IMAGE PROCESSING - SEGMENTATION & BINARY IMAGE ANALISYS

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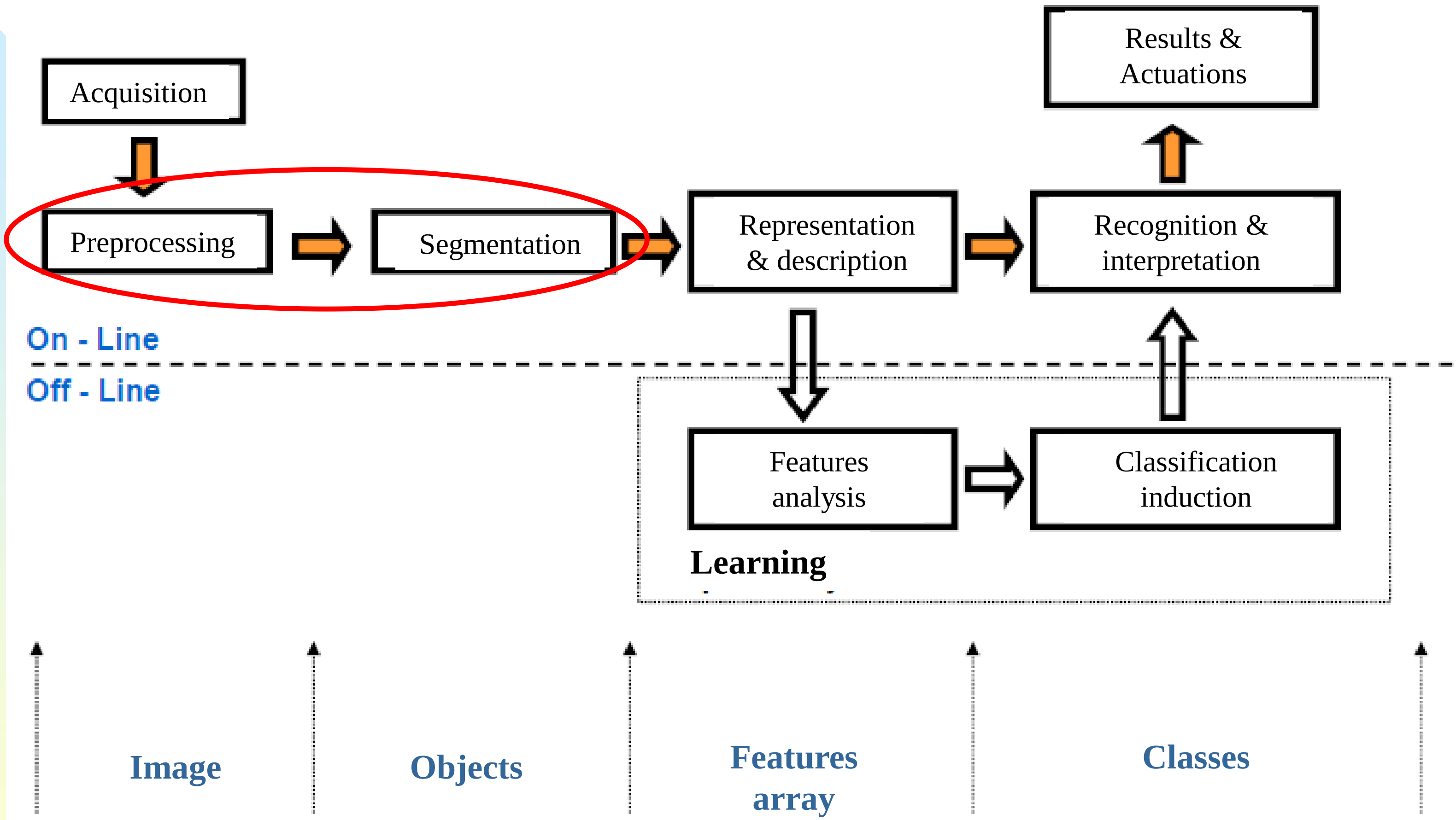
DESIGN STAGES



OUTLINE

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SEGMENTATION

- Segmentation consists in detecting the pixels of interest in the image, differentiating them from the background pixels.
- The pixels of interest become black and the others white or vice versa (binary images).
- Segmentation can be a very complex or very simple problem depending on the type of scene and the quality of the image.

SEGMENTATION - THRESHOLDING

- We analyse the histogram of the image and determine a gray level that separates the background pixels from the object pixels.

Image

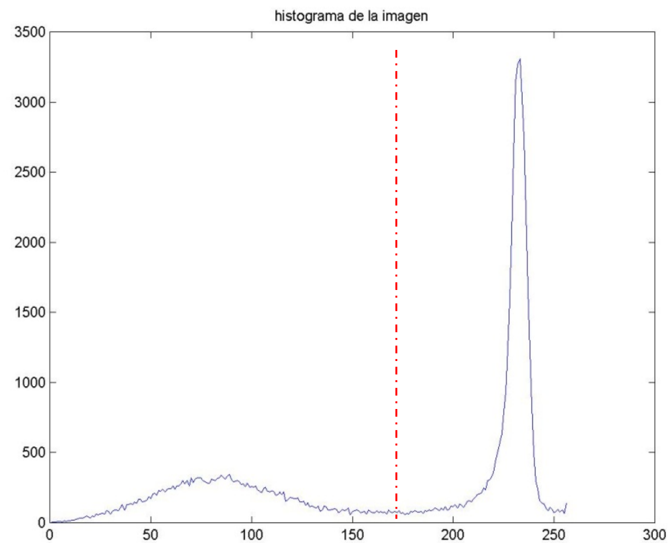

Image histogram

Segmented image

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SEGMENTATION - THRESHOLDING

250	251	250	255	255	250	252	255
249	240	255	246	248	249	254	252
255	255	50	45	51	47	253	255
255	247	49	50	53	50	255	254
248	255	52	50	50	50	245	255
250	241	50	48	55	50	255	248
251	240	255	238	250	240	239	250
253	239	249	255	255	249	250	251

Original image

255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255
255	255	0	0	0	0	255	255
255	255	0	0	0	0	255	255
255	255	0	0	0	0	255	255
255	255	0	0	0	0	255	255
255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255

Binary image

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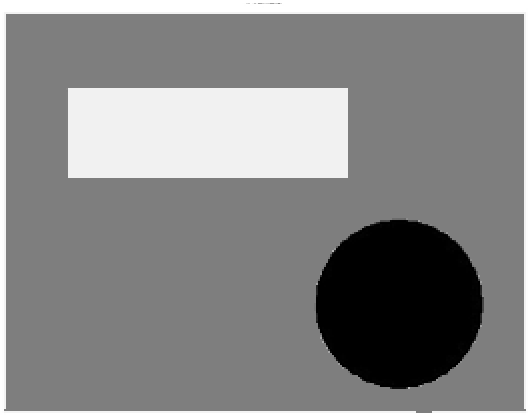
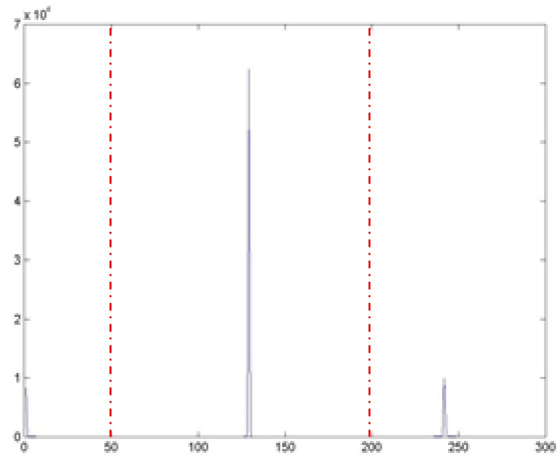
SEGMENTATION IN DIFFERENT BANDS

