计算机辅助手术讲座（10）

Image Guided Surgery (10)

灰度的数学形态学(2)

Mathematical morphology in gray scale (2)

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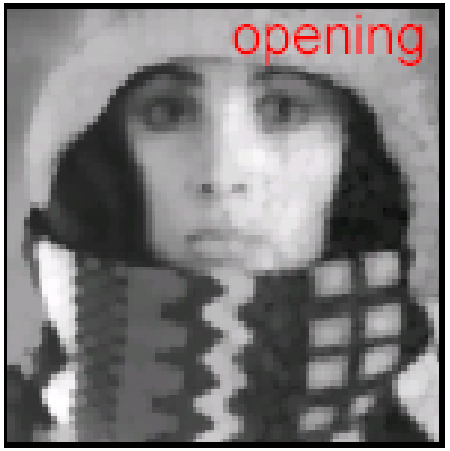
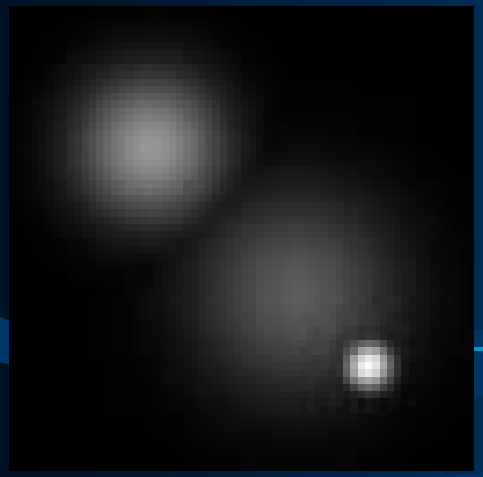
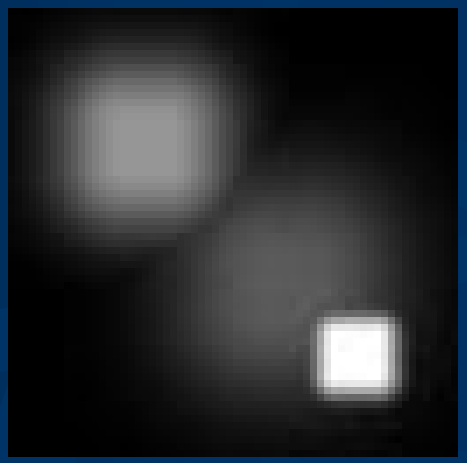
Grayscale Operations



