A multichannel morphological algorithm for texture segmentation

Norberto Malpica, Juan E. Ortuño, Andrés Santos
Departamento de Ingeniería Electrónica
Universidad Politécnica de Madrid

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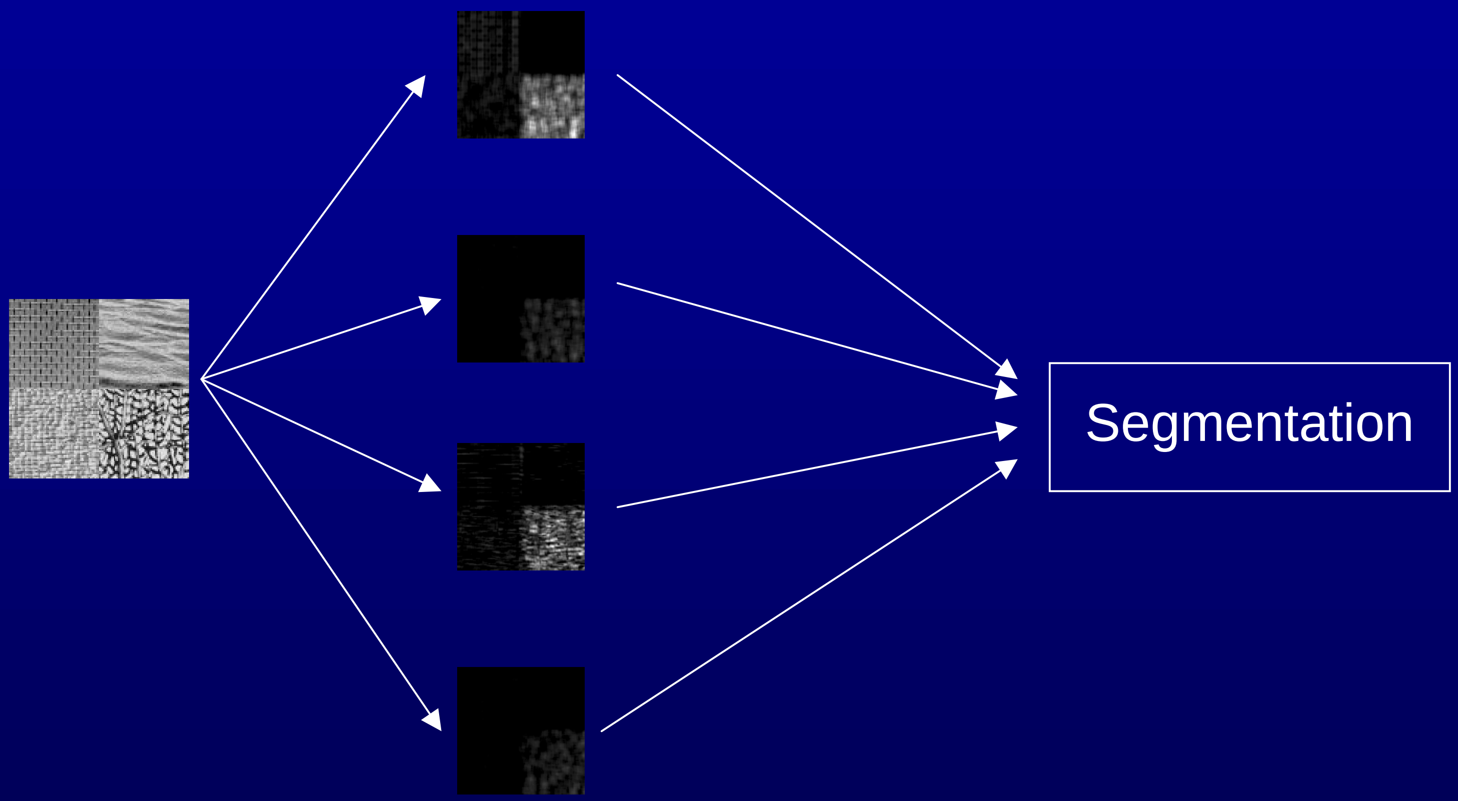
- Gradient of a vector field
- Morphological segmentation
  - Algorithm
  - Results
- Contour based methods
- Conclusions

Introduction

- Grey-level segmentation techniques (region or contour based) assume homogeneity of regions
- Regions can be homogeneous in texture.
- Texture parameters provide a great amount of information (feature maps).



Aim: Adapting grey-level segmentation methods to multichannel information.

Gradient of a vector field

- Grey-level gradient measures differences in gray level values
- In general, gradient measures distance between values in the n-dimensional feature space
- If we have m channels of information:

Euclidean gradient: $Grad_{eucl} = \sqrt{grad_1^2 + grad_2^2 + \ldots + grad_m^2}$

Gradient of a vector field (II)

- f_k : kth component of multichannel image f
- First order Taylor expansion:

$$f(x+a) = f(x) + [f'(x)](a) + \|a\| e(x,a)$$

$$f'(x) = D(x) = \begin{bmatrix} D_1 f_1(x) & D_2 f_1(x) & \cdots & D_n f_1(x) \\ D_1 f_2(x) & D_2 f_2(x) & \cdots & D_n f_2(x) \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ D_1 f_m(x) & D_2 f_m(x) & \cdots & D_n f_m(x) \end{bmatrix}$$

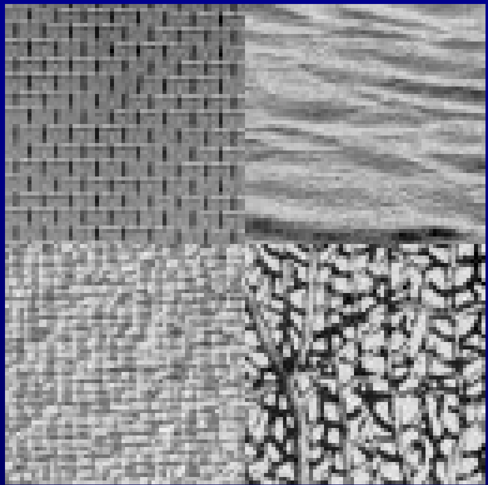
Gradient of a vector field (III)

- If we travel out from x with unit vector u:
  - Distance in the attribute domain $d = \sqrt{uD^T Du}$
- D is maximized/minimized by eigenvectors of $D^T D$
  - Values defined by $\lambda_{\pm}$ (maximum and minimum eigenvalues)
  - Directions defined by $\theta_{\pm}$ (corresponding eigenvectors)

Edges can be defined as a function: $f = f(\lambda_+, \lambda_-)$

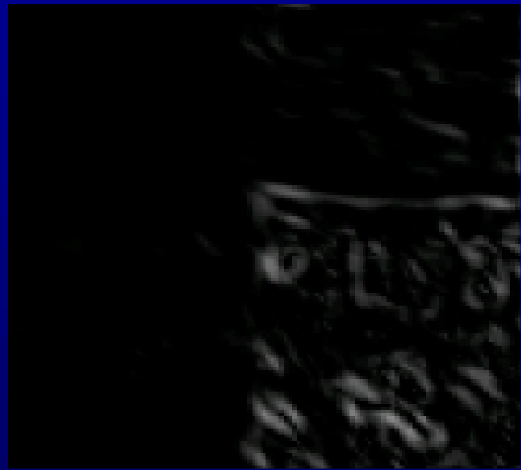
We will use $grad_{vec} = \lambda_+ - \lambda_-$

Multichannel gradient. Example



Initial image

Euclidean gradient



Vector gradient

Vector gradient using 8 GLCM parameter maps

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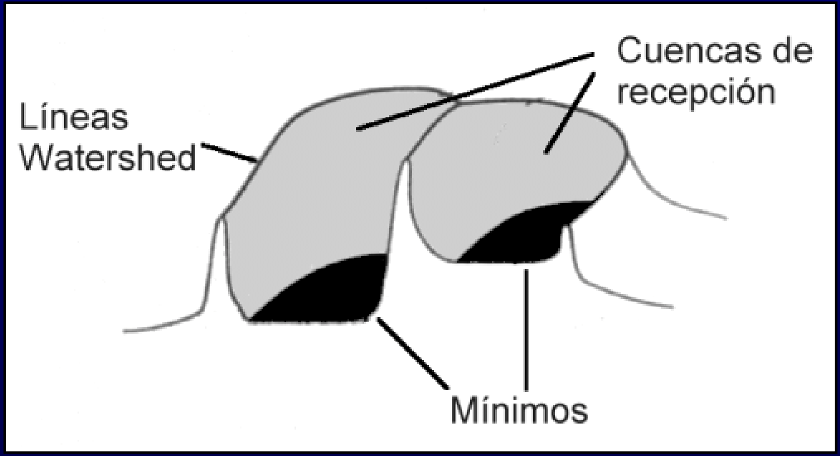
The watershed transform