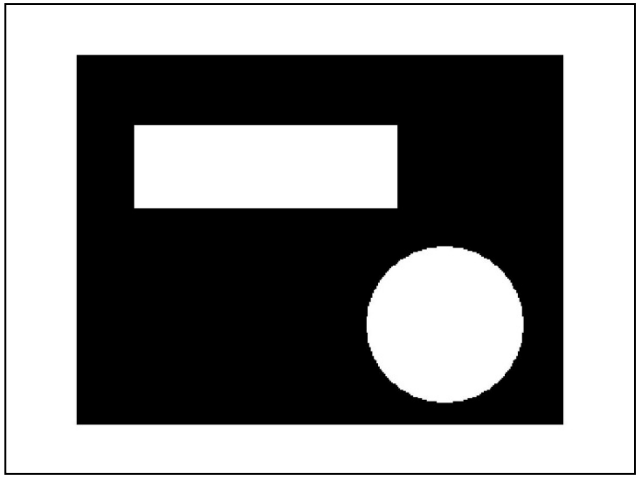
- Several bands can be defined to delimit the grey levels of the object of interest.



Original image



Histogram



Binary image

First band => [0, 50]
Background => [100, 150]
Second band => [200, 255]

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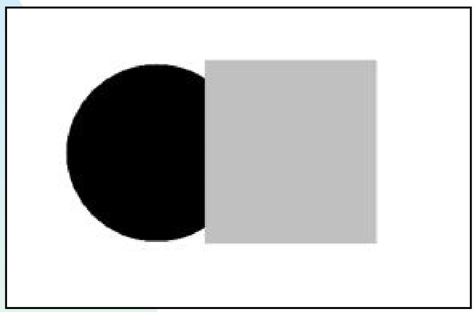
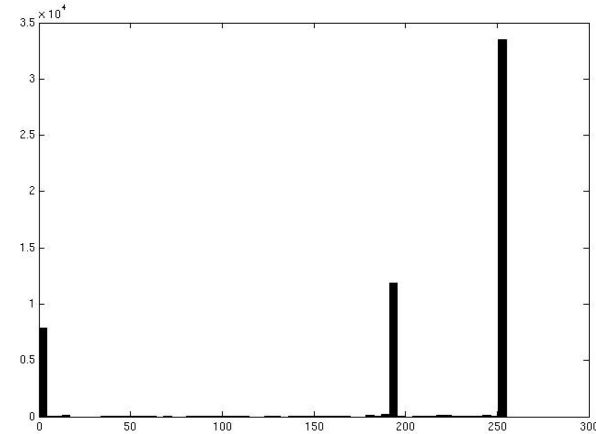
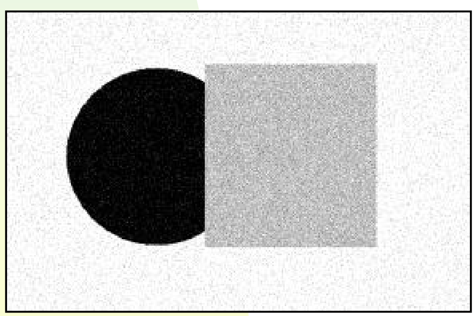
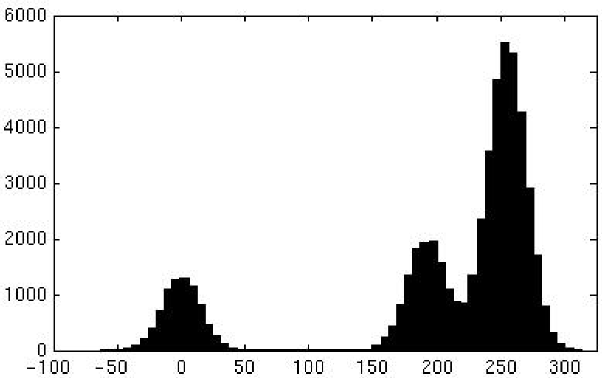
SEGMENTATION PROBLEM

- Mixing of the same color between different objects of interest and background.



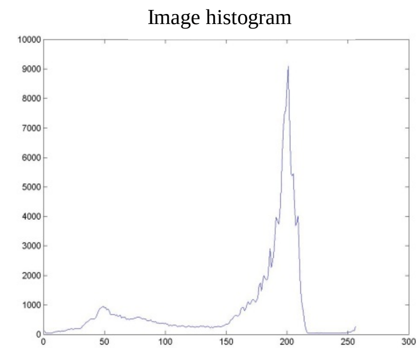


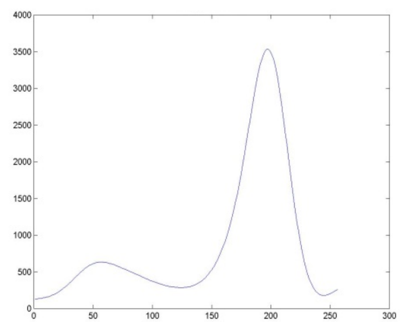




SEGMENTATION PROBLEM

- The histogram valleys are searched and the problem arises when the gray level of the background and that of the objects are mixed.





Filtered histogram applying a 1x3 mean filter 300 times

Segmented image (threshold = 123)

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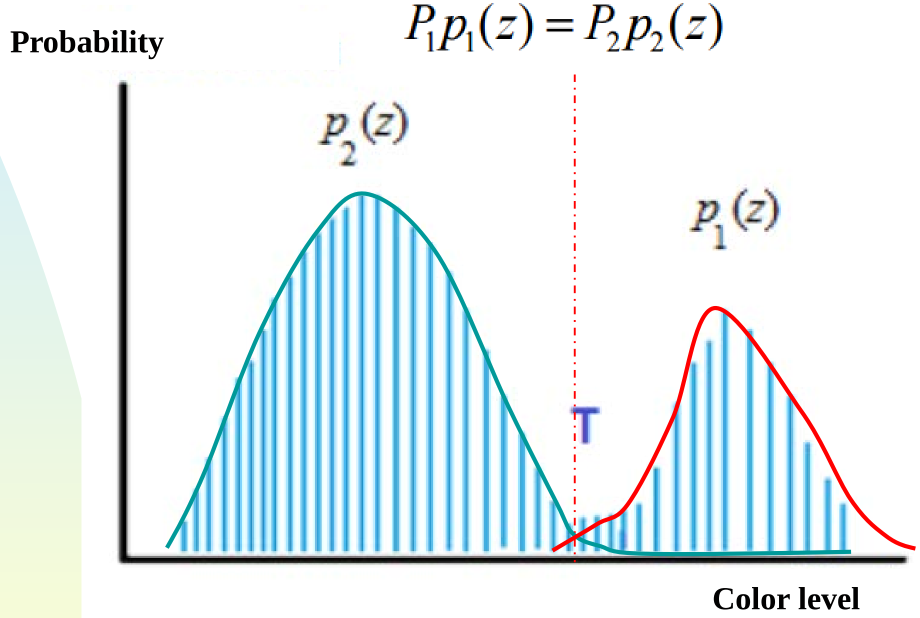
AUTOMATIC THRESHOLD DETECTION

- Bimodal histogram: $p(z) = P_1 p_1(z) + P_2 p_2(z)$

$$d_1(z) = P_1 p_1(z) \quad \text{y} \quad d_2(z) = P_2 p_2(z)$$

$$P_1 p_1(z) = P_2 p_2(z)$$



$$p_1(z) = \frac{1}{\sqrt{2\pi}\sigma_1}\exp\left[-\frac{(z-m_1)^2}{2\sigma_1^2}\right]; \quad p_2(z) = \frac{1}{\sqrt{2\pi}\sigma_2}\exp\left[-\frac{(z-m_2)^2}{2\sigma_2^2}\right]$$