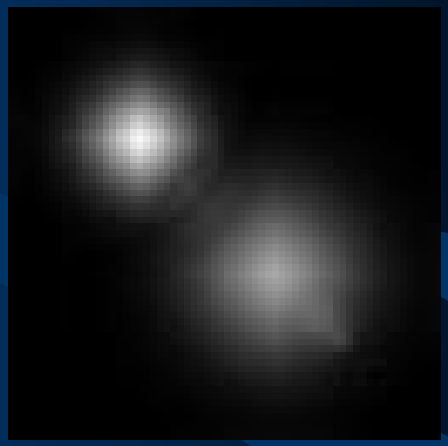
Grayscale Operations



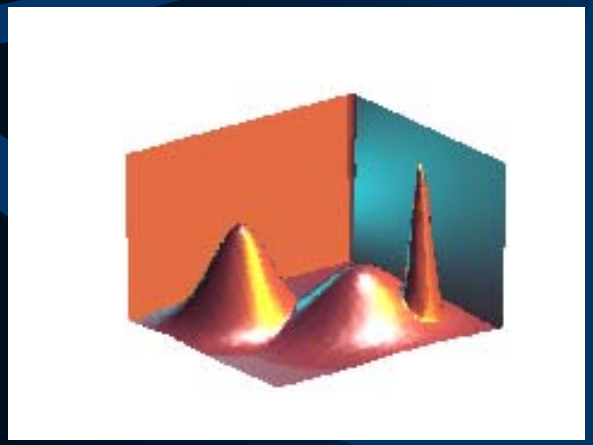
Source

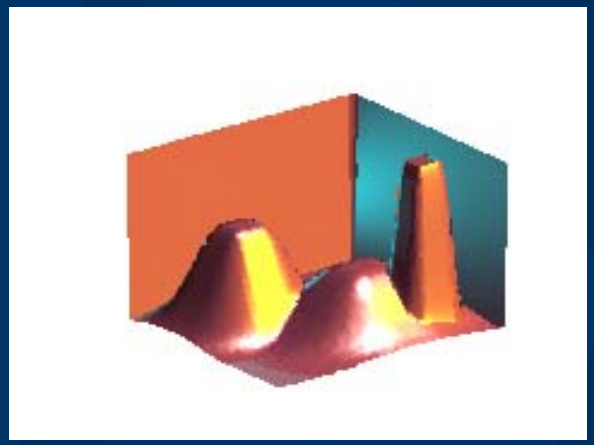


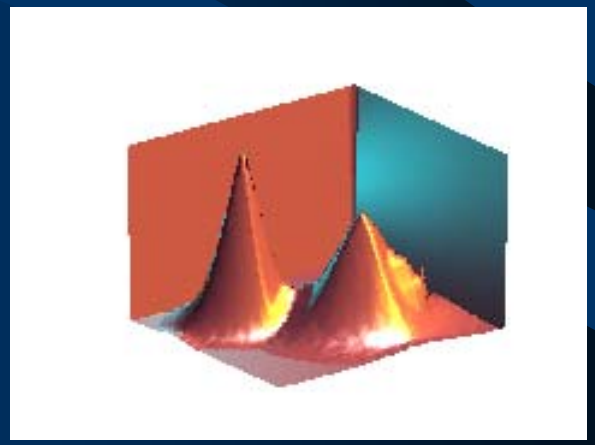
Dilated by a 7X7 box



Eroded by a 7X7 box

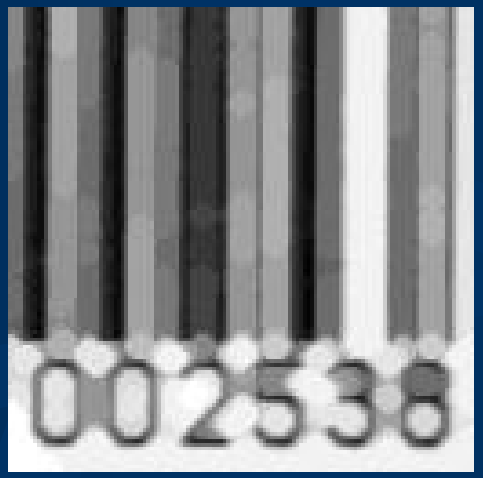




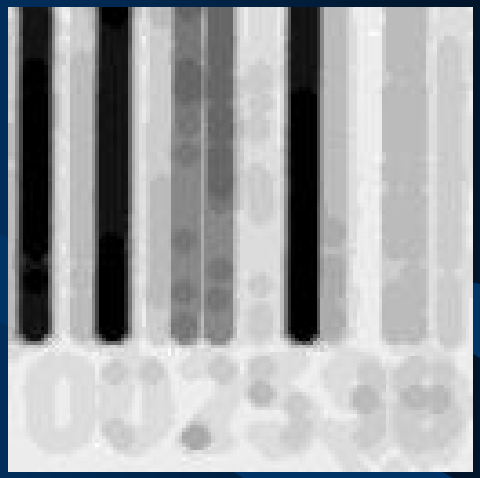


Grayscale Operations

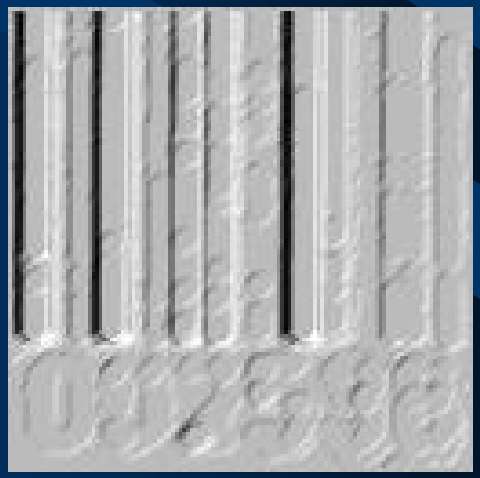
Source



Opened by a disk 3



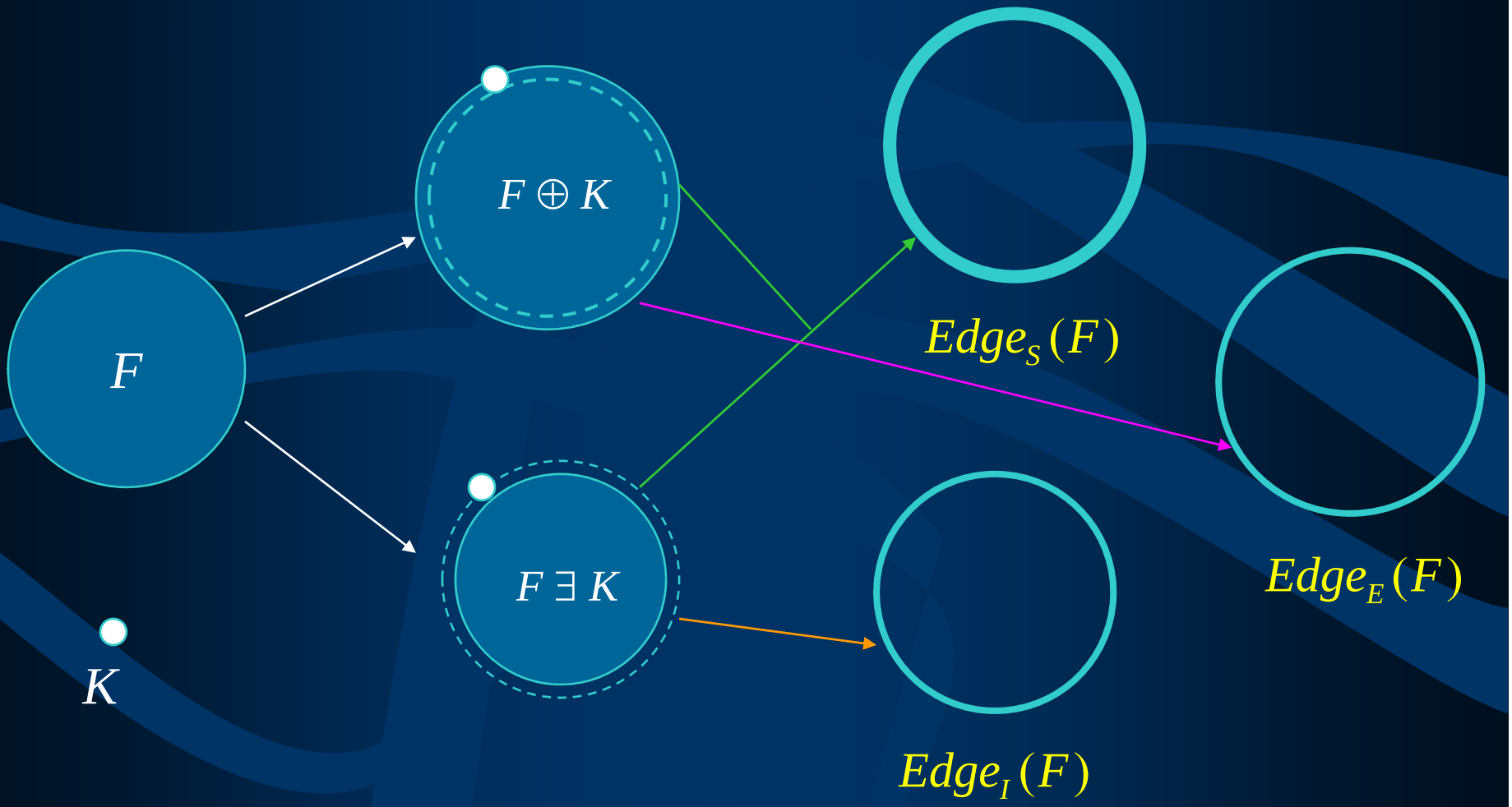
Closed by a disk 3



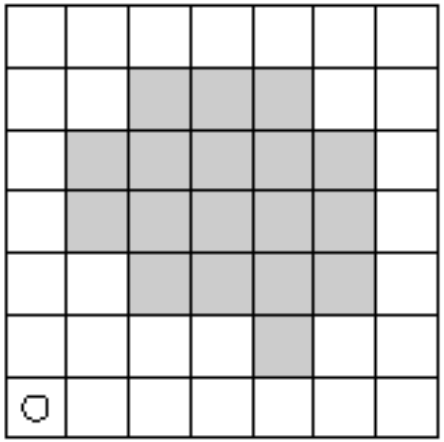
Edge Detection

- Morphological Edge Detection is based on Binary Dilation, Binary Erosion and Image Subtraction.
- Morphological Edge Detection Algorithms:
  - Standard: $Edge_S(F) = (F \oplus K) - (F \$ K)$
  - External: $Edge_E(F) = (F \oplus K) - F$
  - Internal: $Edge_I(F) = F - (F \$ K)$

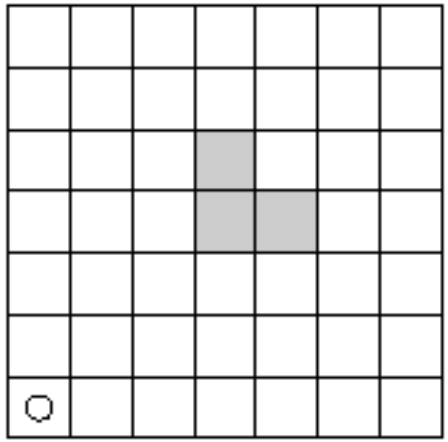
Edge Detection



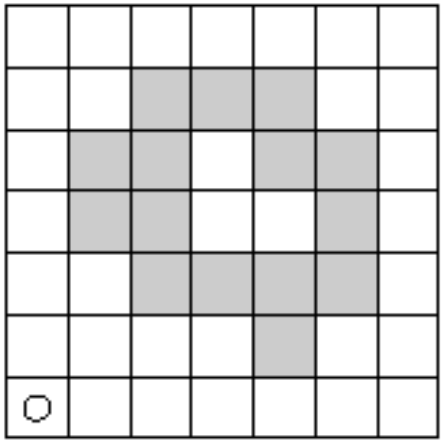
Edge Detection



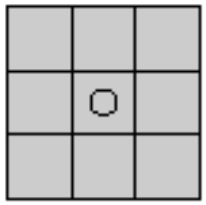
X



$X \ominus S_{3,3}$



$Edge_I(X)$

$S_{3,3} =$ 

Edge Detection

F

$Edge_I(F)$

$Edge_E(F)$

Edge Detection

F

$Edge_S(F)$

$Edge_E(F)$

$Edge_I(F)$

Morphological Gradient

- Morphological Gradient is calculated by grayscale dilation and grayscale Erosion.

$$Gradient(F)_S = \frac{1}{2}[(D_G(F,K) - E_G(F,K)]$$

$$= \frac{1}{2}[(F \oplus_g K) - (F \$_g K)]$$

  - It is quite similar to the standard edge detection
  - We also have external and internal gradient

Morphological Gradient

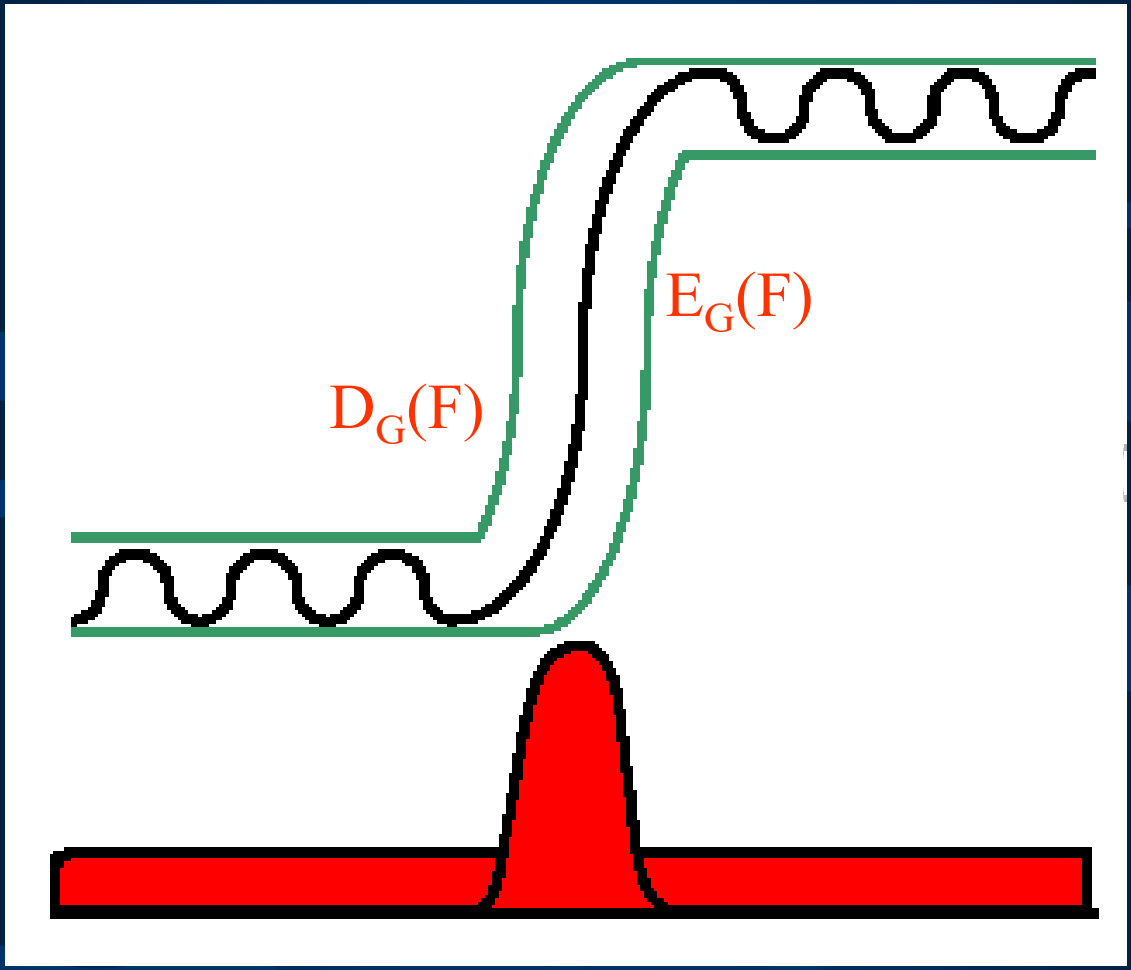
- External Gradient:

$$Gradient(F)_E = \frac{1}{2}[(D_G(F,K) - F] = \frac{1}{2}[(F \oplus_g K) - F]$$

- Internal Gradient:

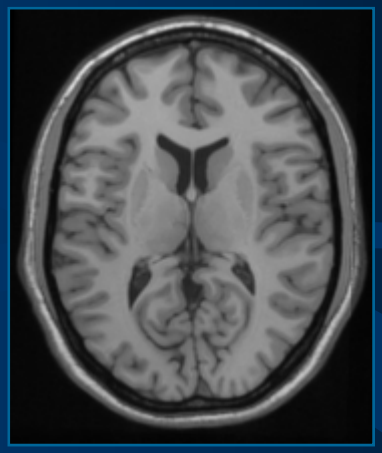
$$Gradient(F)_I = \frac{1}{2}[(F - E_G(F,K)] = \frac{1}{2}[F - (F \ominus_g K)]$$

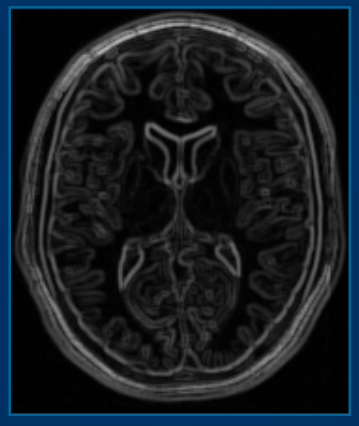
Morphological Gradient



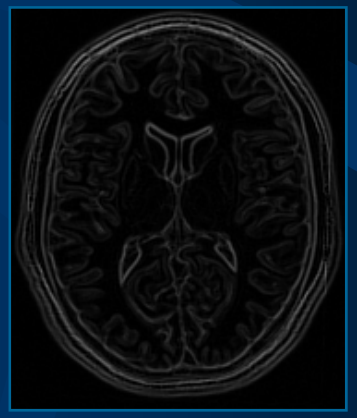
$Gradient(F)_S$

Morphological Gradient

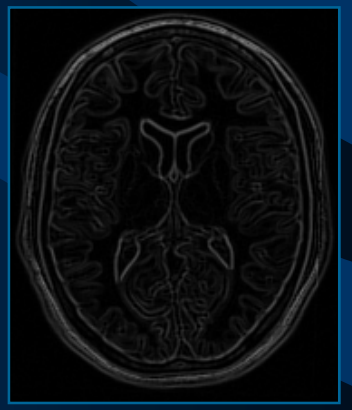




Standard



External



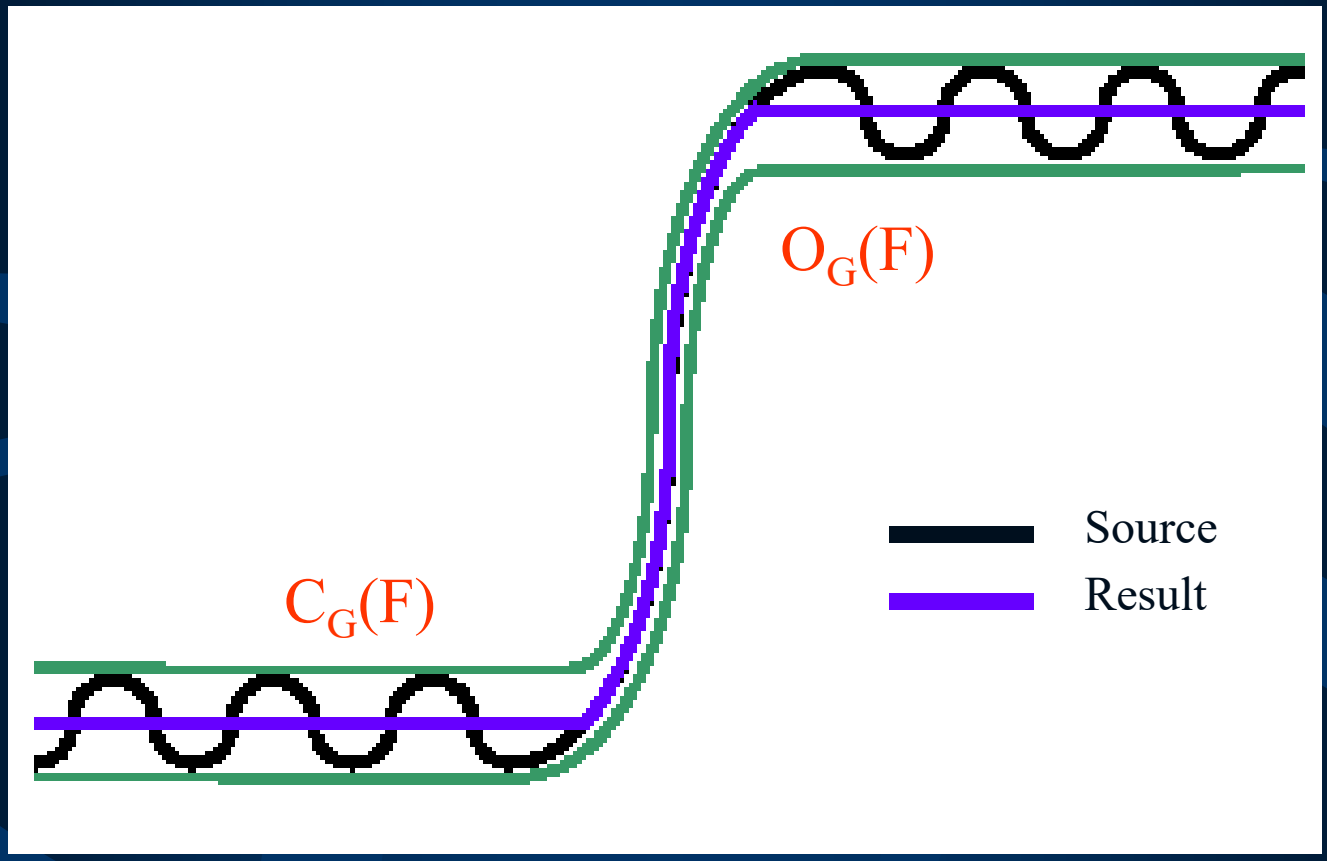
Internal

Morphological Smoothing

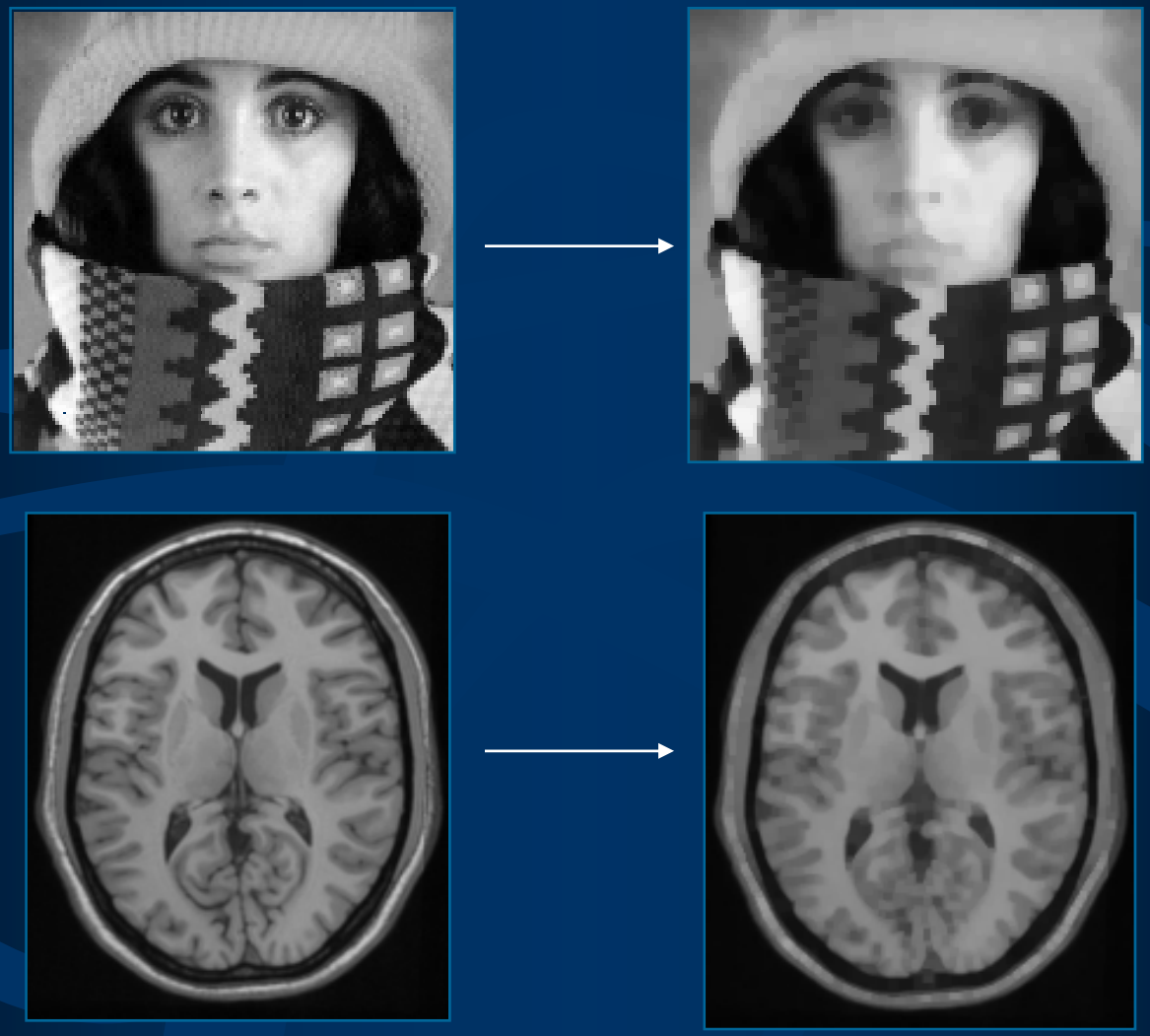
- Morphological Smoothing is based on the observation that a *grayscale opening* smoothes a grayscale image from above the brightness surface and the *grayscale closing* smoothes from below. So we could get both smooth like:

$$MSmooth(F) = C_G(O_G(F, K), K)$$
$$= ((F \circ_g K) \bullet_g K)$$

Morphological Smoothing



Morphological Smoothing



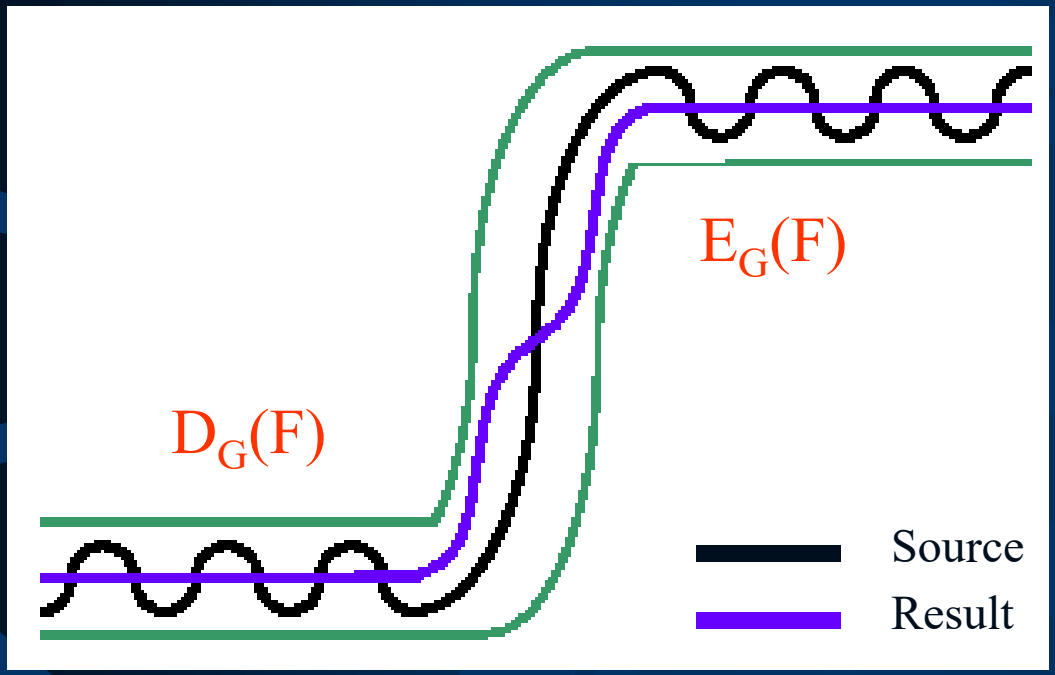
Morphological Smoothing

- Morphological Smoothing can also based on the average of gray scale dilation and erosion, which is so called dynamic smooth:

$$DSmooth(F) = \frac{1}{2}[D_G(F,K) + E_G(F,K)]$$

$$= \frac{1}{2}[(F \oplus_g K) + (F \$_g K)]$$

Morphological Smoothing



Top-hat Transform

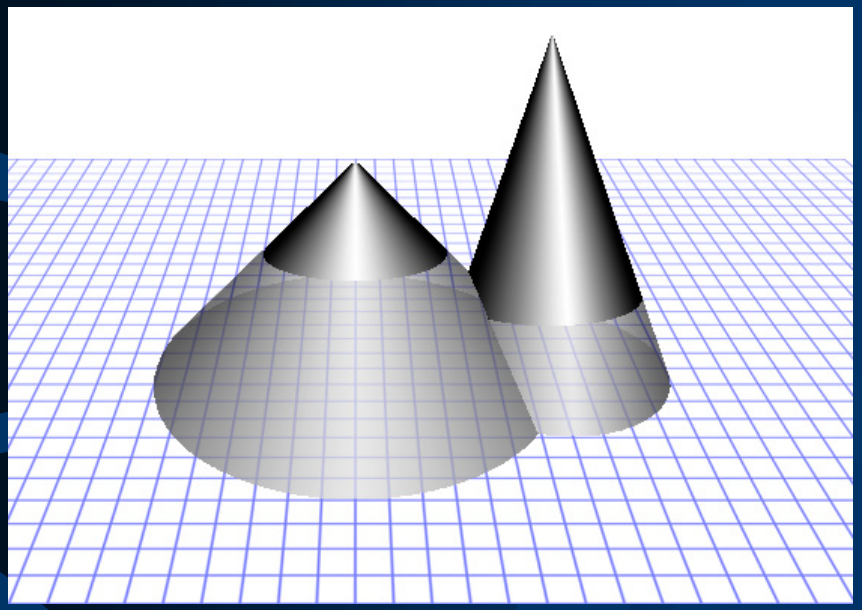
- Top-hat Transform (TT): An efficient segmentation tool for extracting bright (respectively dark) objects from uneven background.
  - White Top-hat Transform (WTT):

$$T_i = F - F \circ_g r_i K \quad (r_i \text{ is the scalar of SE})$$

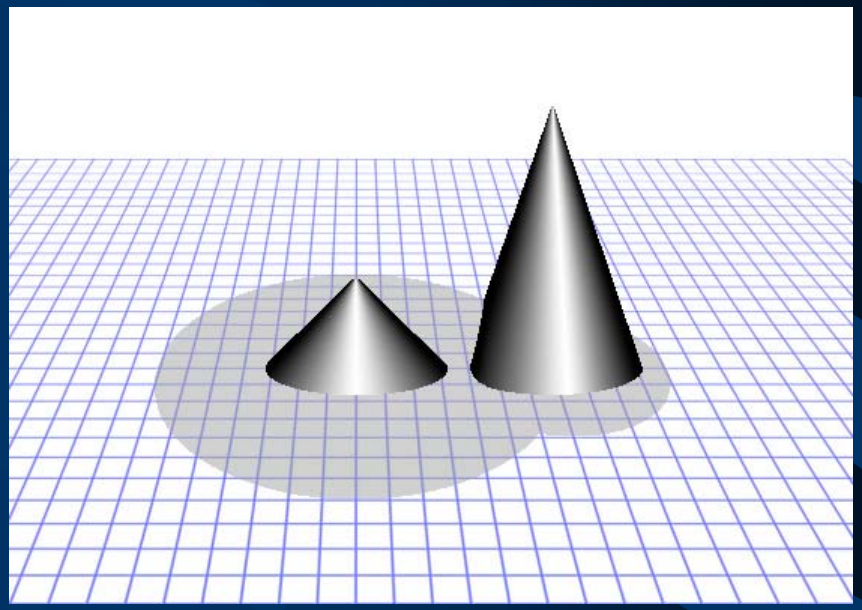
  - Black Top-hat Transform (BTT):