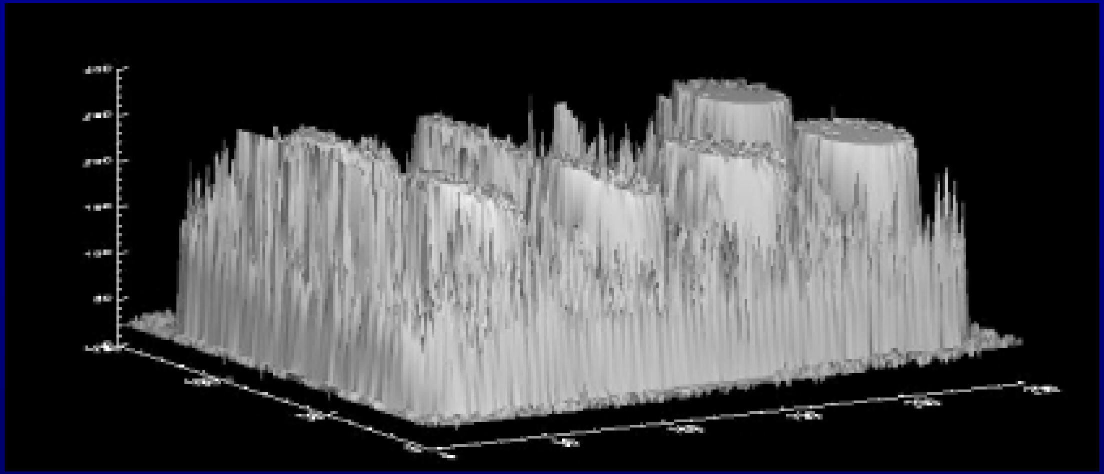
- Idea taken from the field of topograhy
- Applied to surfaces.
- It’s a morphological operator

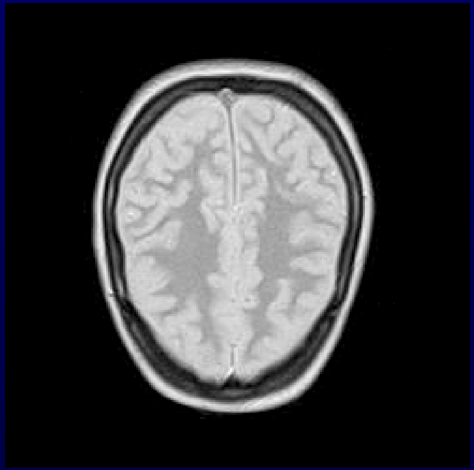


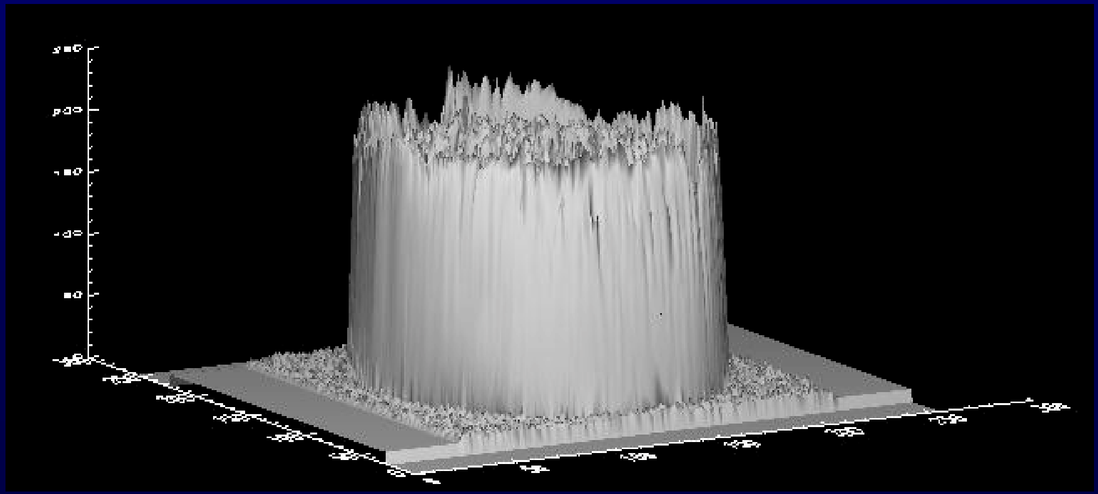
We can use it for image segmentation

Watersheds in digital images (1)

Grey level represents surface height





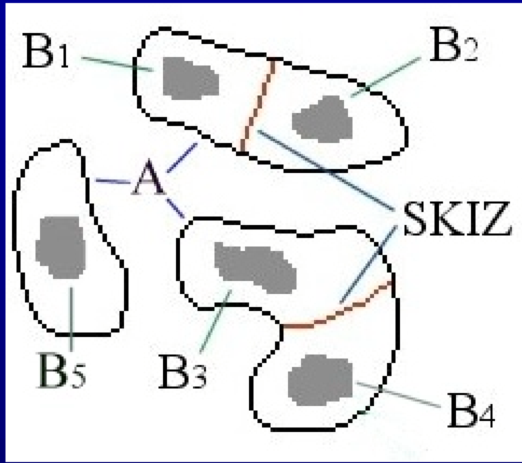


Watersheds in digital images (2)

Geodesic zone of influence:

$$iz_A(B_i) = \{p \in A \mid \forall j \neq i : d_A(p, B_i) < d_A(p, B_j)\}$$

$$IZ_A(B) = \bigcup_{i=1}^{k} iz_A(B_i) \qquad SKIZ_A(B) = A \setminus IZ_A(B)$$



Threshold : $T_h = \{p \in D \mid f(p) \leq h\}$

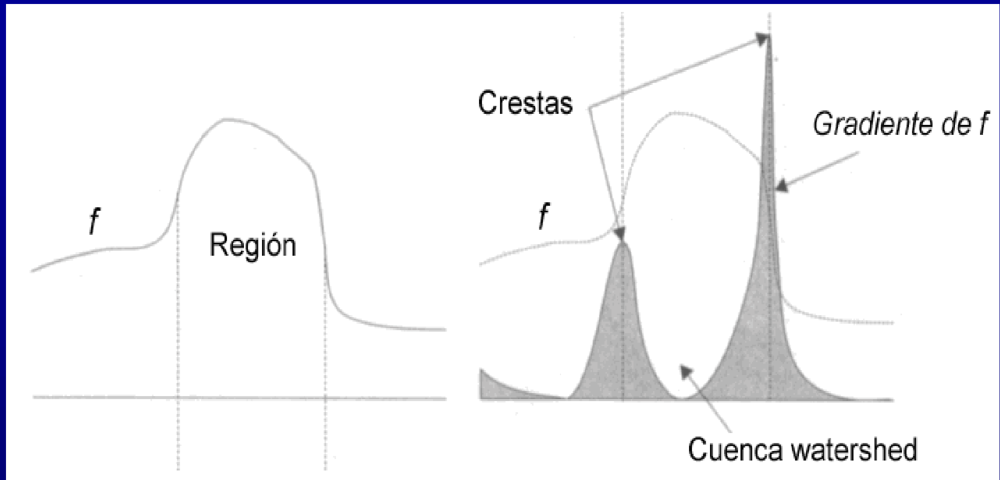
Watershed transform definition *(Vincent)*

$$\begin{cases} X_{h_{\min}} = \{p \in D \mid f(p) = h_{\min}\} = T_{h_{\min}} \\ X_{h+1} = MIN_{h+1} \cup IZ_{T_{h+1}}(X_h), h \in [h_{\min}, h_{\max}) \end{cases}$$