AUTOMATIC THRESHOLD DETECTION

$$p_1(z) = \frac{1}{\sqrt{2\pi}\sigma_1}\exp\left[-\frac{(z-m_1)^2}{2\sigma_1^2}\right]; \quad p_2(z) = \frac{1}{\sqrt{2\pi}\sigma_2}\exp\left[-\frac{(z-m_2)^2}{2\sigma_2^2}\right]$$

$$P_1 p_1(z) = P_2 p_2(z)$$

z = T

$$AT^2 + BT + C = 0$$

$$A = \sigma_1^2 - \sigma_2^2$$

$$B = 2(m_1\sigma_2^2 - m_2\sigma_1^2)$$

$$C = \sigma_1^2 m_2^2 - \sigma_2^2 m_1^2 + 2\sigma_1^2\sigma_2^2 \ln\frac{\sigma_2 P_1}{\sigma_2 P_2}$$

$\sigma_1 = \sigma_2 = \sigma$

$$\boxed{T = \frac{m_1 + m_2}{2} + \frac{\sigma^2}{m_1 - m_2}\ln\frac{P_2}{P_1}}$$

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AUTOMATIC THRESHOLD DETECTION OTSU ALGORITHM

$$w_1(t) = \sum_{z=1}^{T} P(z) \;\text{ y }\; w_2(t) = \sum_{z=T+1}^{L} P(z)$$

$$\mu_1(t) = \sum_{z=1}^{T} z\frac{P(z)}{w_1(t)} \;\text{ y }\; \mu_2(t) = \sum_{z=T+1}^{L} z\frac{P(z)}{w_2(t)}$$

$$\sigma_1^2(t) = \sum_{z=1}^{T} (z-\mu_1(t))^2 \frac{P(z)}{w_1(t)} \;\text{ y }\; \sigma_2^2(t) = \sum_{z=T+1}^{L} (z-\mu_2(t))^2 \frac{P(z)}{w_2(t)}$$

$$\sigma_w^2(t) = w_1(t)\sigma_1^2(t) + w_2(t)\sigma_2^2(t)$$

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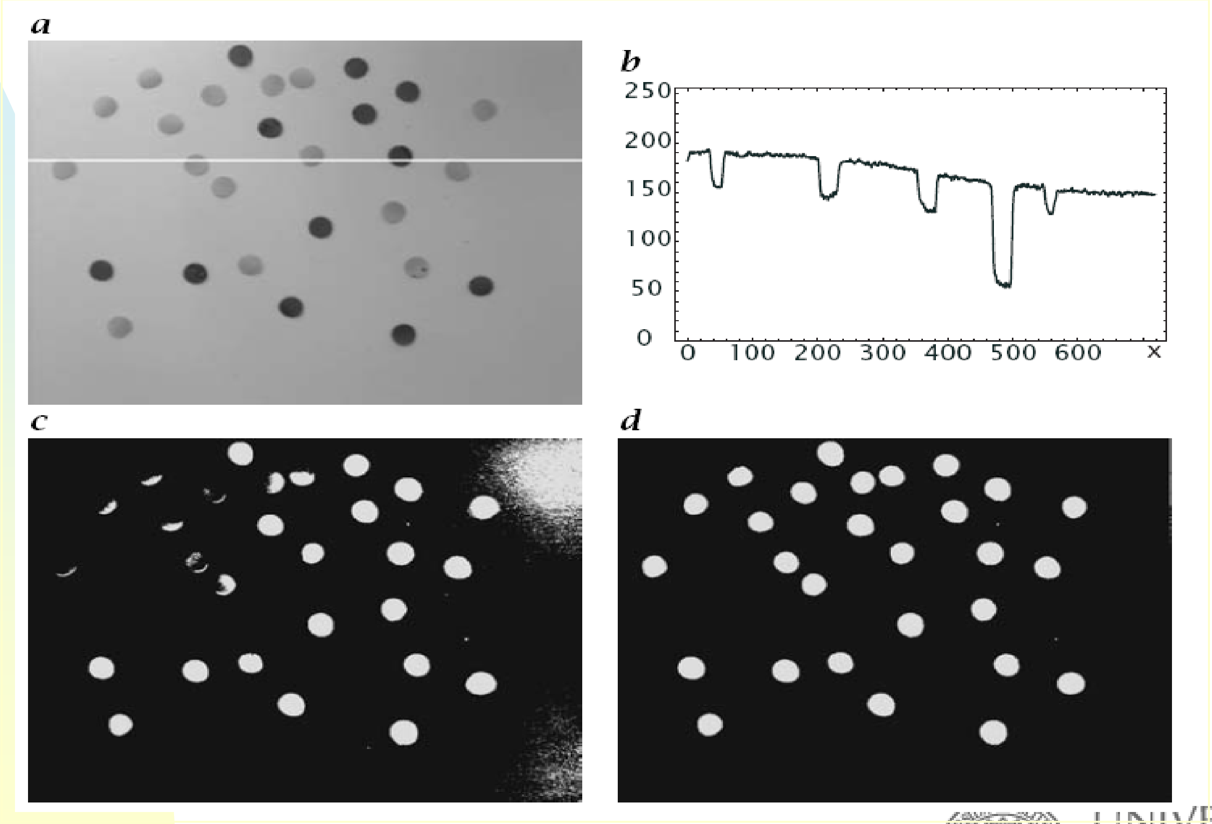
ADAPTATIVE SEGMENTATION

- For non-uniform backgrounds or objects, line-by-line segmentation is possible by detecting and correcting for brightness variations.
- Different segmentation thresholds can be defined based on the mean or median of neighboring pixels.



ANALYSIS OF BINARY IMAGES

- They try to improve the quality of the segmented image. There are different techniques:
  - BORDERS (Outline): detects edges in a binary image.
  - EROSION (Erode): removes edge layers to separate overlapping objects.
  - DILATATION (Dilate): adds edge layers
  - OPENING and CLOSING: filters out small objects and closes holes
  - DISTANCE TRANSFORM MAP: distance of pixels to the background
  - SKELETONIZATION
- Subsequently we proceed to connected-components LABELING that allows to identify the pixels that belong to the objects of interest...

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PIXELS CONNECTIVITY

- **4-Connectivity**

$A_0 = x,y$
$A_1 = x,y+1$
$A_3 = x-1,y$
$A_5 = x,y-1$
$A_7 = x+1,y$

Coordinates of the 4 neighbors of the pixel (x, y)

	A_3	
A_5	A_0	A_1
	A_7	

4 connectivity

- **8-Conectivity**

$A_0 = x,y$

$A_1 = x,y+1$	$A_2 = x-1,y+1$
$A_3 = x-1,y$	$A_4 = x-1,y-1$
$A_5 = x,y-1$	$A_6 = x+1,y-1$
$A_7 = x+1,y$	$A_8 = x+1,y+1$

Coordinates of the 8 neighbors of the pixel (x, y)

