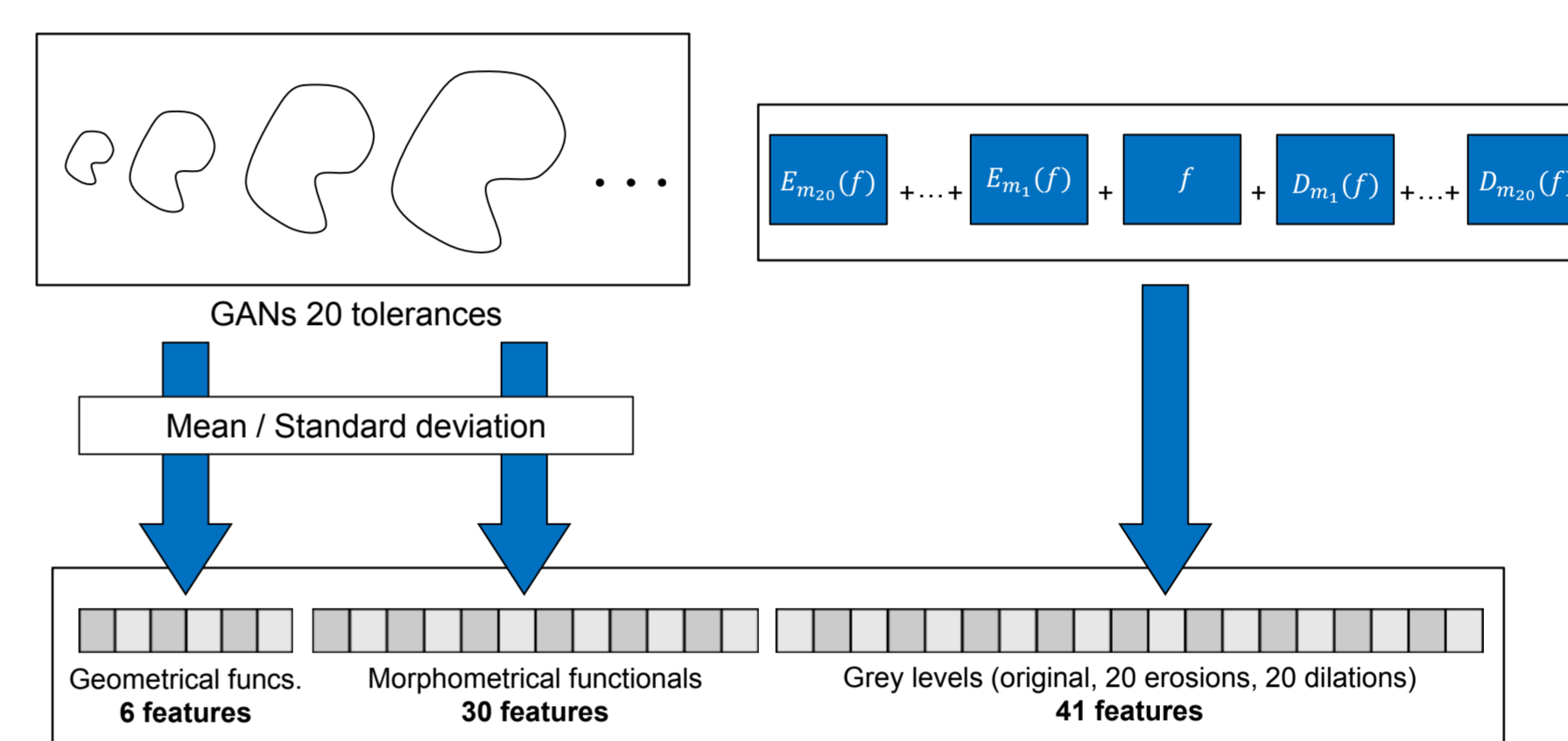
$$V_m^h(x) = C_{\{y \in D: |h(y) - h(x)| \leq m\}}(x)$$

### Where

- $D$ : Spatial support, ( $D \subseteq \mathbb{R}^2$ )
- $h$ : Criterion mapping, ( $h: D \rightarrow \mathbb{R}$ )
- $m$ : Tolerance factor
- $C_X(x)$ : Path connected component of  $X$  containing  $x$ .