$$T_i = F \bullet_g r_i K - F$$

Top-hat Transform

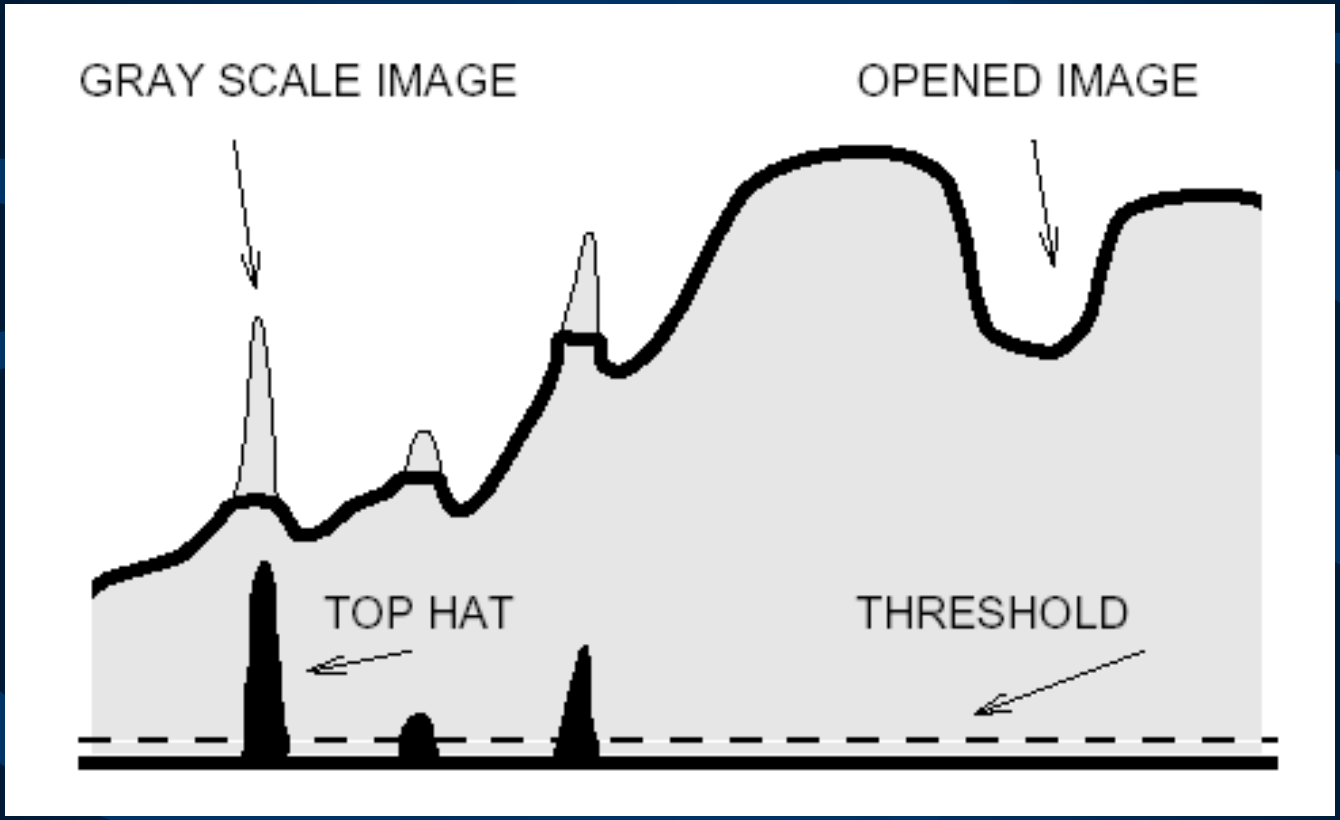


tophat + opened = original

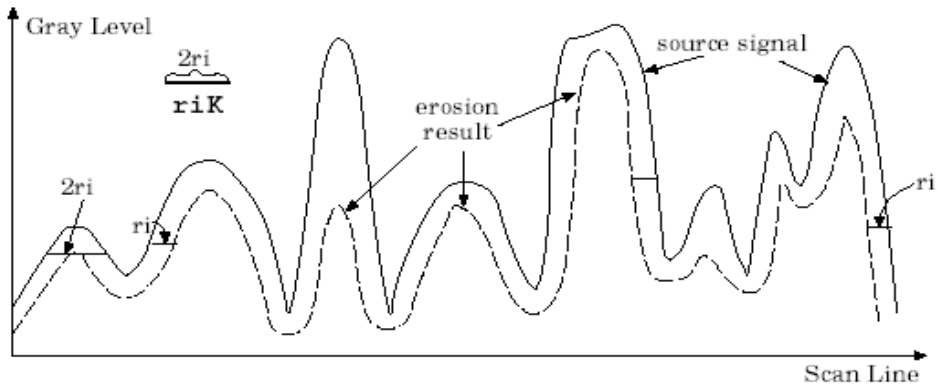


tophat: original - opening

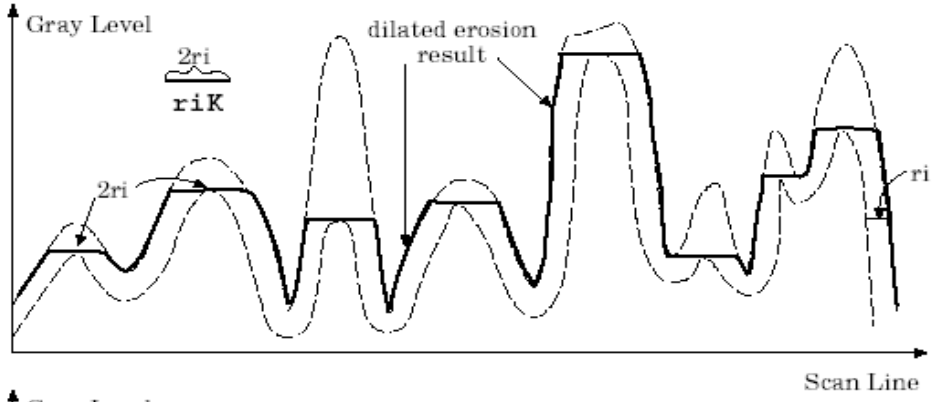
Top-hat Transform



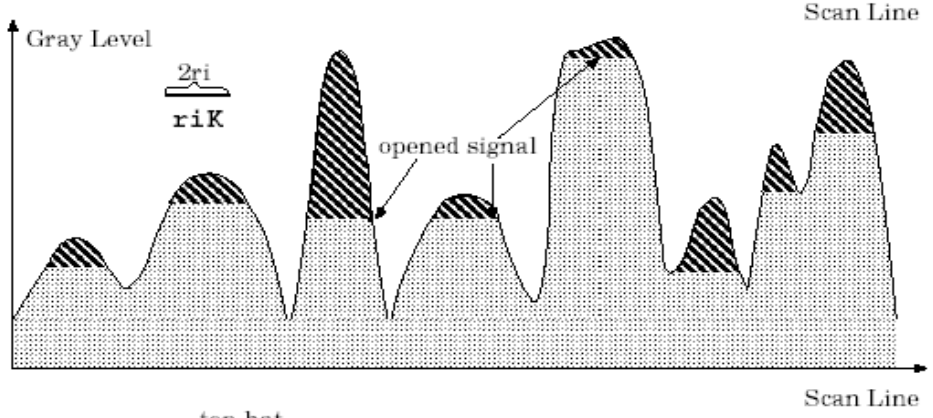
Top-hat Transform



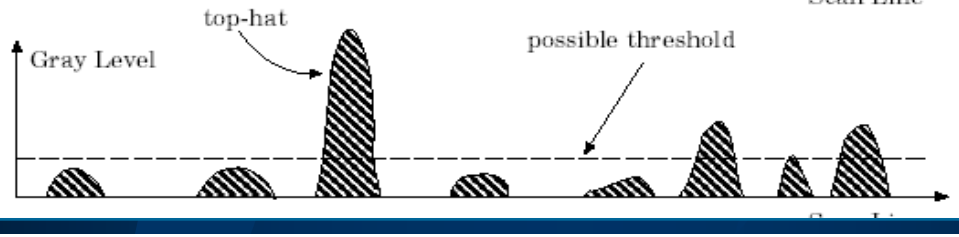
(a) Source Singnal and its erosion result