A_4	A_3	A_2
A_5	A_0	A_1
A_6	A_7	A_8

8 connectivity

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PIXELS CONNECTIVITY

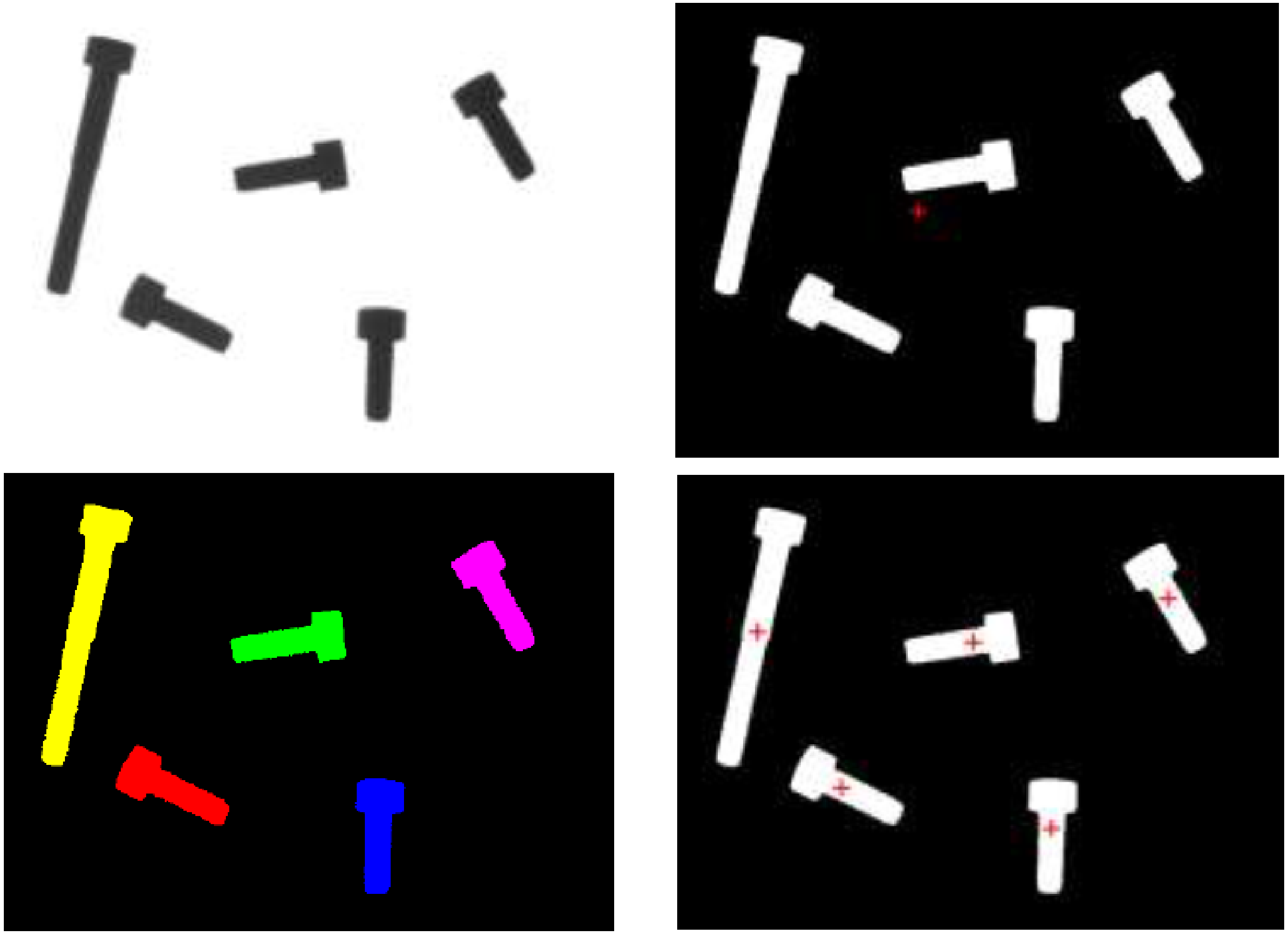
How many objects of interest are in the following image?

1	0
0	1

Problem: if the object and the background are 8-connected.

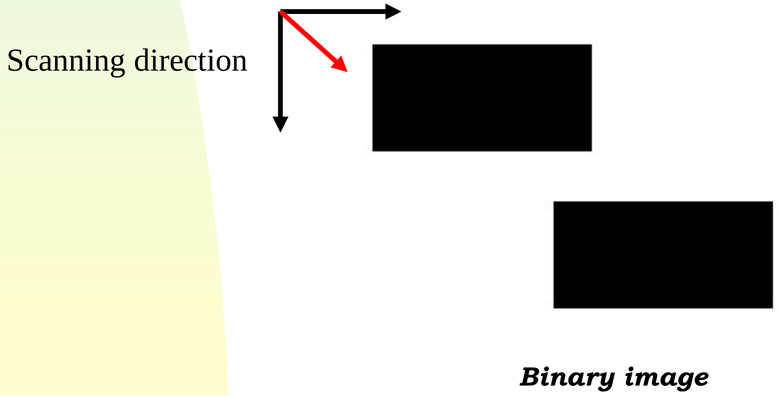
Solution: object 8-connected and background 4-connected.

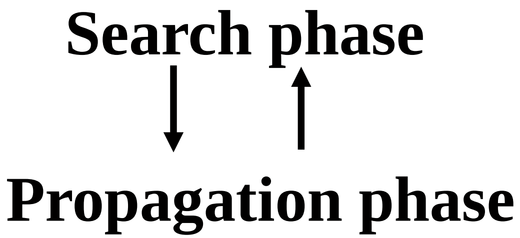
CONNECTED-COMPONENT LABELING



BASIC LABELING ALGORITHM

- The binary image is scanned from left to right and from top to bottom searching an unlabeled object pixel.
- Each time an unlabeled object pixel is found, it is labeled and this label is propagated around to all the connected object pixels.
- When propagation is finished, a search for a new unlabeled object pixel is started.
- The algorithm finishes when search doesn't find any unlabeled object pixel.





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LABELING ALGORITHM

```
[ [P0:=0] ]; N:=0; found:=true;
repeat until not found
  % search phase
  found:=false;
  [ [ if ((A0=1)&(P0=0)&not found) then N:=N+1; P0:=N; found :=true;] ];
  if found then
    % propagation phase
     finished:=false;
     repeat until finished
        finished:=true;
        [ [ if (A0=1)&(P0=0)& ( (P1=N)|(P2=N)|(P3=N)|(P4=N)|...|(P8=N))
         then P0:=N; finished:=false;] ];
```

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LABELING ALGORITHM - IMAGES

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

Labeled image - P

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LABELING ALGORITHM

```
[ [P0:=0] ]; N:=0; found:=true;
repeat until not found
  % search phase
  found:=false;
  [ [ if ((A0=1)&(P0=0)&not found) then N:=N+1; P0:=N; found :=true;] ];
  if found then
    % propagation phase
     finished:=false;
     repeat until finished
        finished:=true;
        [ [ if (A0=1)&(P0=0)& ( (P1=N)|(P2=N)|(P3=N)|(P4=N)|...|(P8=N))
         then P0:=N; finished:=false;] ];
```

LABELING ALGORITHM - INITIALIZATION

N:=0 found:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM

```
[ [P0:=0] ]; N:=0; found:=true;
repeat until not found
  % search phase
  found:=false;
  [ [ if ((A0=1)&(P0=0)&not found) then N:=N+1; P0:=N; found :=true;] ];
  if found then
    % propagation phase
    finished:=false;
    repeat until finished
      finished:=true;
      [ [ if (A0=1)&(P0=0)& ( (P1=N)|(P2=N)|(P3=N)|(P4=N)|...|(P8=N))
      then P0:=N; finished:=false;] ];
```

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LABELING ALGORITHM – SEARCH PHASE

N:=0 $\boxed{\text{found:=false}}$

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM – SEARCH PHASE

N:=1

found:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM

```
[ [P0:=0] ]; N:=0; found:=true;
repeat until not found
  % search phase
  found:=false;
  [ [ if ((A0=1)&(P0=0)&not found) then N:=N+1; P0:=N; found :=true;] ];
  if found then
    % propagation phase
     finished:=false;
     repeat until finished
        finished:=true;
        [ [ if (A0=1)&(P0=0)& ( (P1=N)|(P2=N)|(P3=N)|(P4=N)|...|(P8=N))
         then P0:=N; finished:=false;] ];
```

LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=false

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=false

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=1 found:=true finished:=false

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=1 found:=true finished:=false

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=false

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

LABELING ALGORITHM - PROPAGATION

N:=1 | found:=true | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

LABELING ALGORITHM

```
[ [P0:=0] ]; N:=0; found:=true;
repeat until not found
  % search phase
  found:=false;
  [ [ if ((A0=1)&(P0=0)&not found) then N:=N+1; P0:=N; found :=true;] ];
  if found then
    % propagation phase
     finished:=false;
     repeat until finished
        finished:=true;
        [ [ if (A0=1)&(P0=0)& ( (P1=N)|(P2=N)|(P3=N)|(P4=N)|...|(P8=N))
        then P0:=N; finished:=false;] ];
```

LABELING ALGORITHM – SEARCH PHASE

N:=1 $\boxed{\text{found:=false}}$ finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

LABELING ALGORITHM – SEARCH PHASE

N:=2 $\boxed{\text{found:=true}}$ finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	2	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=2 | found:=true | finished:=false

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	2	2	0
0	0	0	0	0	2	2	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM - PROPAGATION

N:=2 | found:=true | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	2	2	0
0	0	0	0	0	2	2	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM – SEARCH PHASE

N:=2 | found:=true | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	2	2	0
0	0	0	0	0	2	2	0
0	0	0	0	0	0	0	0

Labeled image - P

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LABELING ALGORITHM – END

N:=2 | found:=false | finished:=true

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0

Binary image - A

0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
0	0	0	0	0	2	2	0
0	0	0	0	0	2	2	0
0	0	0	0	0	0	0	0

Labeled image - P

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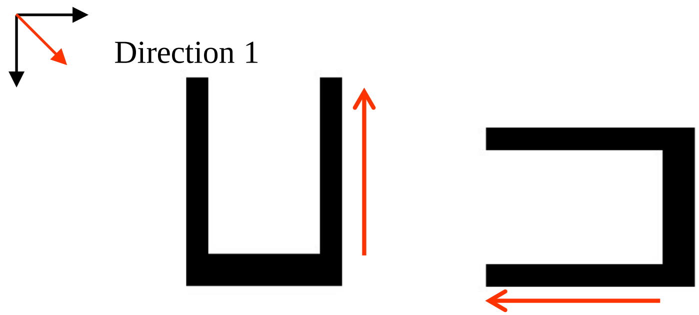
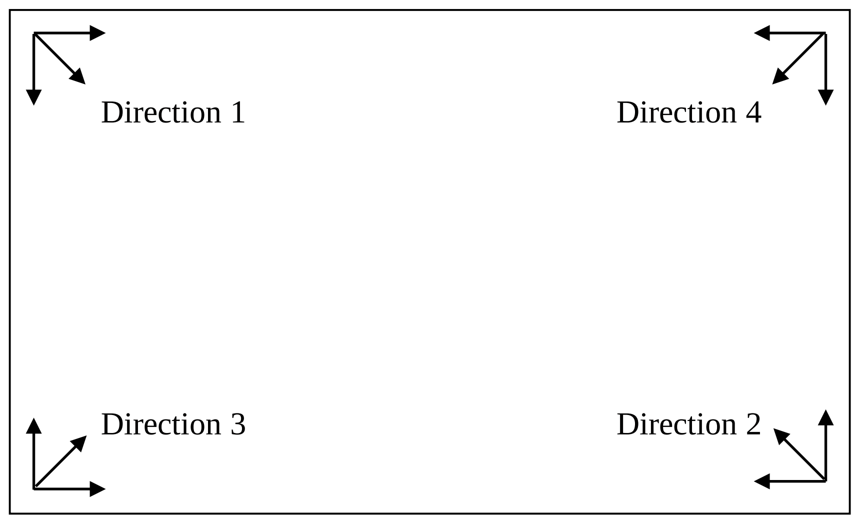
LABELING ALGORITHM – OPTIMIZATION

- Problem:



Problems with upstream propagation

- Solution:



Scanning directions

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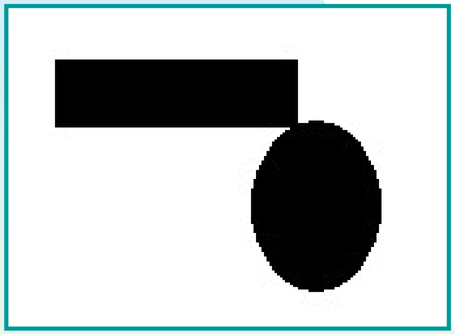
EROSION

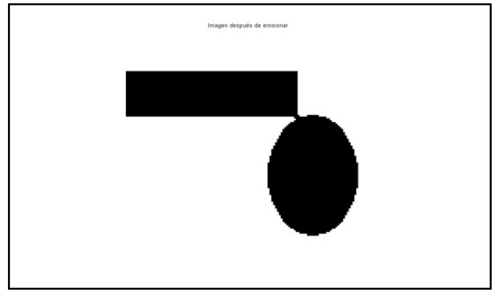
- When applying erosion transform, pixels that are connected to background are removed.

- Erosion reduces the size of objects and deforms their outline. This effect is different if 4 or 8-connectivity is used.