## Final pixel descriptor



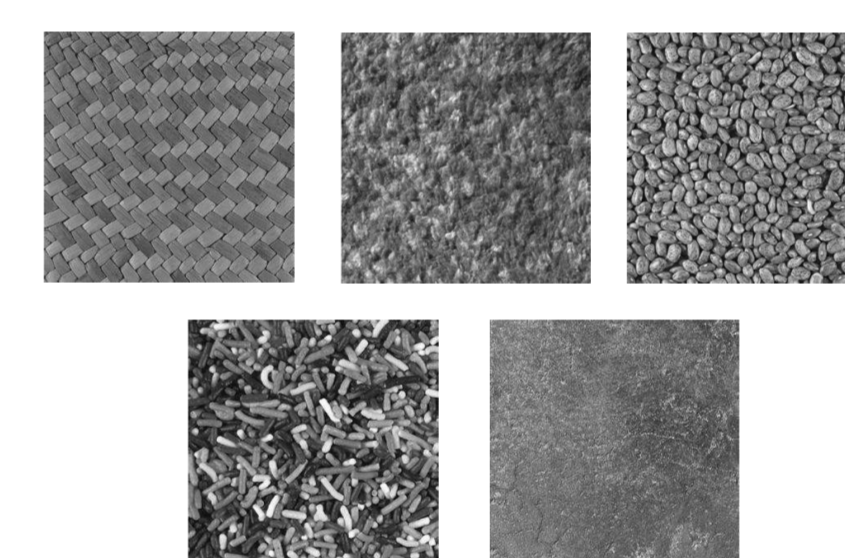
## Experiments

### Other adaptive neighborhoods

- **Morphological Amoebas (MA)** [Lerallut, et al., IVC, 2007]
- **Adaptive Geodesic Neighborhoods (AGN)** [Grazzini et al., PR, 2009]
- **Saliency Adaptive Structuring Elements (SASE)** [Curic et al., IEEE IJSTSP, 2012]

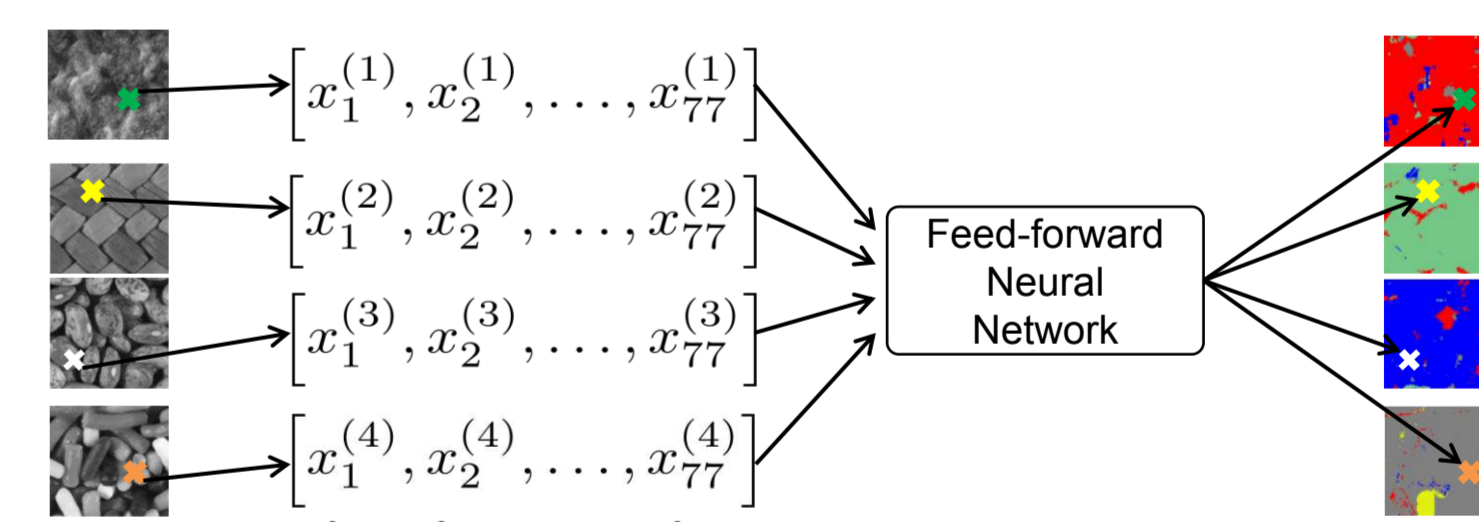
### Data

- 5 classes, 5 images/class
- Size: 102 x 102
- Dataset: 260100 pixels



### Classification

- Feed-forward Neural Network
- One hidden layer
- Sigmoid transfer function
- 10-fold cross validation