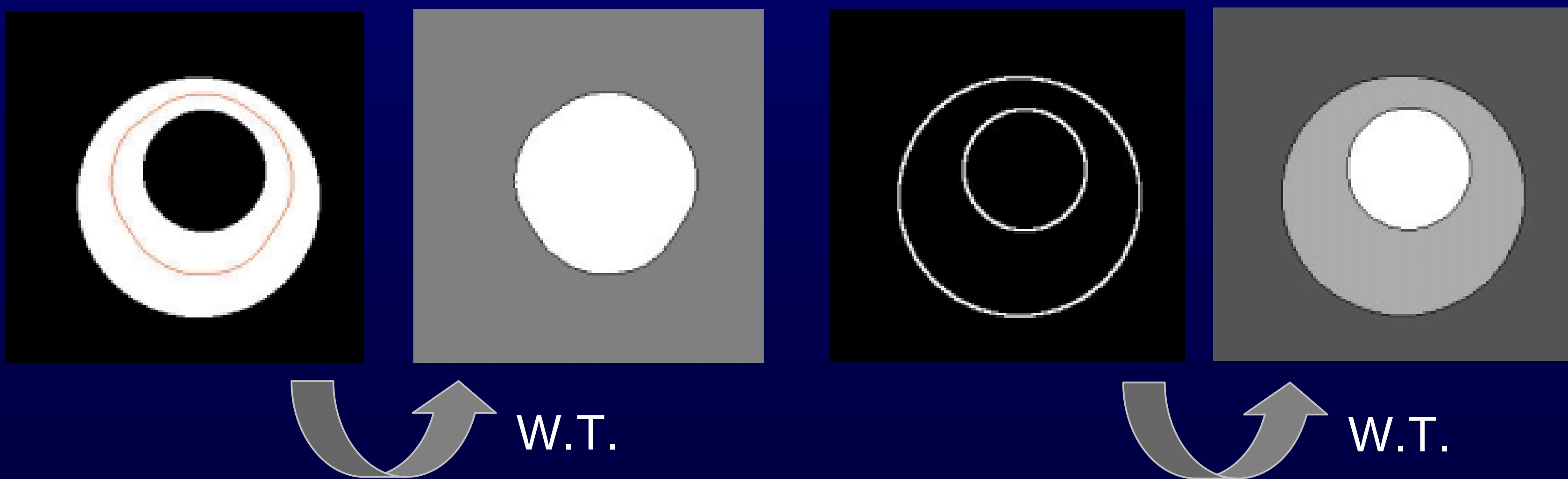
$$Wshed(f) = D \setminus X_{h_{\max}}$$ ← Watershed lines

- Level by level
- Algorithm
- immersion

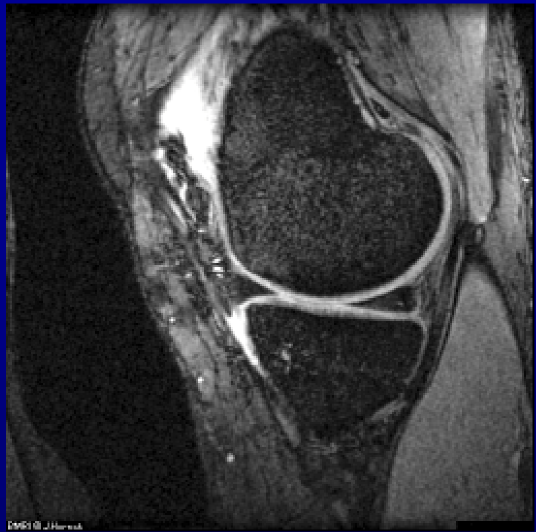
Watershed of the gradient



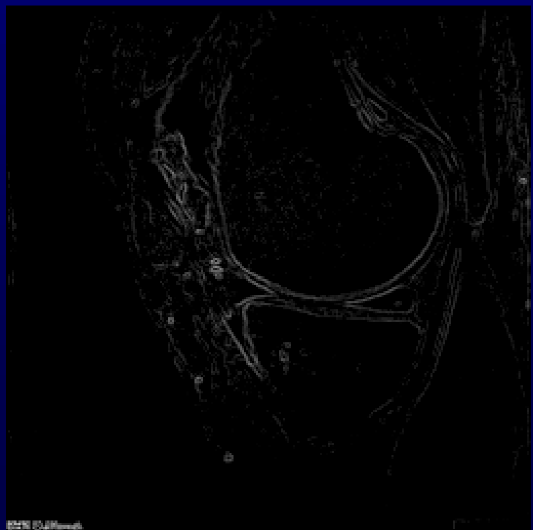
Homogeneus regions separated by a high gradient.



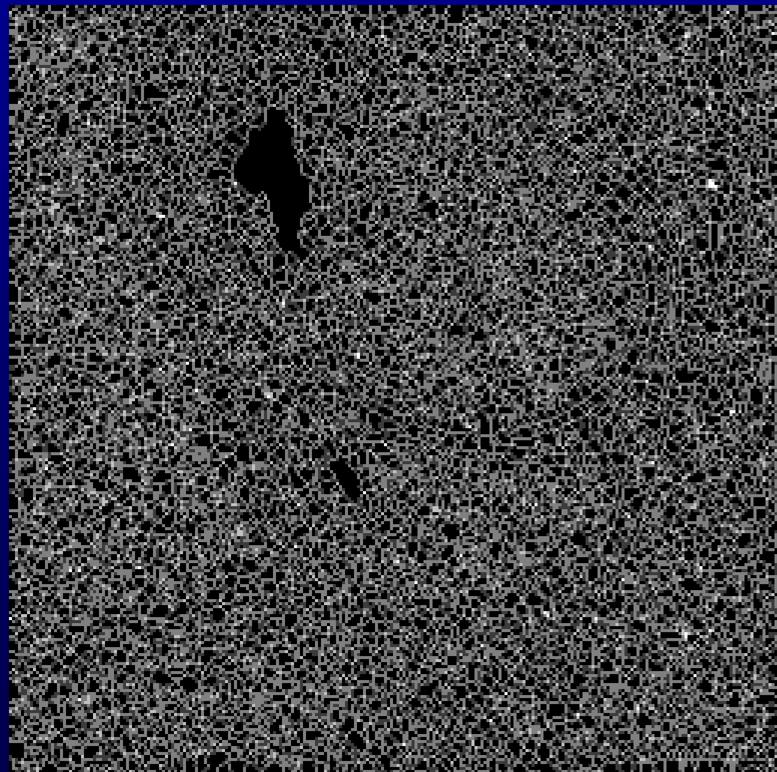
Watershed.Examples



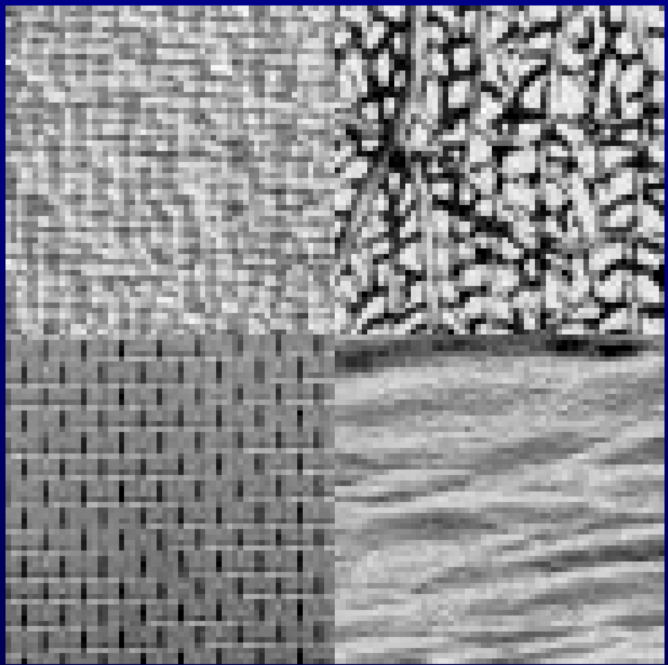
$|\nabla I|$

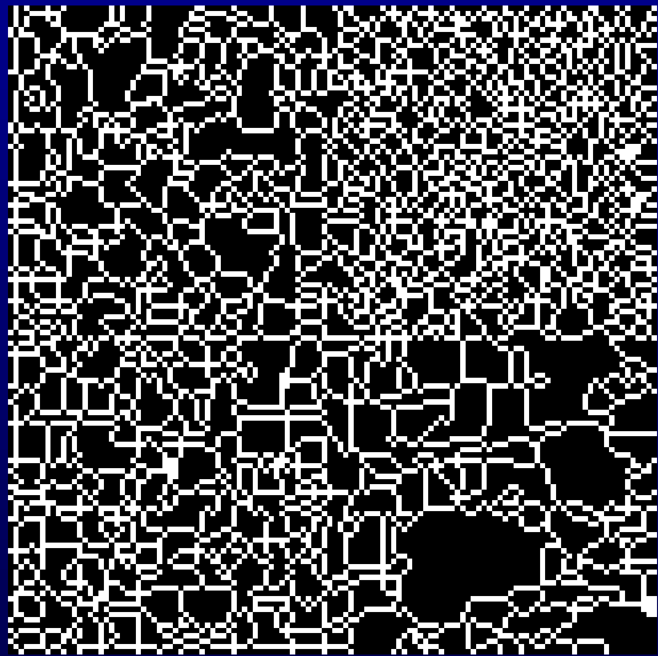


W.T.