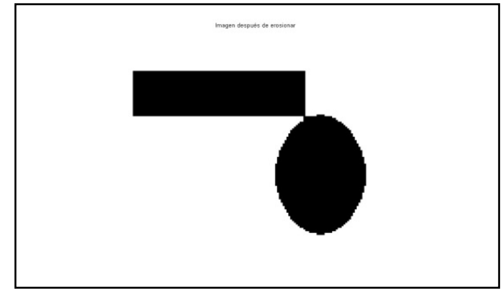
EROSION



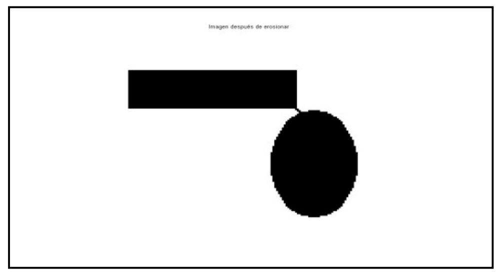
Binary image



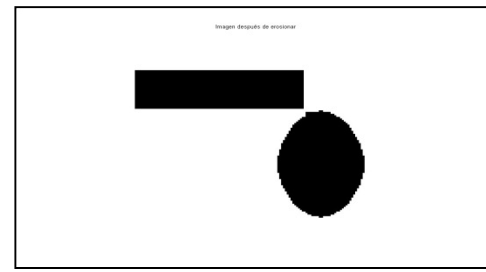
1 iteration using 4 connectivity



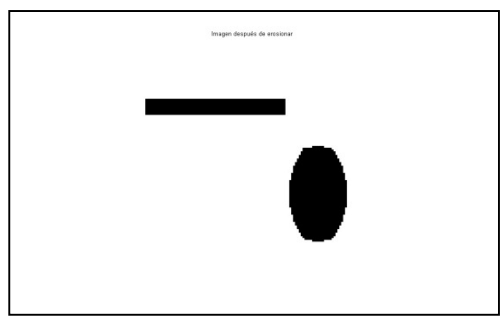
1 iteration using 8 connectivity



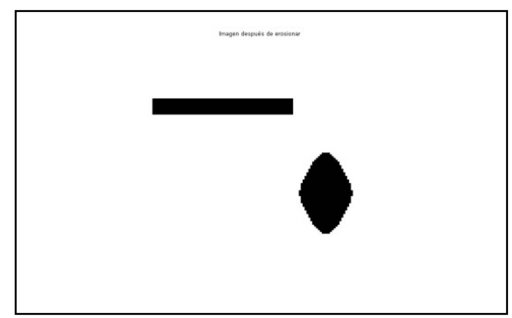
2 iterations using 4 connectivity



2 iterations using 8 connectivity



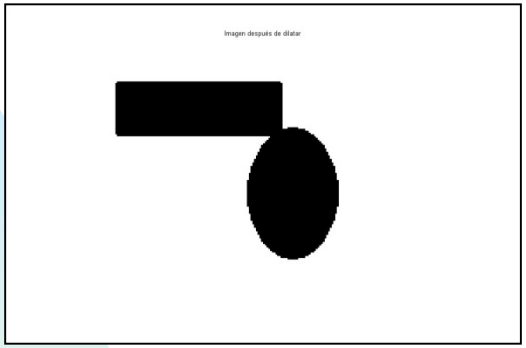
10 iterations using 4 connectivity



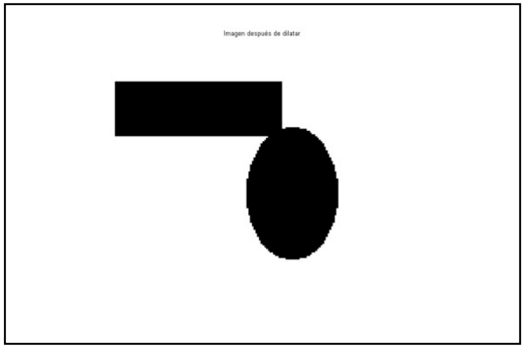
10 iterations using 8 connectivity

DILATATION

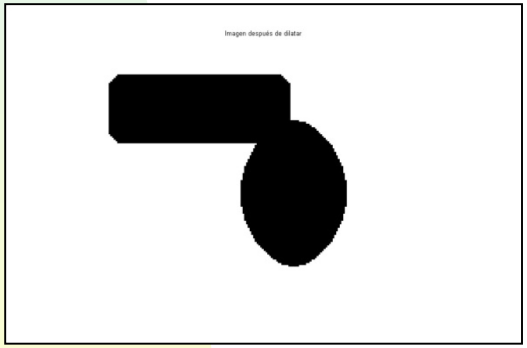
- It is just opposite of erosion



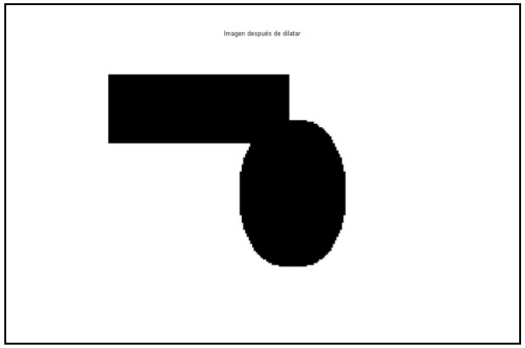
1 iteration using 4 connectivity



1 iteration using 8 connectivity



5 iterations using 4 connectivity



5 iterations using 8 connectivity

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OPENING AND CLOSING

- Erosion is used to eliminate noise and separate objects.
- Dilation is used to fill holes.
- Since both operations change the size of the object, it is necessary to combine them to preserve the size of the object.
    - OPENING: N erosions + N dilatations
    - CLOSING: N dilatations + N erosions

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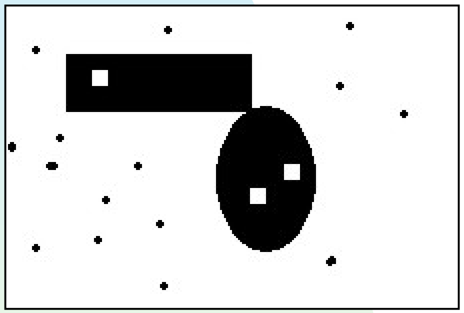
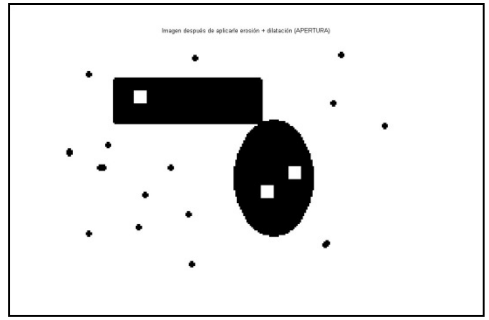
OPENING



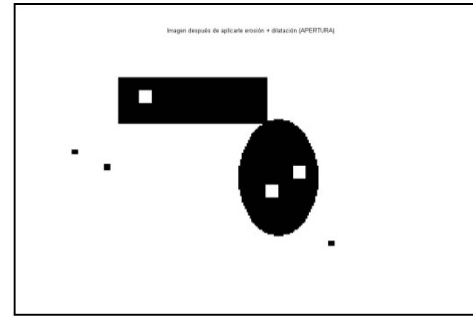
Binary image



1 opening iteration

1 erosion + 1 dilatation

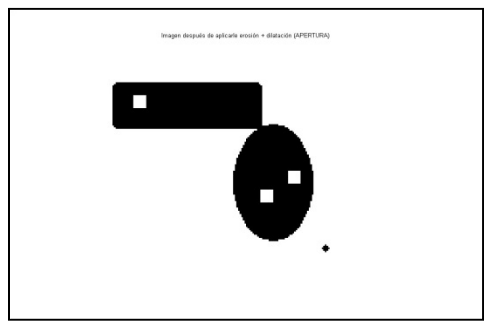
4-Conectivity



1 opening iteration

1 erosion + 1 dilatation

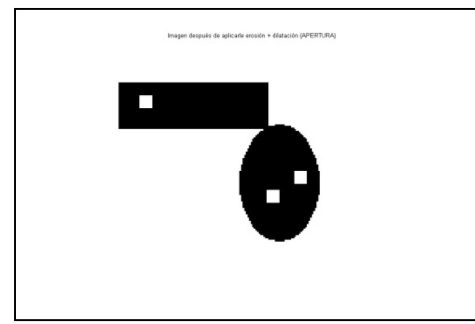
8-Conectivity



2 opening iteration

2 erosions + 2 dilatations

4-Conectivity



2 opening iteration

2 erosions + 2 dilatations

8-Conectivity

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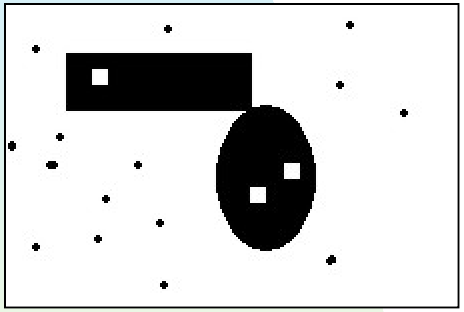
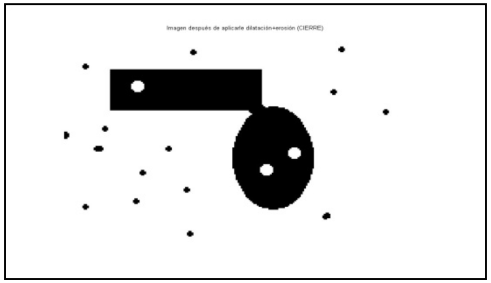
CLOSING