(b) Dilated erosion result



(c) The result of opened signal



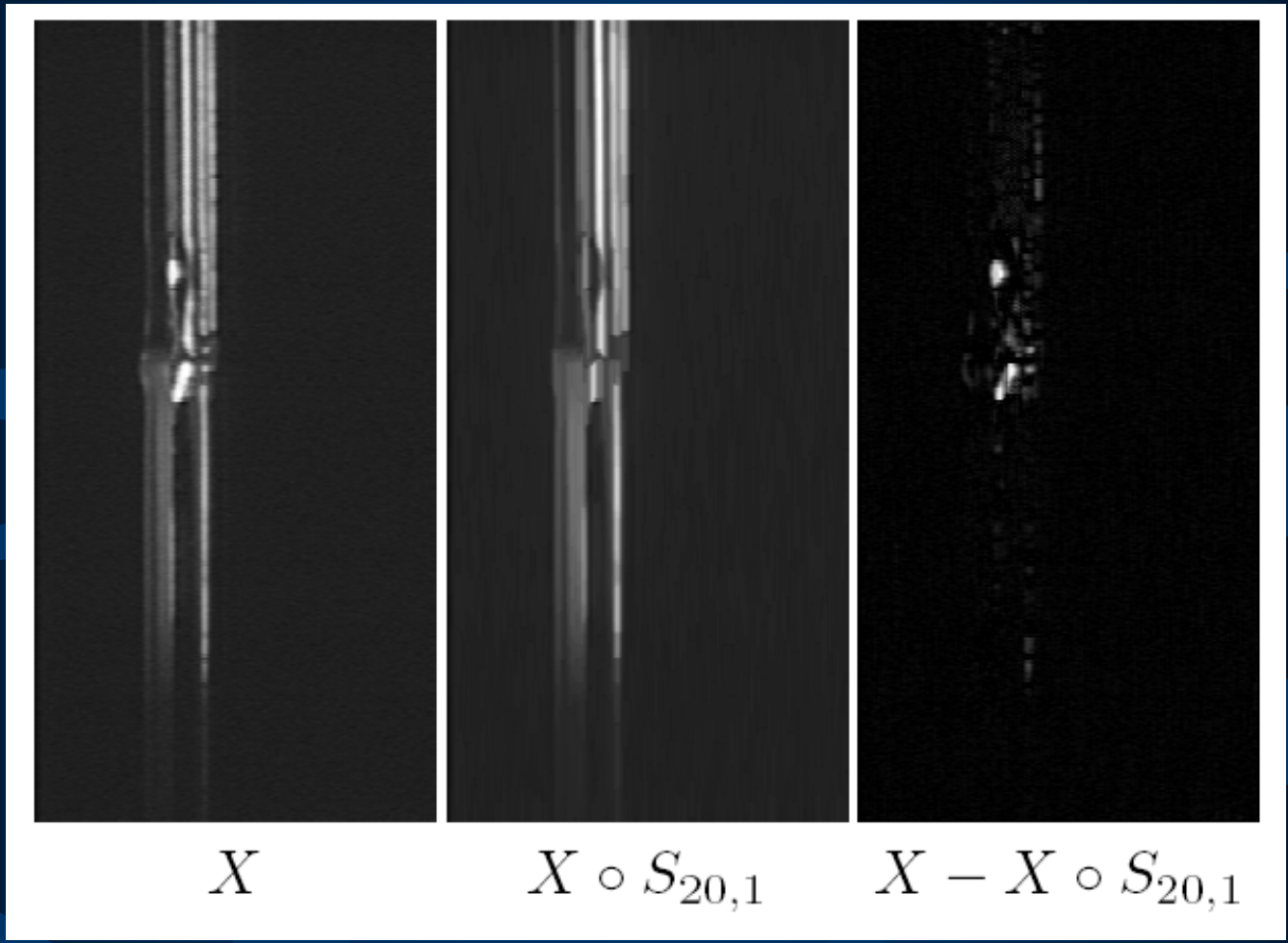
(d) Tophat: Ti

Top-hat Transform

BTT

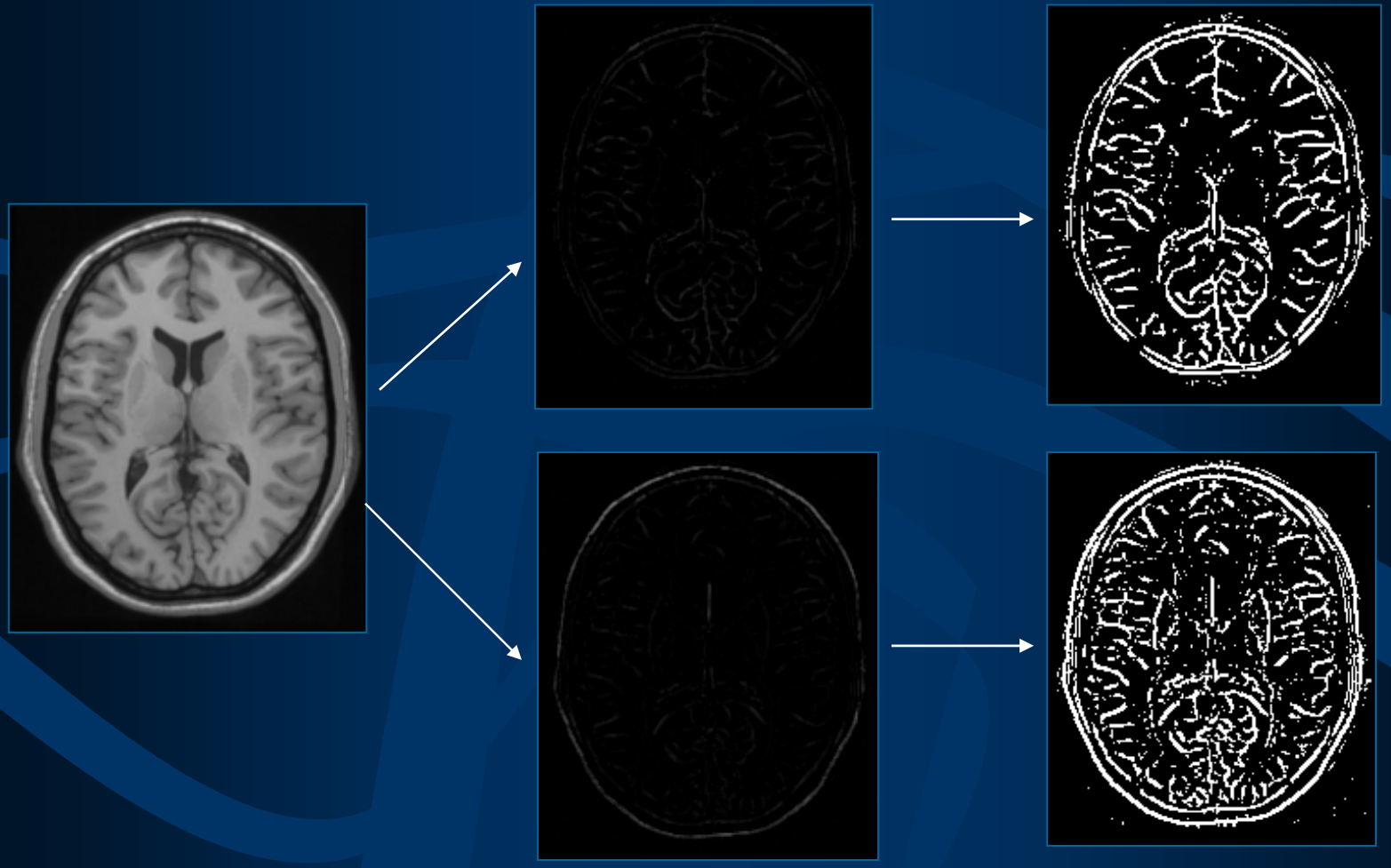
WTT

Top-hat Transform



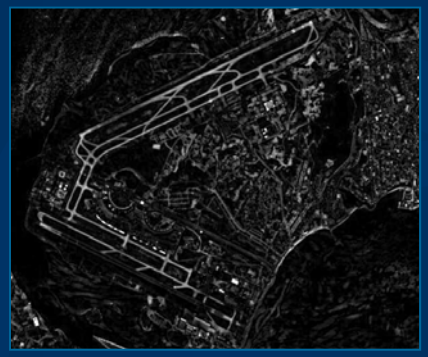
Inspection of a maximal thermometer capillary

Top-hat Transform

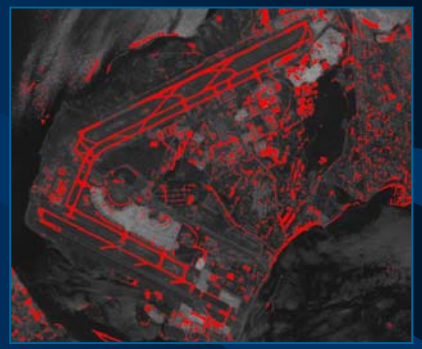


Application 1
Detecting runways in satellite airport imagery

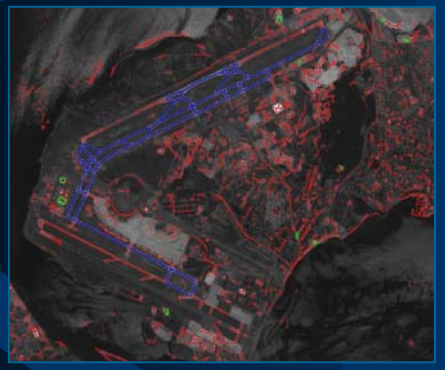
Source



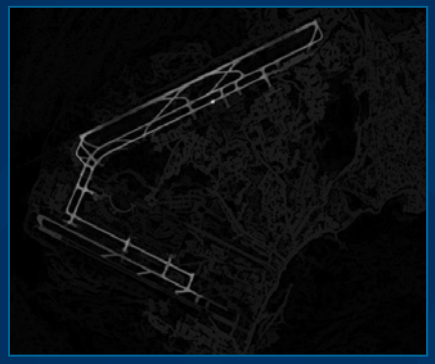
WTT



Threshold



Detect long feature

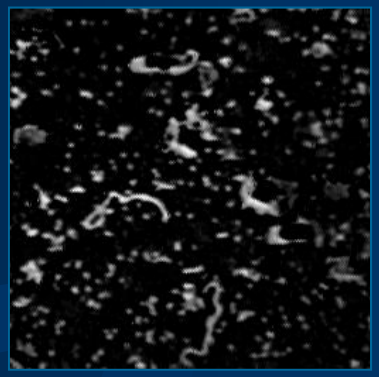


Reconstruction

Final result

Application 2
Detect Filarial Worms

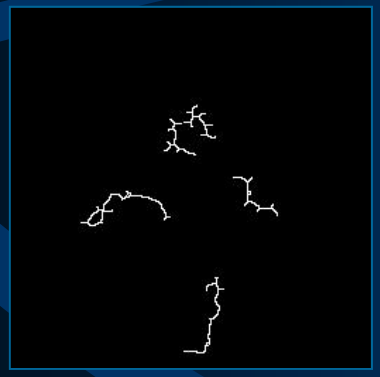
Source



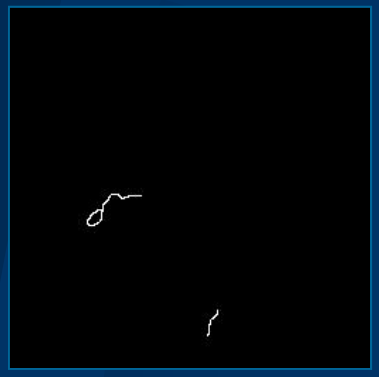
BTT

Remove Noises

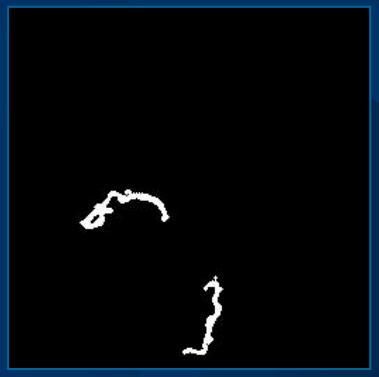
Threshold



Skeleton



Eliminate short structures



Reconstruction

Final result

Differential TT

- Difficulties of TT:
  1. Difficult to distinguish ROI for more complicated cases.
  2. Difficult to define the sizes of SE.
- Differential Top-hat Transformation (DTT): employ a series of SE (same shape, different sizes) into TT application to find out the difference between T_i and T_{i-1}:

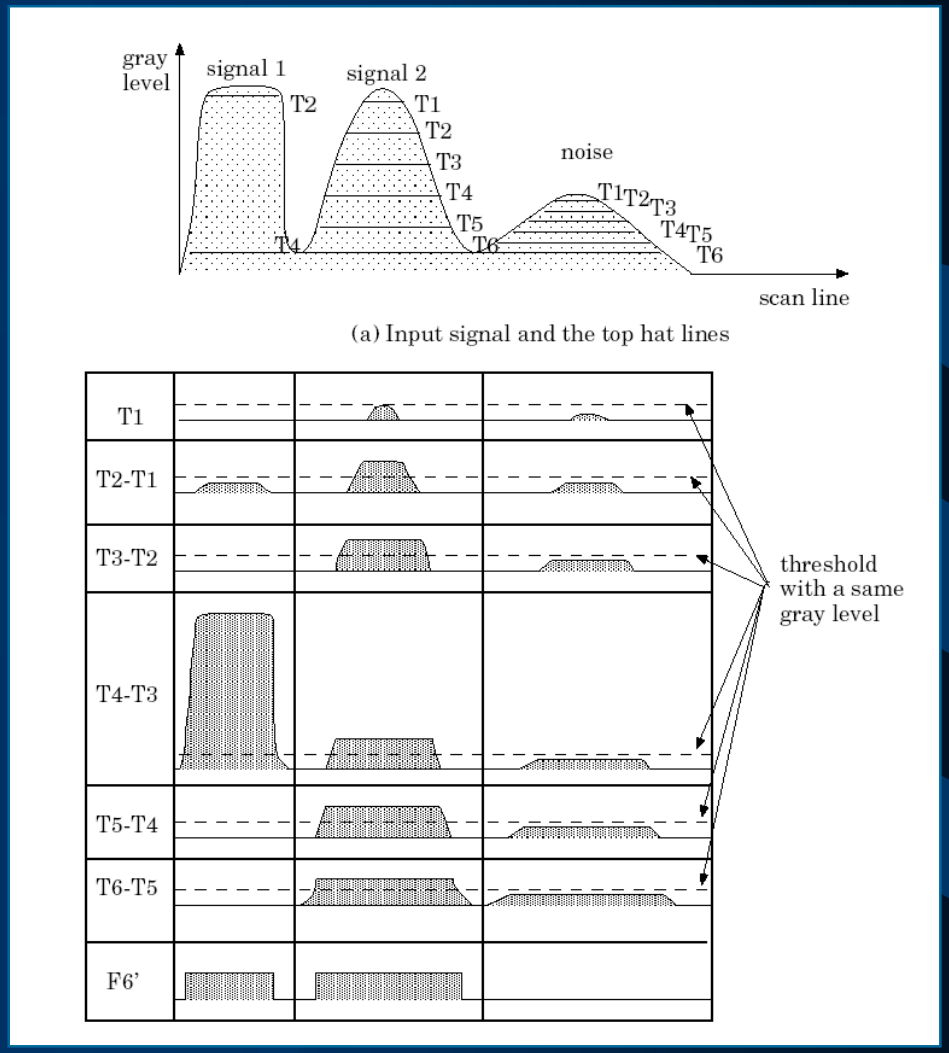
$$F_i = |T_i - T_{i-1}|_B - F'_{i-1}$$

$$where,\ F'_i = \bigcup_{1 \le j \le i} F_j;\ F'_1 = \varnothing$$

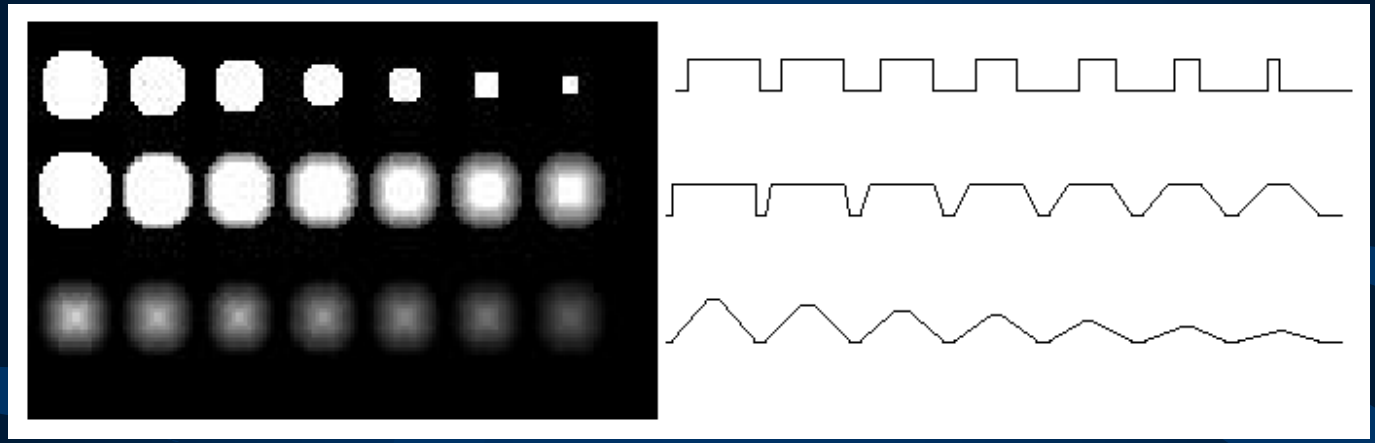
($|T|_B$ stands for a threshold operation)

DTT: The Principle

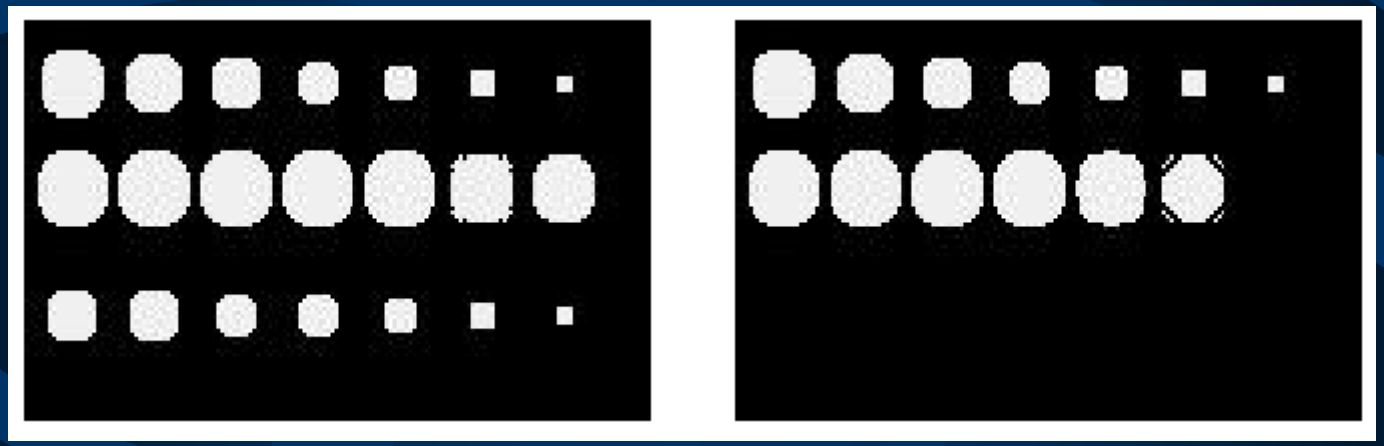
- How it works:
  1. Find a series of TT:
  2. Calculate the subtraction between and
  3. Threshold the results of by same threshold level.
  4. Put them together by OR
- What's better:
  1. Differentiate the signal slopes in steepness and only pick up the objects with high gradient
  2. Sort the objects by sizes.



DTT: A Model Testing



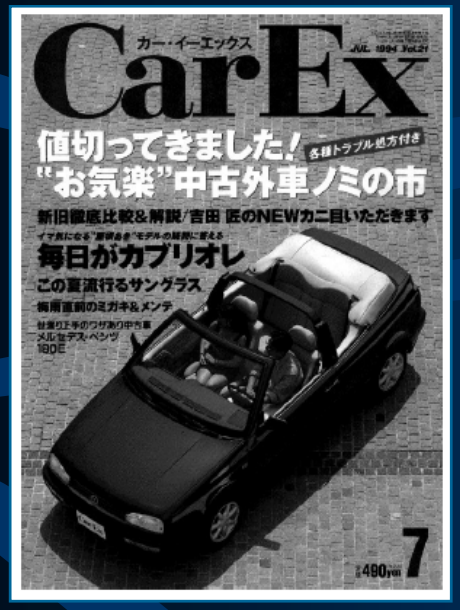
Source testing image and its cross section view