## Local features

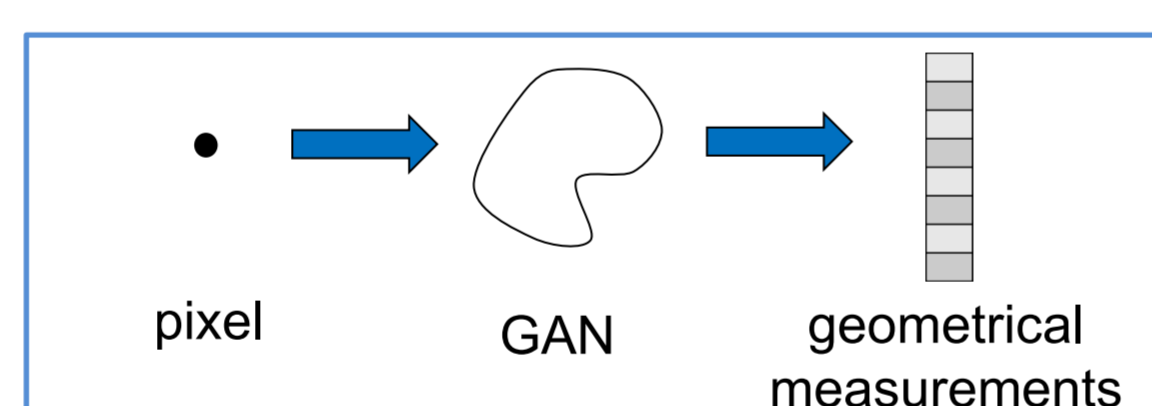
### 1) Geometrical features: GAN-based Minkowski functionals

#### GAN-based Minkowski Map

$$\mu_m^h(x) = \mu(V_m^h(x))$$

Where  $\mu$  denotes a density functional:

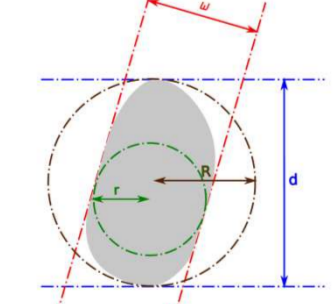
- **Area** ( $\mu \equiv A_A$ )
- **Perimeter** ( $\mu \equiv P_A$ )
- **Euler Number** ( $\mu \equiv \chi_A$ )



### 2) Morphometrical functionals

#### Geometrical functionals

- Area ( $A$ )
- Perimeter ( $P$ )
- Inscribed / circumscribed circles radii ( $r, R$ )
- Feret diameters ( $w, d$ )



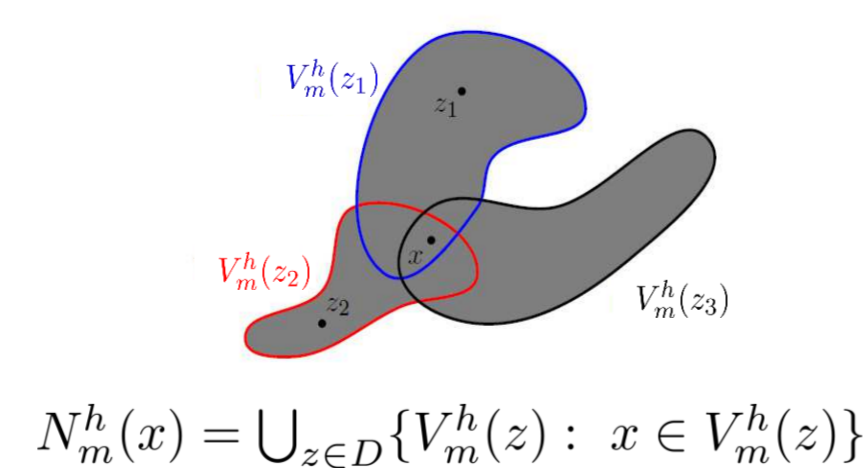
#### Morphometrical functionals

Geometrical functionals	Inequalities	Morphological functionals
$r, R$	$r \leq R$	$r/R$
$\omega, R$	$\omega \leq 2R$	$\omega/2R$
$A, R$	$A \leq \pi R^2$	$A/\pi R^2$
$d, R$	$d \leq 2R$	$d/2R$
$r, d$	$2r \leq d$	$2r/d$
$\omega, d$	$\omega \leq d$	$\omega/d$
$A, d$	$4A \leq \pi d^2$	$4A/\pi d^2$
$R, d$	$\sqrt{3}R \leq d$	$\sqrt{3}R/d$
$r, P$	$2\pi r \leq P$	$2\pi r/P$
$\omega, P$	$\pi\omega \leq P$	$\pi\omega/P$
$A, P$	$4\pi A \leq P^2$	$4\pi A/P^2$
$d, P$	$2d \leq P$	$2d/P$
$R, P$	$4R \leq P$	$4R/P$
$r, A$	$\pi r^2 \leq A$	$\pi r^2/A$
$r, \omega$	$2r \leq \omega$	$2r/\omega$