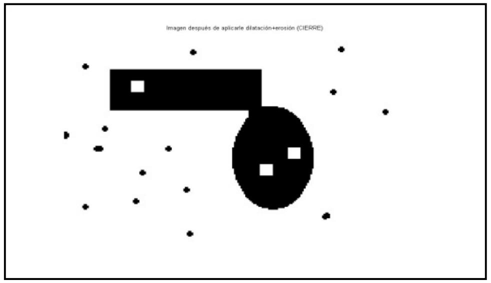
Binary image



2 closing iterations

2 dilatations + 2 erosions

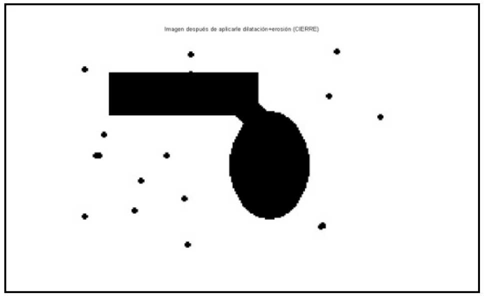
4-Conectivity



2 closing iterations

2 dilatations + 2 erosions

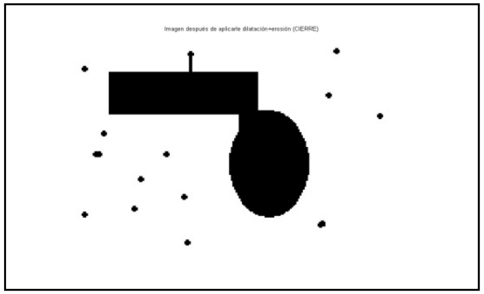
8-Conectivity



5 closing iterations

5 dilatations + 5 erosions

4-Conectivity



5 closing iterations

5 dilatations + 5 erosions

8-Conectivity

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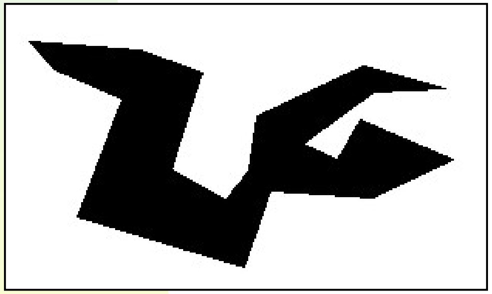
DISTANCE TRANSFORM MAP

- For each pixel of the source image, calculates the distance to the closest background pixel.
- It is performed by successive erosions. In each erosion a distance is assigned to the pixels removed. The loop is repeated until no pixels of interest remain.



Binary image

Distance transform map using erosions

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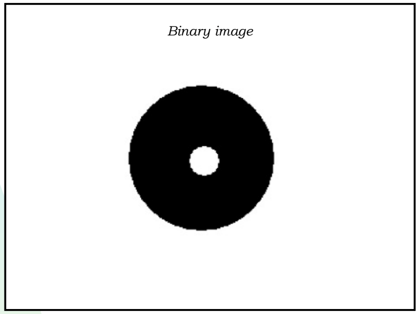
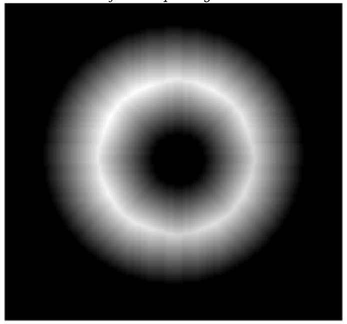
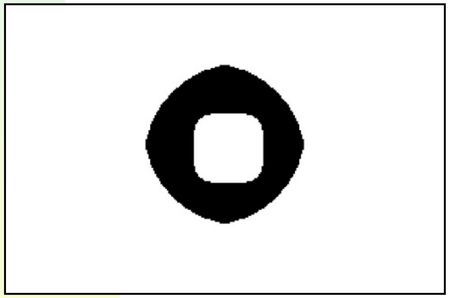
EROSION USING DISTANCE TRANSFORM MAP

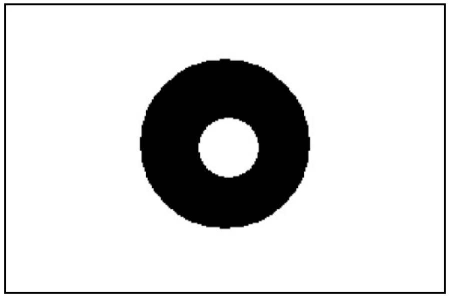
- A threshold is set for the distance to the background from which erosion is desired
- In this way, the shapes of the objects are conserved better.







Eroded image applying 10 iterations using 8-conectivity



Eroded image applying Euclidean distance map

Threshold=15

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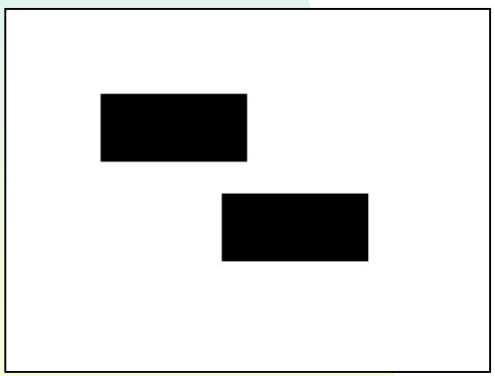
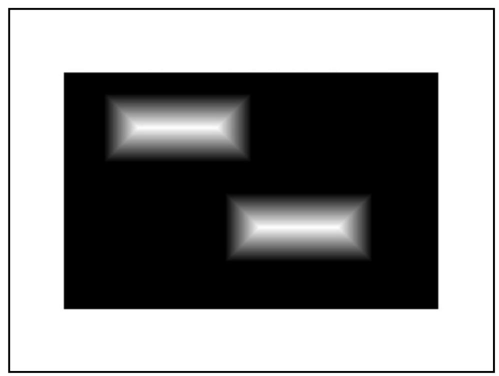
SKELETONIZATION

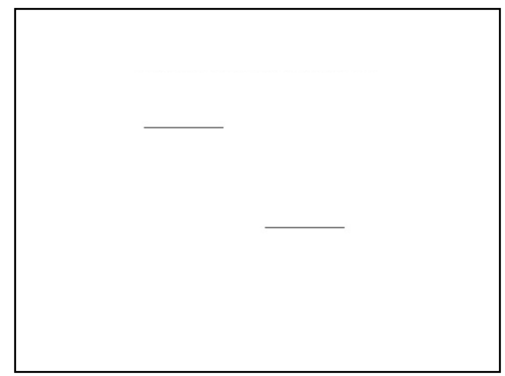
- The skeleton of a shape is the thinnest version of that shape, that is equidistant to its boundaries.
- The algorithm searches for pixels with maximum distances to the background to determine the skeleton of the object.



Binary image



Euclidean distance map



Eroded image applying Euclidean distance map

Threshold=maximum

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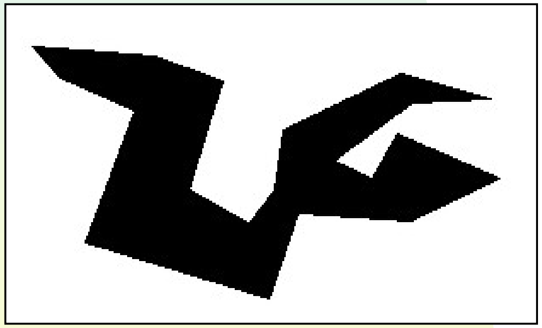
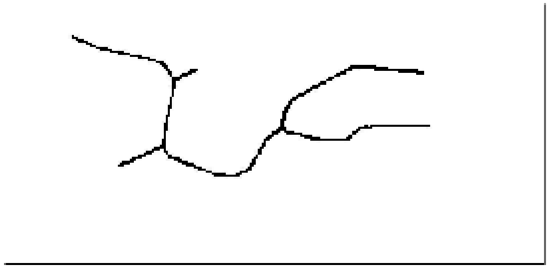
SKELETONIZATION

- The problem arises when there are local maxima that also represent the skeleton of the object.
- In this case the Zhang-Sue algorithm or skeletonization by masks is used.