Watershed. Examples (II)

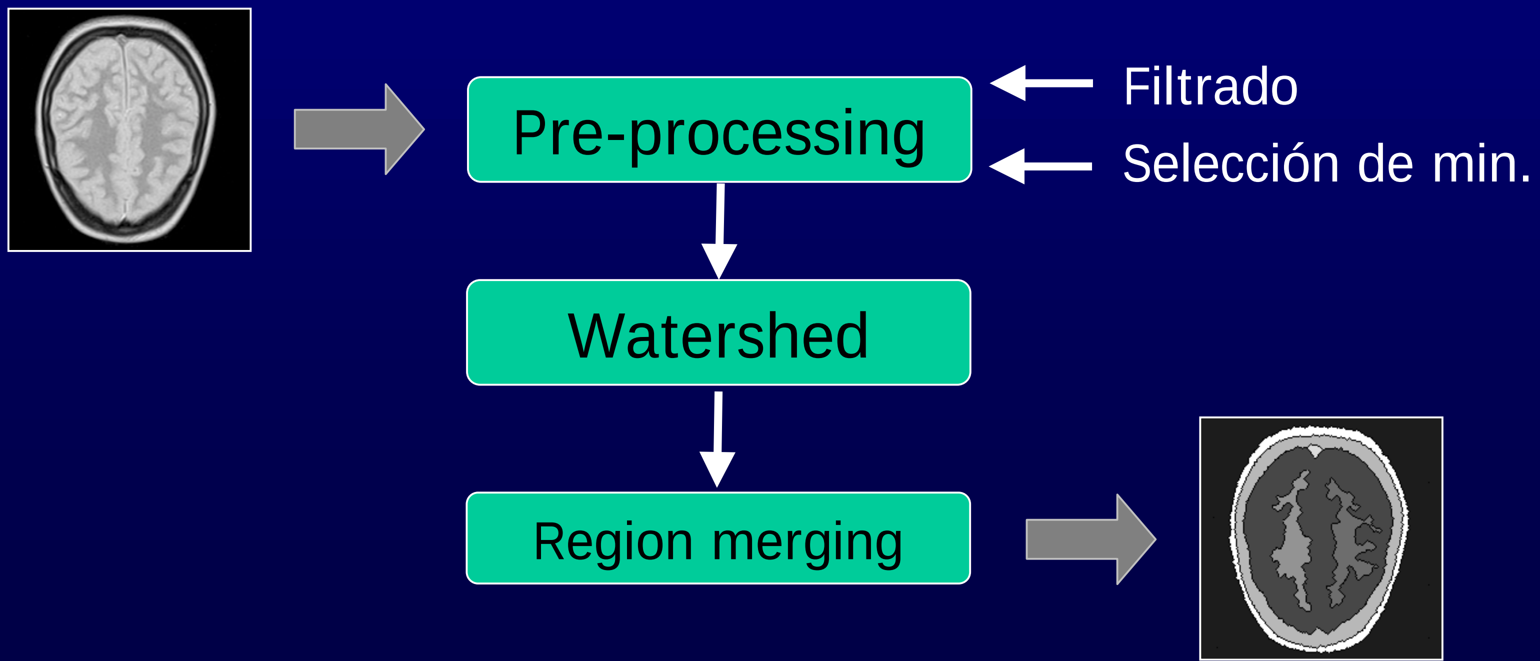




Oversegmentation

- Problem: Too many regions
  - Noisy images
  - Precise gradient calculation

We need to reduce the number of regions

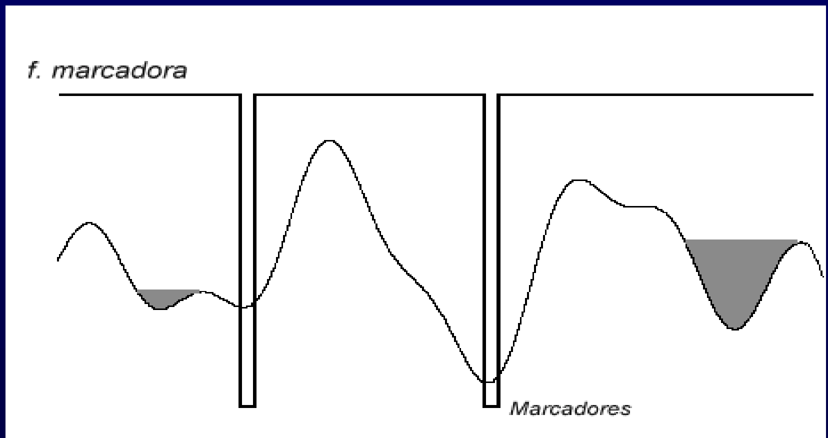


Minima selection: Dual reconstruction

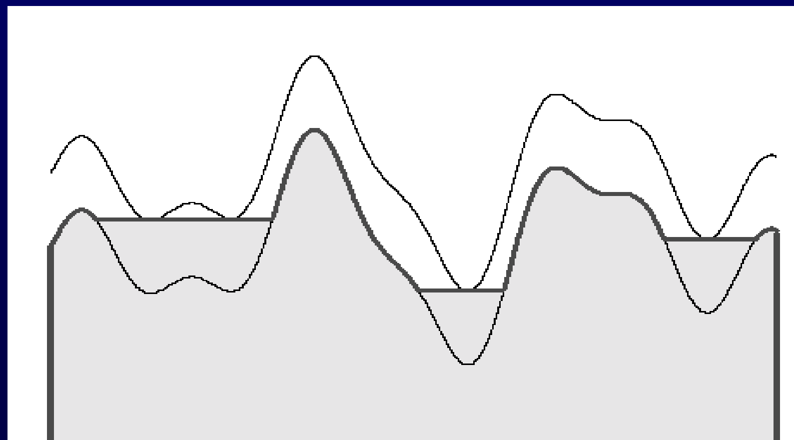
– Reduce the number of significant minima by filling non significant minima (*swamping*)
– Morphological reconstruction by erosion