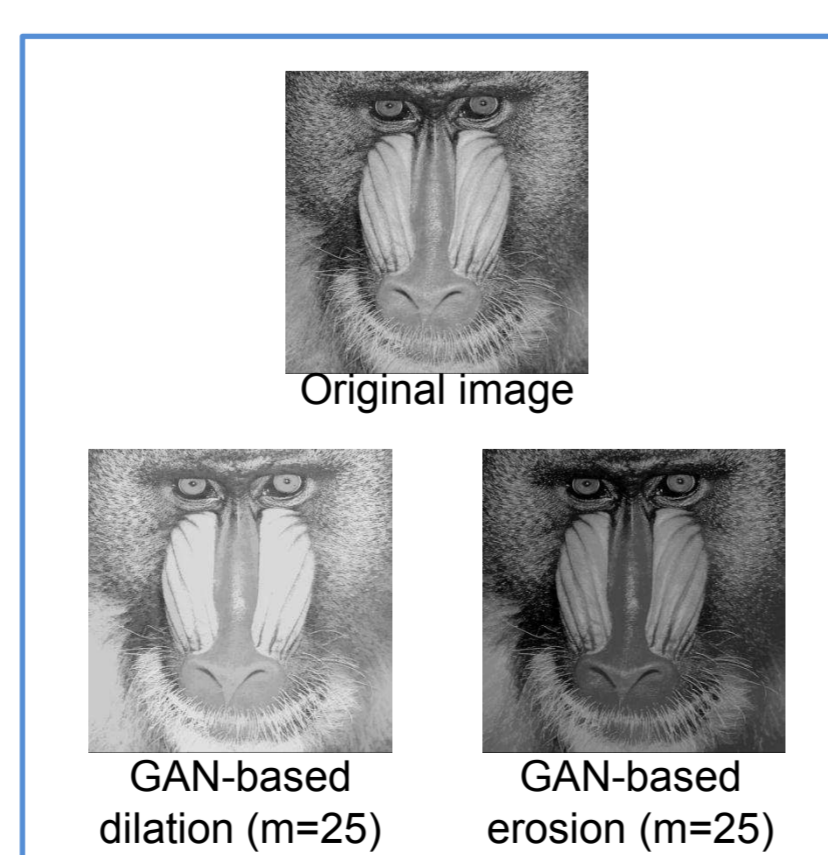
### 3) Gray-level features

GAN-based **Erosion**:  $E_m^h(f)(x) = \inf_{w \in N_m^h(x)}(f(w))$

GAN-based **Dilation**:  $D_m^h(f)(x) = \sup_{w \in N_m^h(x)}(f(w))$



$$X_n(x) = [E_{m_n}^h(f)(x), \dots, E_{m_1}^h(f)(x), f(x), D_{m_1}^h(f)(x), \dots, D_{m_n}^h(f)(x)]$$



## Results

- Average and standard deviation accuracy.
- Different neurons in hidden layer and training cycles.
- Best results: GAN-based descriptors.

Cycles	Neurons	MA		AGN		SASE		GAN	
		Acc.(%)	Std	Acc.(%)	Std	Acc.(%)	Std	Acc.(%)	Std
500	9	90.37	0.02	73.42	0.02	66.65	0.11	95.92	0.02
600	9	89.93	0.01	72.87	0.02	60.65	0.09	95.58	0.02
700	9	89.74	0.02	74.08	0.03	<b>68.18</b>	0.09	<b>97.25</b>	0.01
500	11	89.93	0.01	73.00	0.02	63.44	0.07	96.39	0.01
600	11	89.60	0.02	72.89	0.02	61.52	0.08	96.19	0.02
700	11	89.75	0.01	73.67	0.03	62.53	0.08	96.43	0.02
500	13	90.17	0.01	72.39	0.03	64.17	0.09	95.40	0.02
600	13	89.85	0.01	73.44	0.02	64.46	0.07	95.64	0.03
700	13	90.68	0.01	<b>75.04</b>	0.02	63.23	0.08	96.07	0.02
500	15	90.15	0.01	74.47	0.02	60.22	0.10	96.73	0.02
600	15	<b>91.13</b>	0.02	74.18	0.01	67.71	0.08	96.32	0.02
700	15	89.89	0.01	74.01	0.01	64.88	0.11	94.47	0.02

## Conclusion and Perspectives

- Pixel descriptor: **Geometrical + Morphometrical + Intensity** features of adaptive neighborhoods of the pixel
- Comparison of different adaptive neighborhoods: MA, AGN, SASE and GAN

### Perspectives

- Extension to color images.
- Application to image segmentation, classification of textures, etc.
- Study of relevant features.