TT result

DTT result

DTT: A Real Image Testing



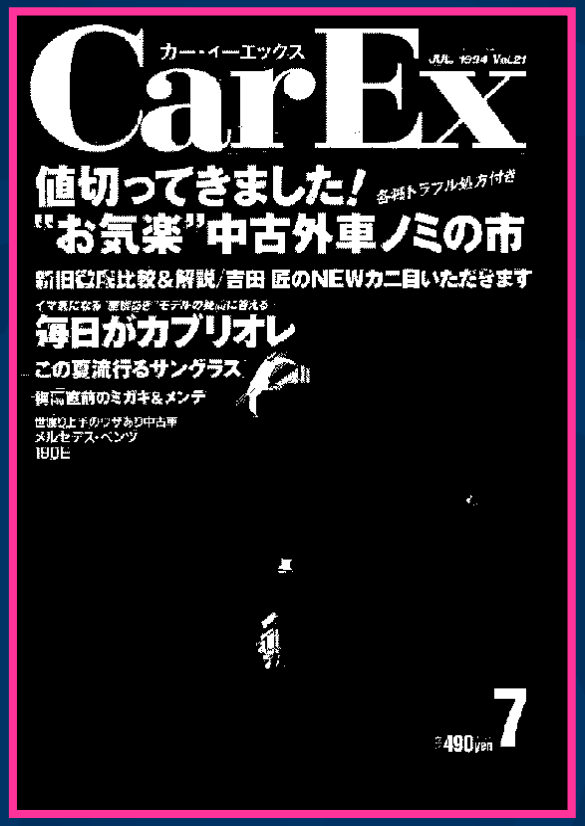
(a) Result of TT

(b) Result of DTT

Application

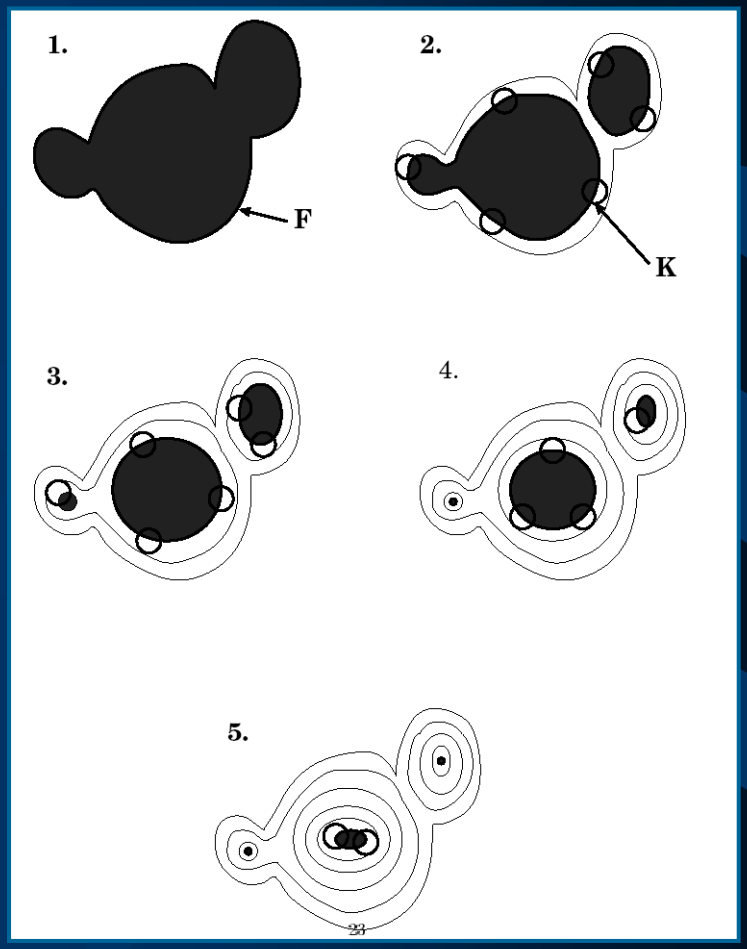
- *Character Extraction From Cover Image*

Application

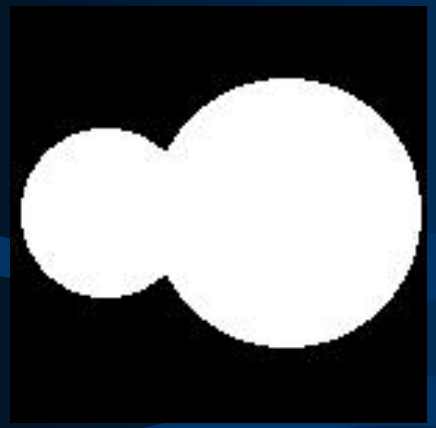


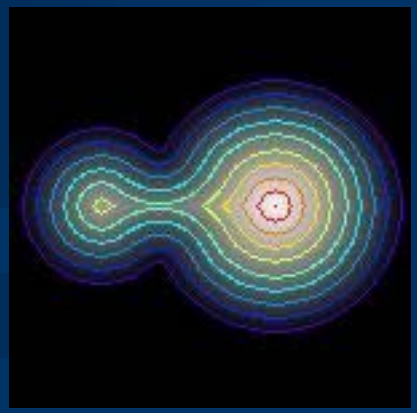
Ultimate Erosion

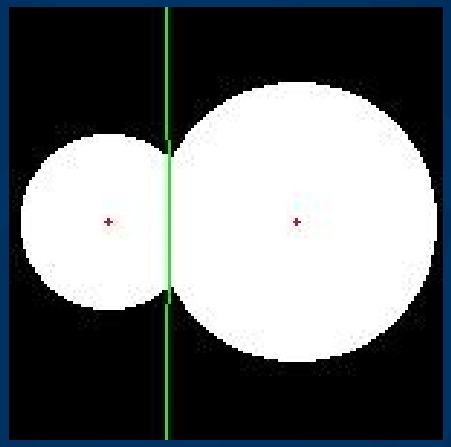
- Ultimate Erosion (UE) is based on Recursive Erosion operation.
- “Keep aside each connected components just before it is removed throughout the recursive erosion process”.

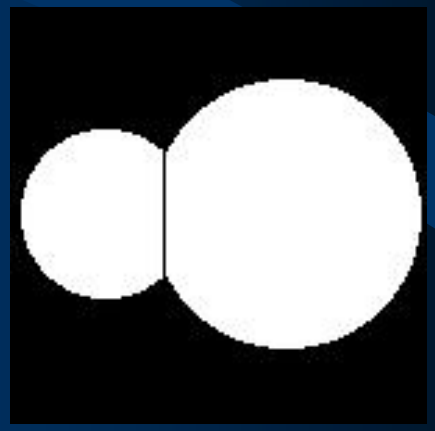


Ultimate Erosion







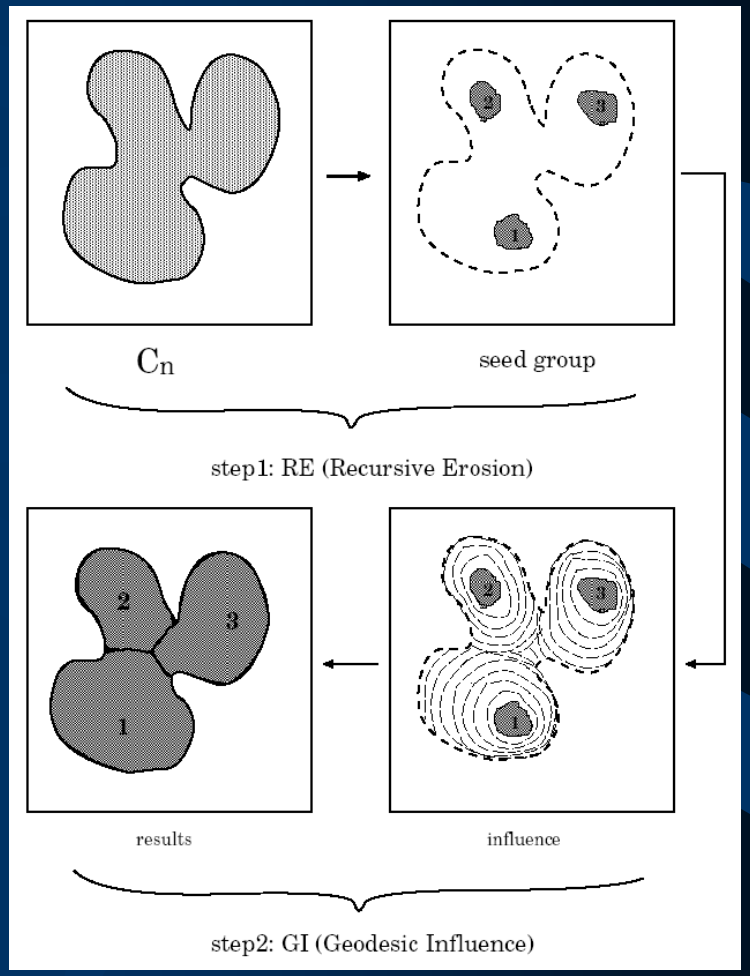


Geodesic Influence

- Geodesic Influence (GI) is based on Recursive Dilation operation with mask which also called conditional dilation.
- Reconstruct the seeds by the restriction of the mask, and distribute the pixels on the interface by means of “first come first serve”.

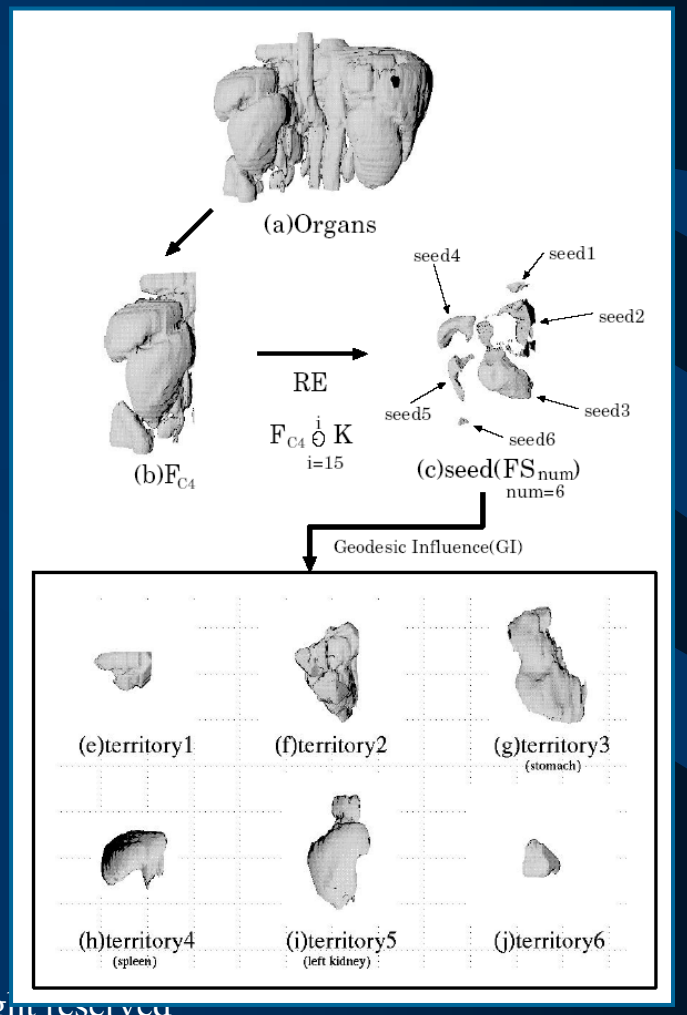
UE and GI

- UE: split a connected region (have to be convex) gradually and record the iteration number.
- GI: Reconstruct the split regions and get the segments.



Application

- Segment connected organs:
  1. RE: region shrinking to generate all the candidate seeds
  2. GI: region reconstruction to recover separated organs



Discussion