$$f_M^{k+1}(p) = \max\left(f_O(p),\ f_M^k(p)\Theta B\right)$$

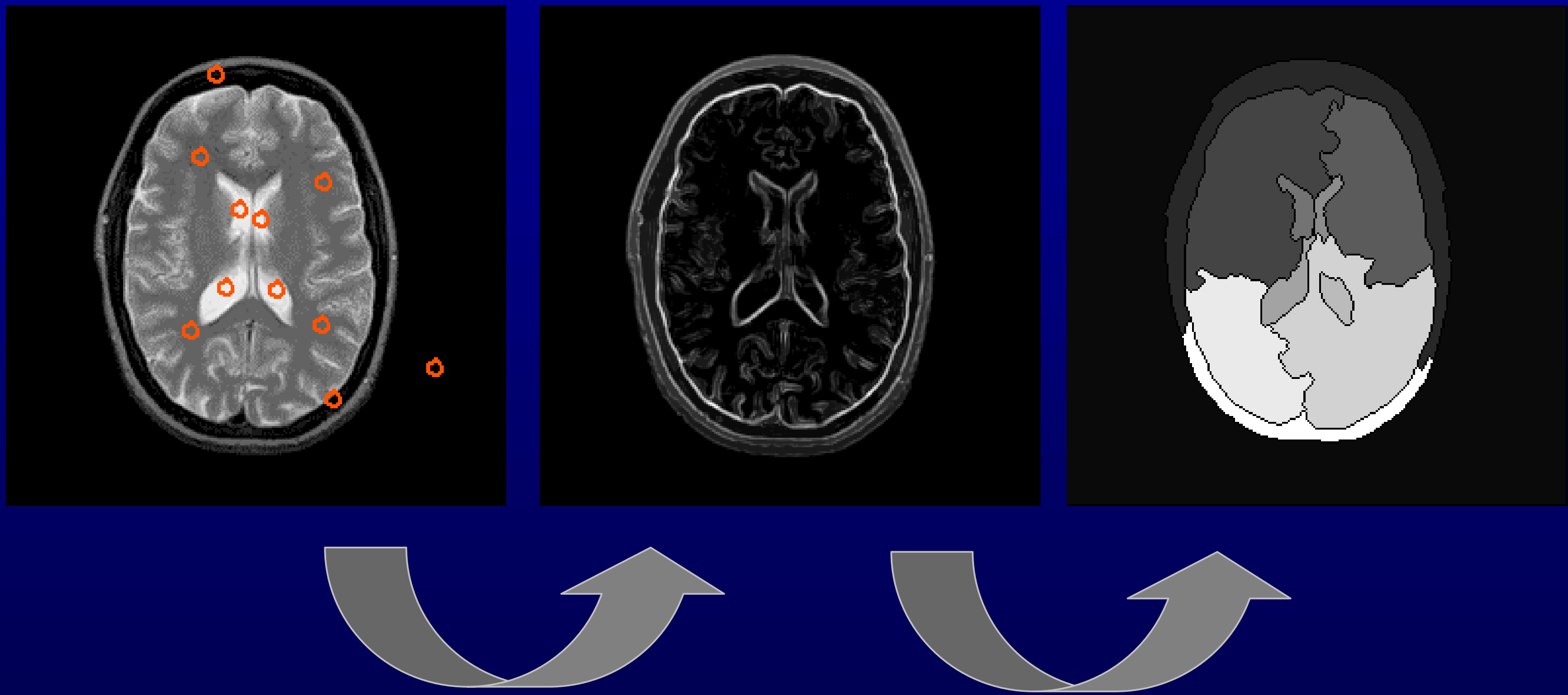
Manual selection



Automatic selection



Manual minima selection



Gradient + reconstruction

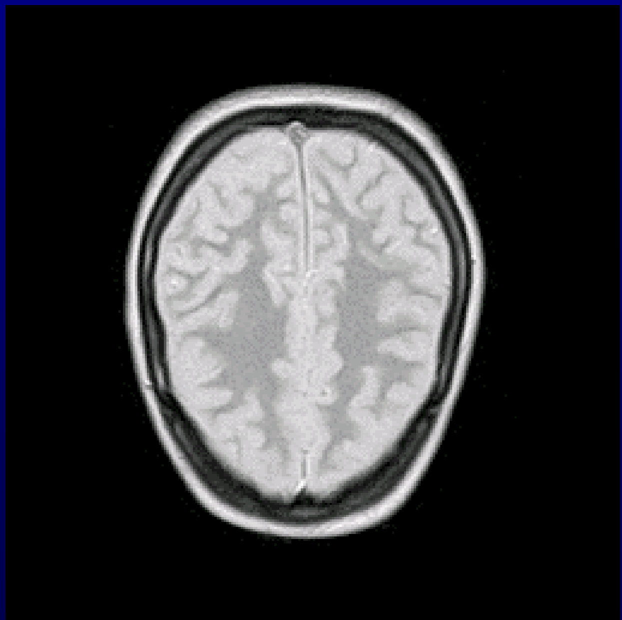
Watershed transform

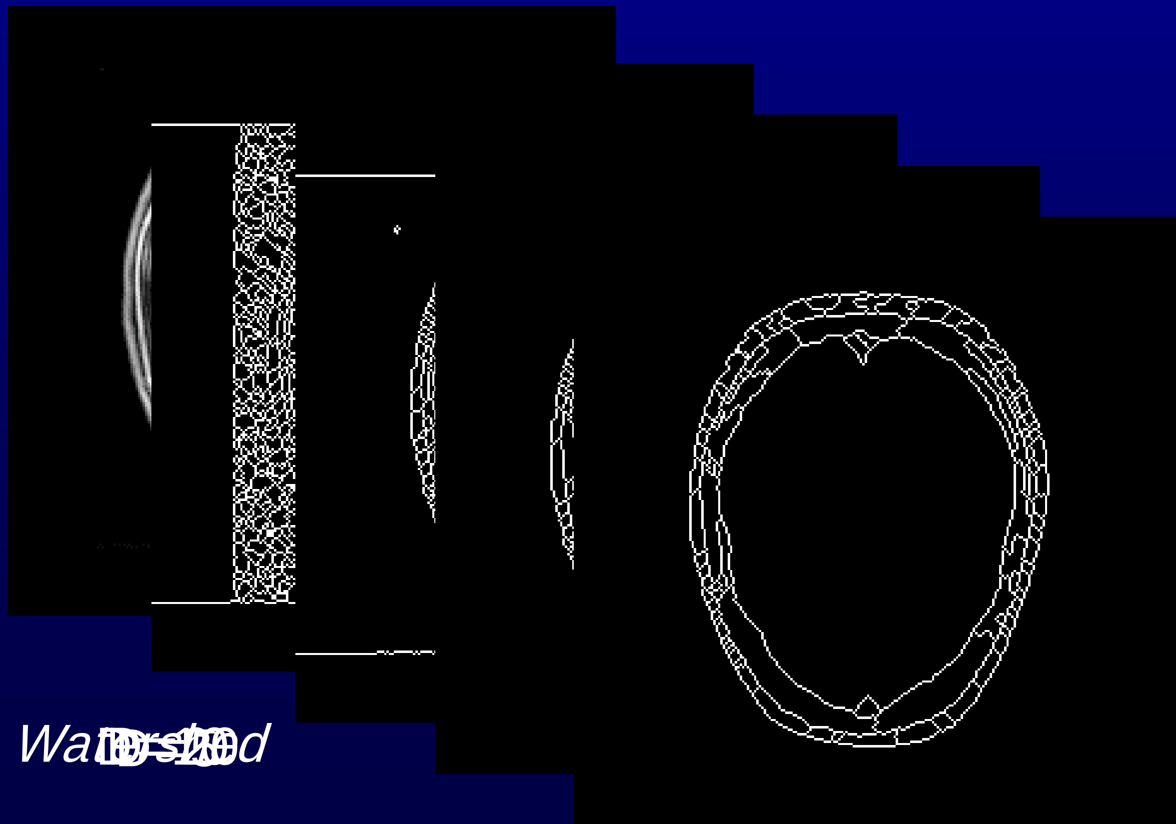
Automatic minima selection (1)

Dynamics of minima.

– Reconstruction by erosion of f(x+D) over f(x).

– Minima with dynamics < D are eliminated

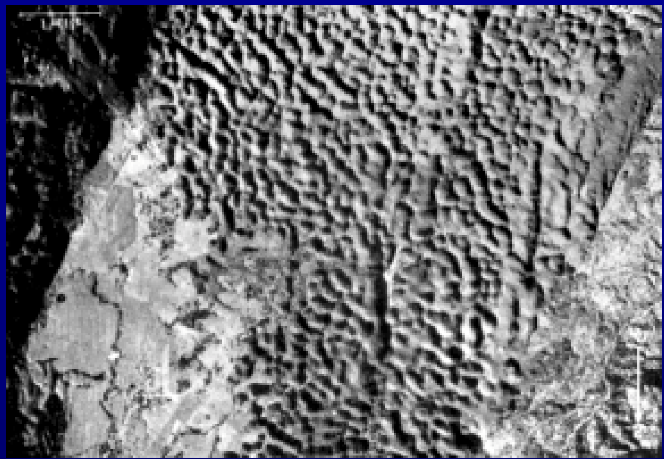




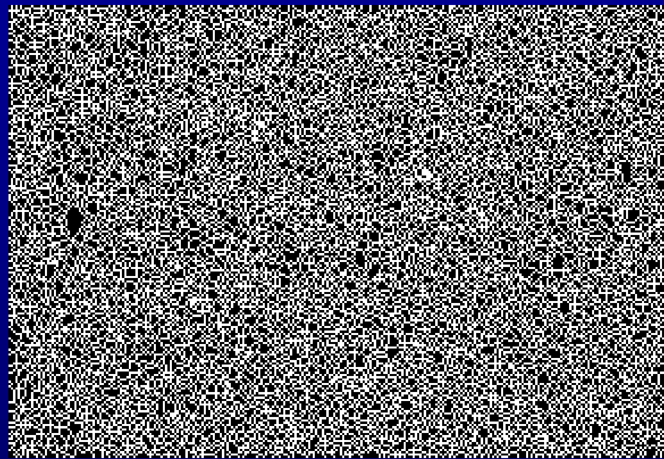
Watershed

Automatic minima selection (2)

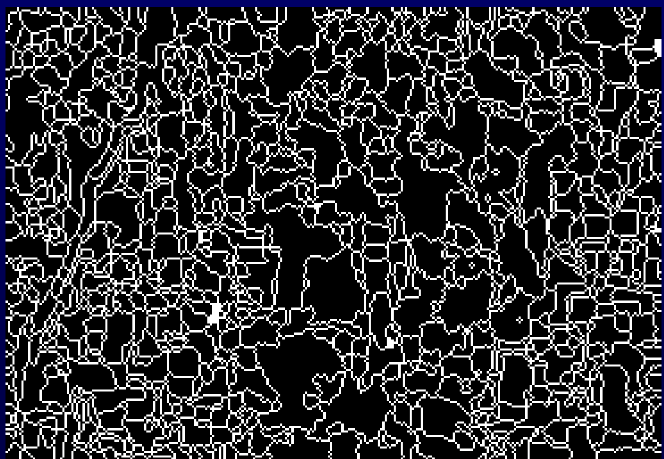
Selection of minima on a vector gradient