Binary image

Euclidean distance map



Skeleton image applying Zhang-Sue algorithm

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SKELETONIZATION

- Skeletonization with masks makes the pixels that match the mask become background and those that do not remain as they are.
- Successive passes are made until the image is unchanged.

  - 255 – background
  - 0 – pixel of interest
  - () – any

255	255	255
	0	
0	0	0

255		0
255	0	0
255		0

0	0	0
	0	
255	255	255

0		255
0	0	255
0		255

	255	255
0	0	255
	0	

255	255	
255	0	0
	0	

	0	
255	0	0
255	255	

	0	
0	0	255
	255	255

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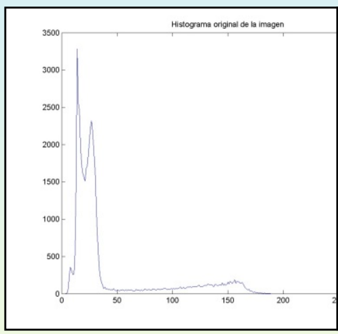
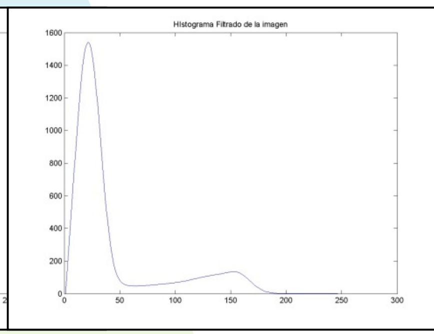
EXAMPLE

Counting beans



Original histogram

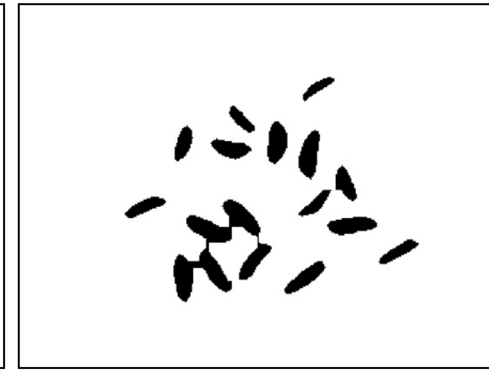


Filtered histogram

Segmented Image

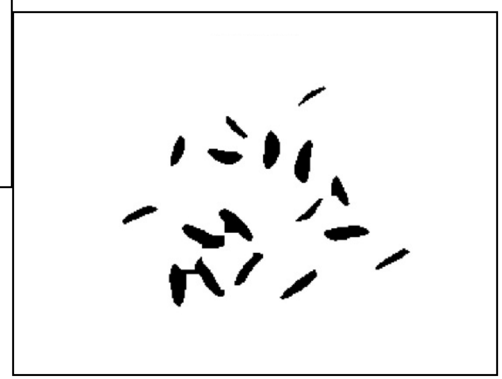
1 iteration of erosion

Number of objects: 12



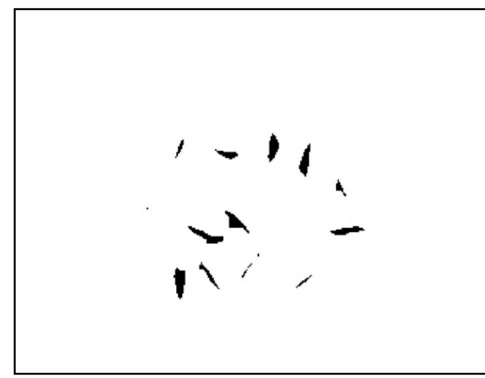
3 iterations of erosion

Number of objects: 13



4 iterations of erosion

Number of objects: 16



6 iterations of erosion

Number of objects: 14

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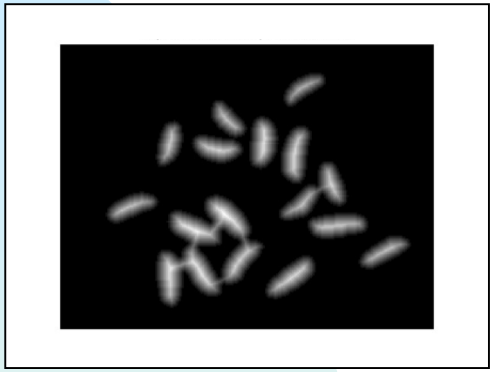
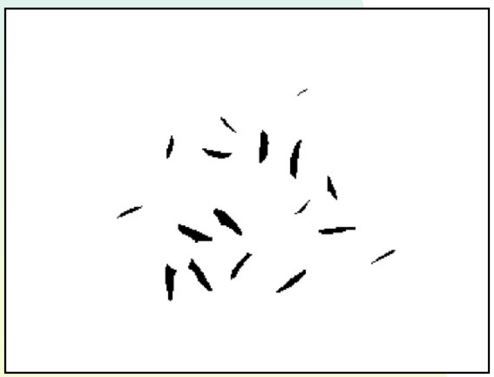
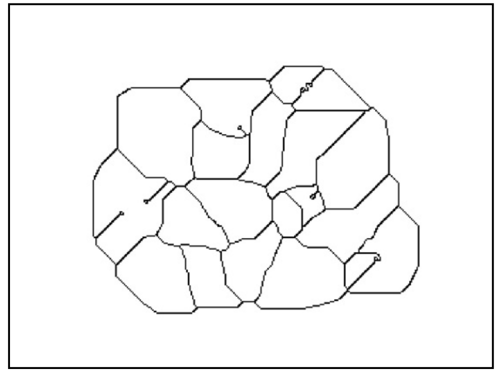
EXAMPLE



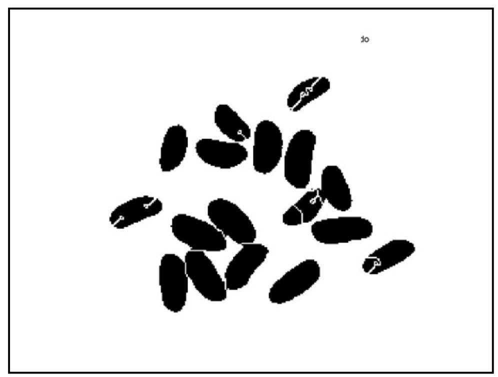
Euclidean distance map



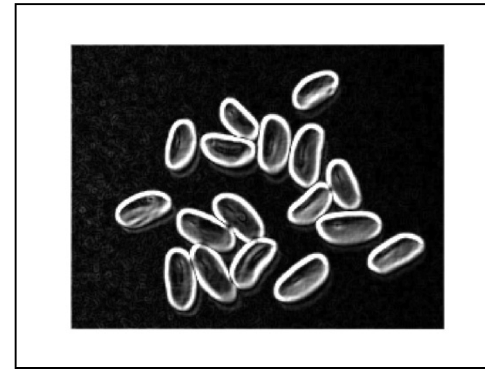
Threshold Euclidean distance map



Background skeleton



Subtracting background skeleton to segmented image



Sobel filter

Subtracting Sobel filter to segmented image

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CONCLUSIONS

- Image processing aims to improve image quality by removing noise or enhancing the information of interest.
- It is more interesting to improve image quality at the capture stage and to simplify processing as much as possible.
- The segmentation process should be as simple as possible.
- The labeling algorithm will define the objects of interest as those groupings of connected pixels of interest.

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QUESTIONS, COMMENTS OR REQUESTS

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