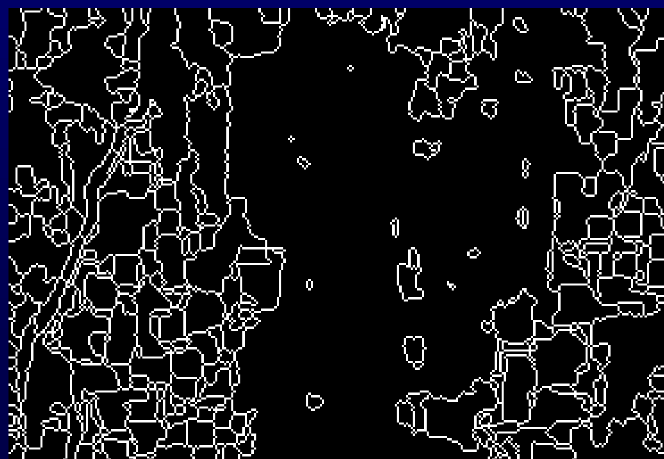
Aerial image



Aerial image



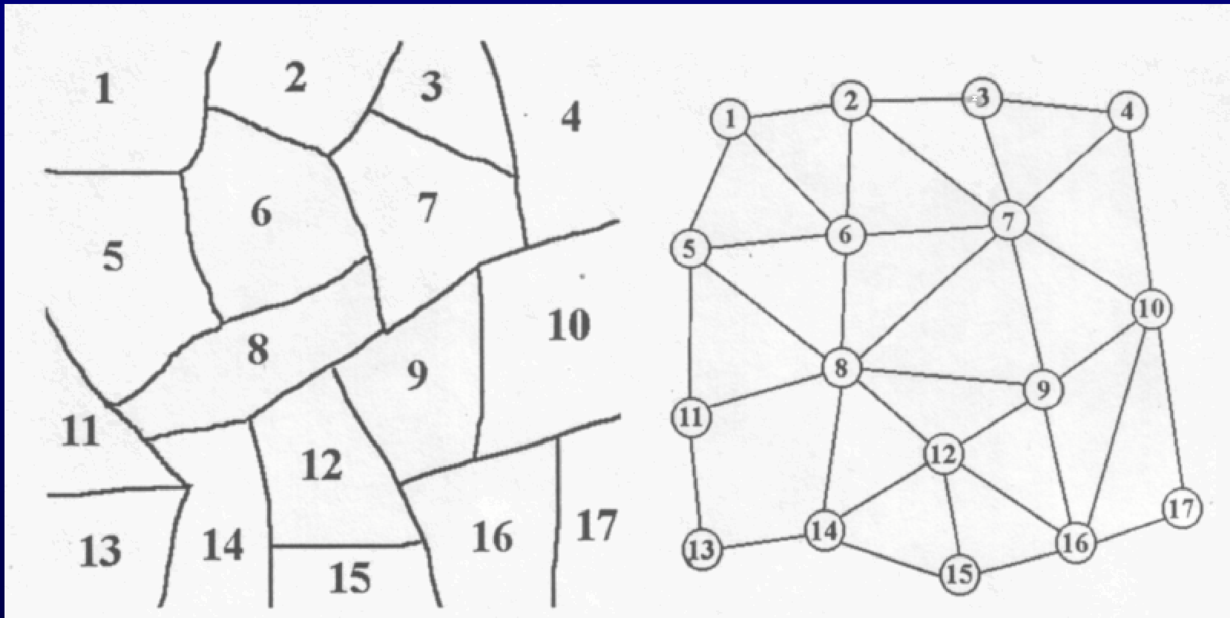
Selection with D = 8



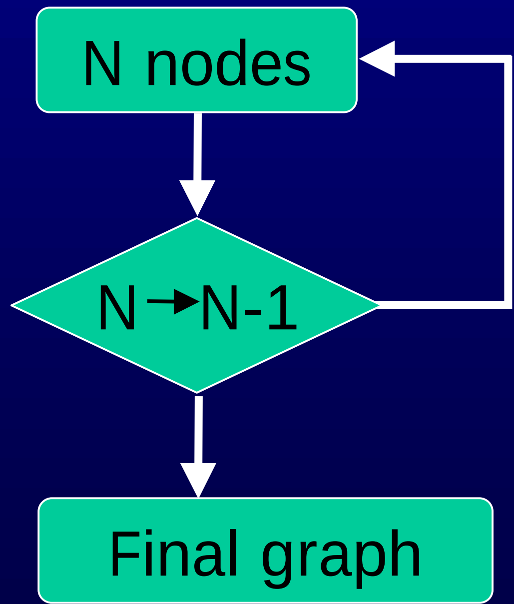
Selection with D = 12

Post-processing

- Region merging
- Basins are procesed using a region adjacency graph (RAG)
- Image is only analized once



(a) Partición de la imagen (b) Grafo de regiones



Multichannel merging

- Regions are merged according to a similarity criterion
- Two criteria have been tested:
  - Difference of mean values: $Diff = \sqrt{\sum_{i=1}^{n} (\mu_{1i} - \mu_{2i})}$
  - Hotelling's T^2 test

$$T^2 = (\bar{x}_1 - x_2)^T \left[\sqrt{\frac{1}{n_1} + \frac{1}{n_2}} S \right]^{-1} (\bar{x}_1 - \bar{x}_2)$$

$$S = \sqrt{\frac{n_1 \Sigma_1 + n_2 \Sigma_2}{n_1 + n_2}}$$

Region merging (2)

- Similar regions search algorithm
  - Test all neighbour couples in every iteration
  - Only test the axes of the smallest region
- Stop condition
  - Final number of regions desired
  - Threshold of similarity measure

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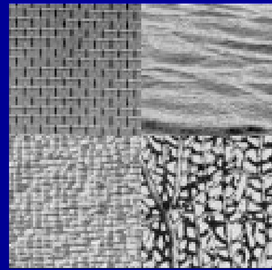
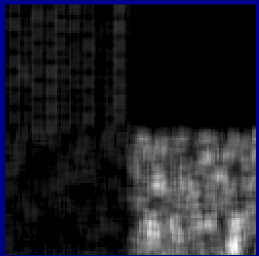
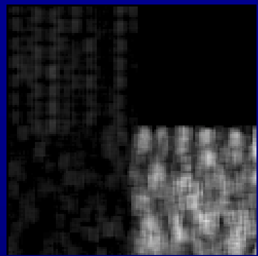
Feature maps

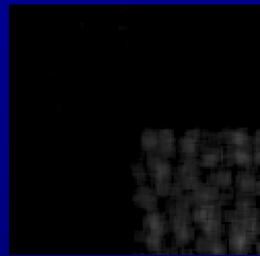




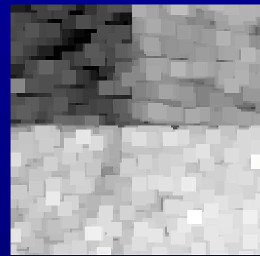
S10contrast



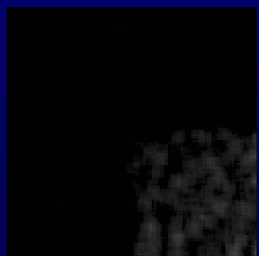
s20difvarnc



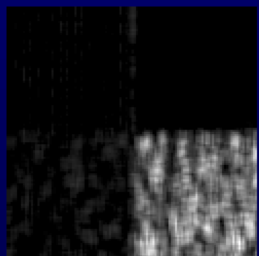
s10difvarnc



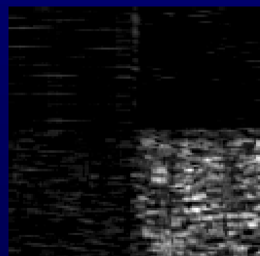
perc99



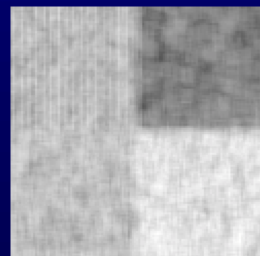
S1_1difvarnc



S30contrast

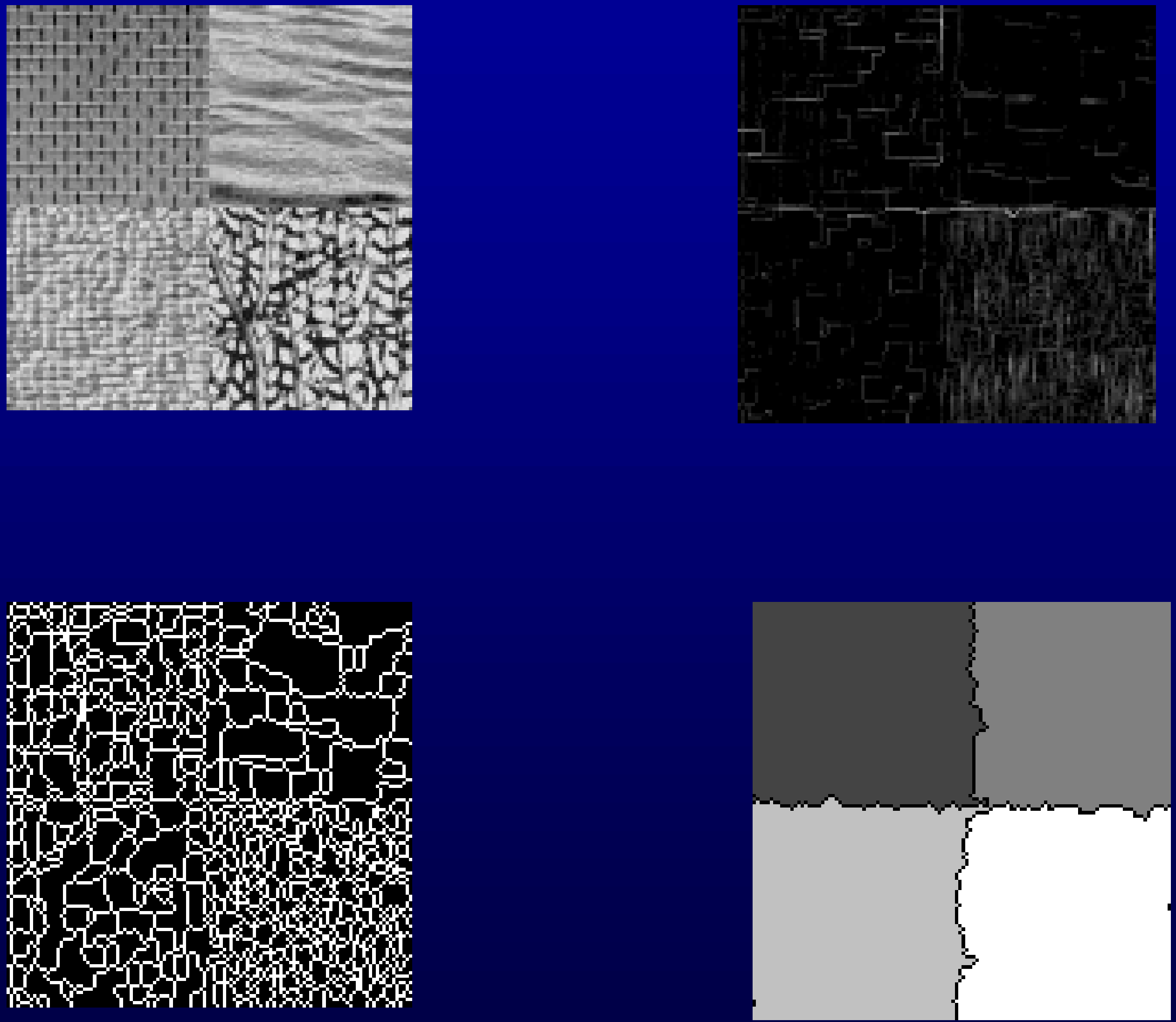


s05sumvarnc

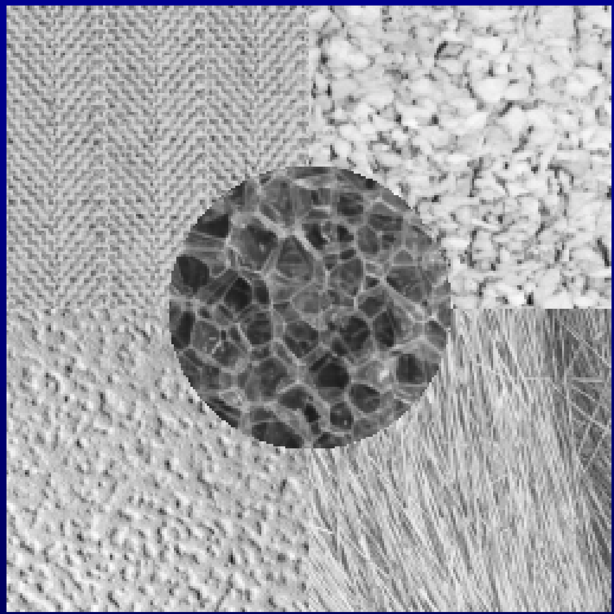


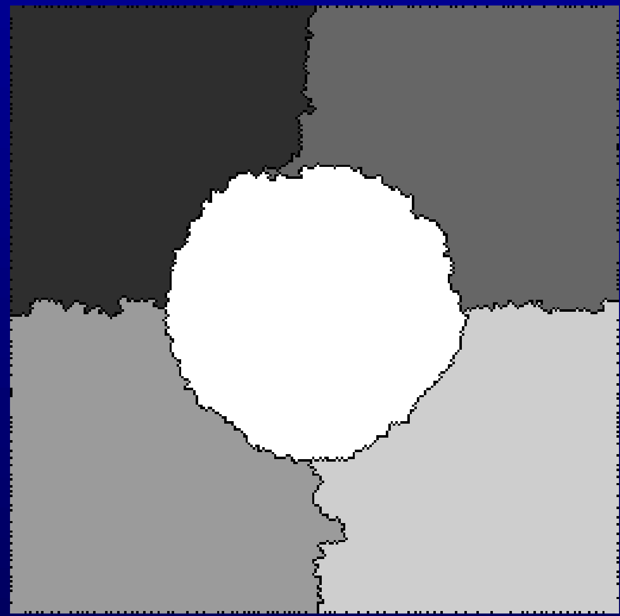
s10difentrp

Results

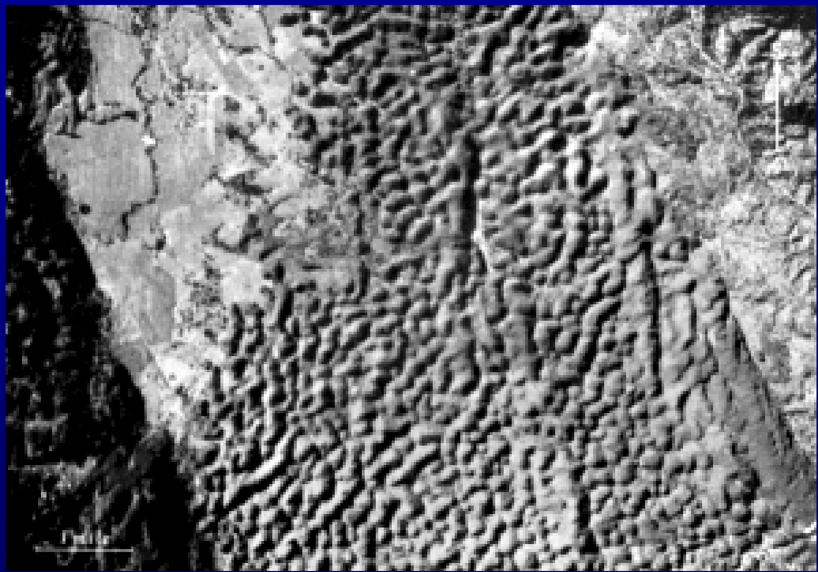


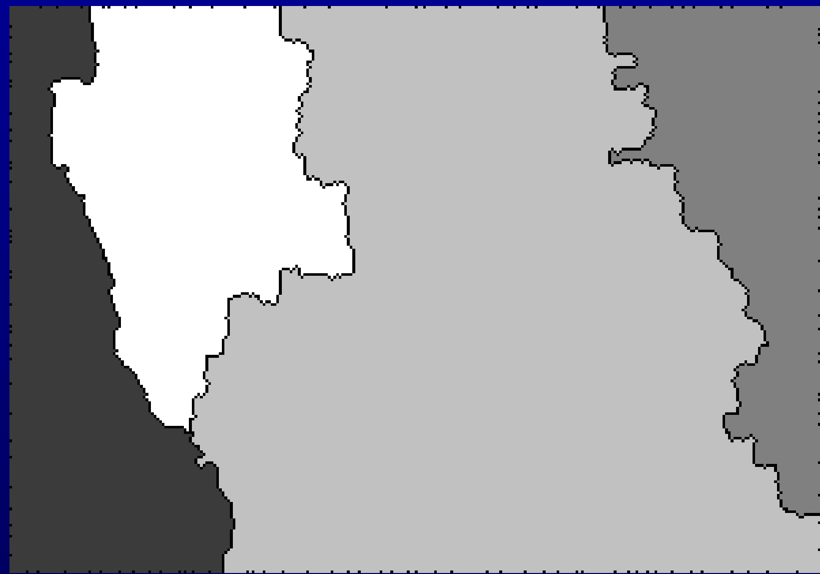
Results (II)





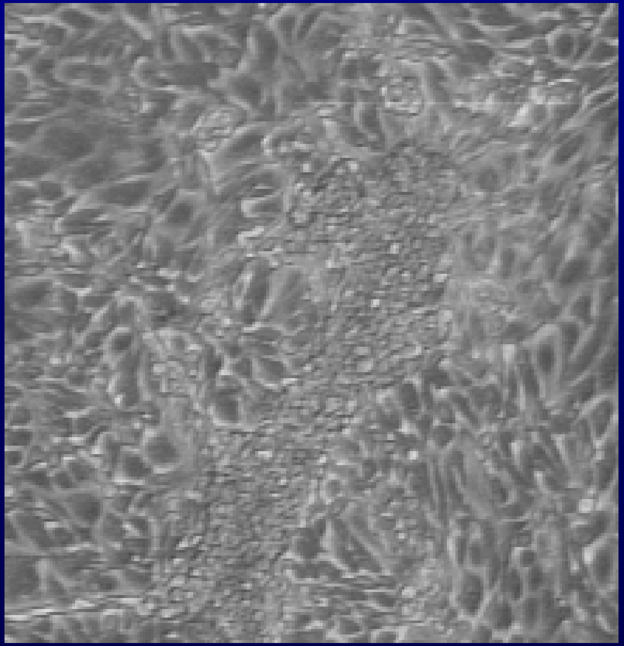
Results (3)



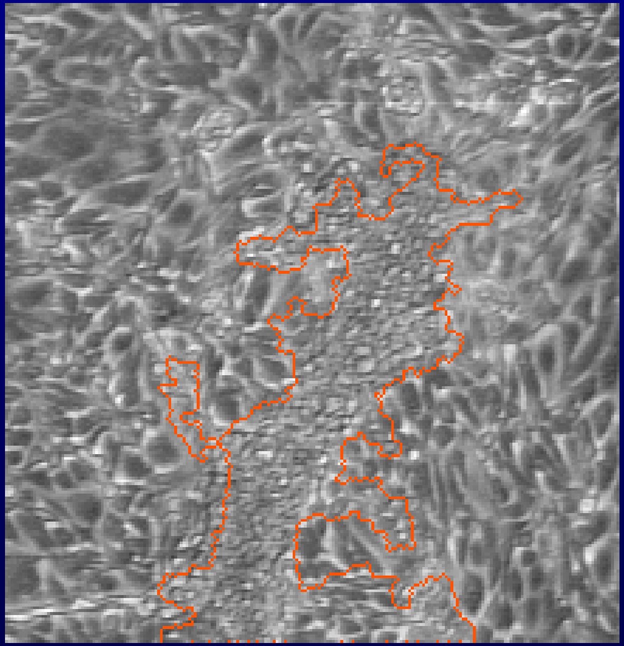


Results(4)

- Aim: Segmenting dead from live cells in a cell culture
- Texture: 3 histogram and 7 GLCM parameters (9x9 window)

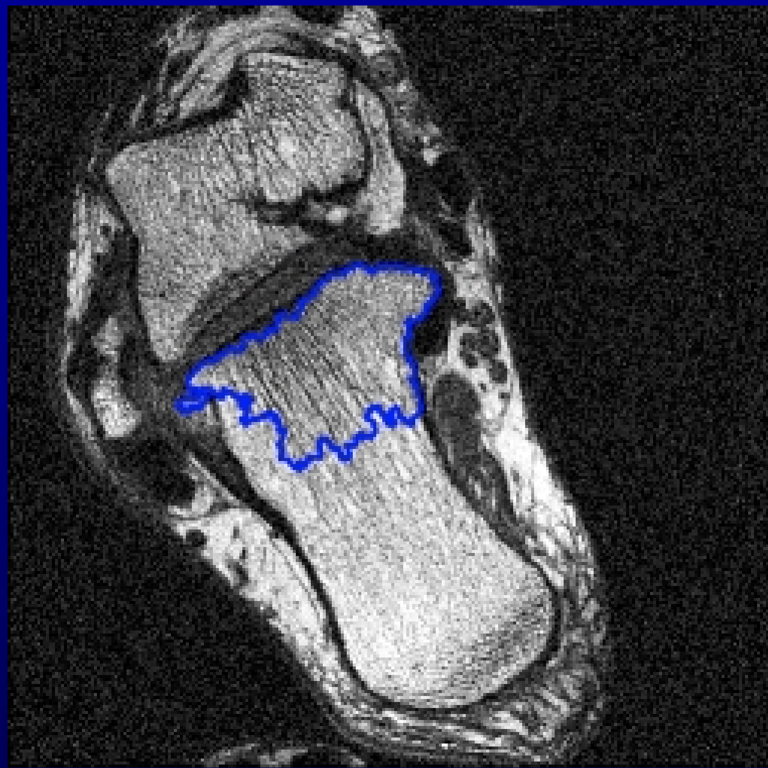


Original image

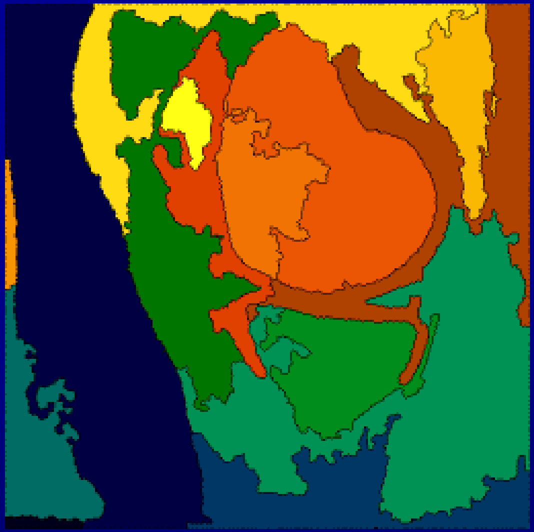


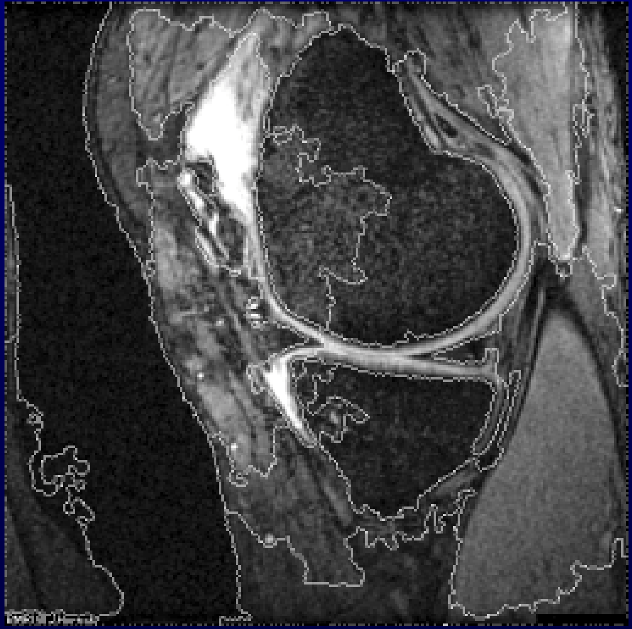
Segmented dead cells

Results (5)



Results(6)





Extension of other techniques

- Contour based methods, such as deformable models can be adapted using the vector gradient.
- We can include shape and curvature constraints, while working in the multichannel space.
- Results on MRI knee using variance were presented in Lorigo et al., MICCAI 98

Geodesic snakes. Example

Conclusions

- A multichannel watershed-based segmentation has been proposed and tested.
- Resolution
  - Depends on the size of the texture window
  - Could be improved by a smaller scale segmentation in borders.
- Works well with a known number of textures
- For specific object segmentation, other techniques can be used. Initialization is a subject.