

Segmentation and Thresholding: Processing of binary images

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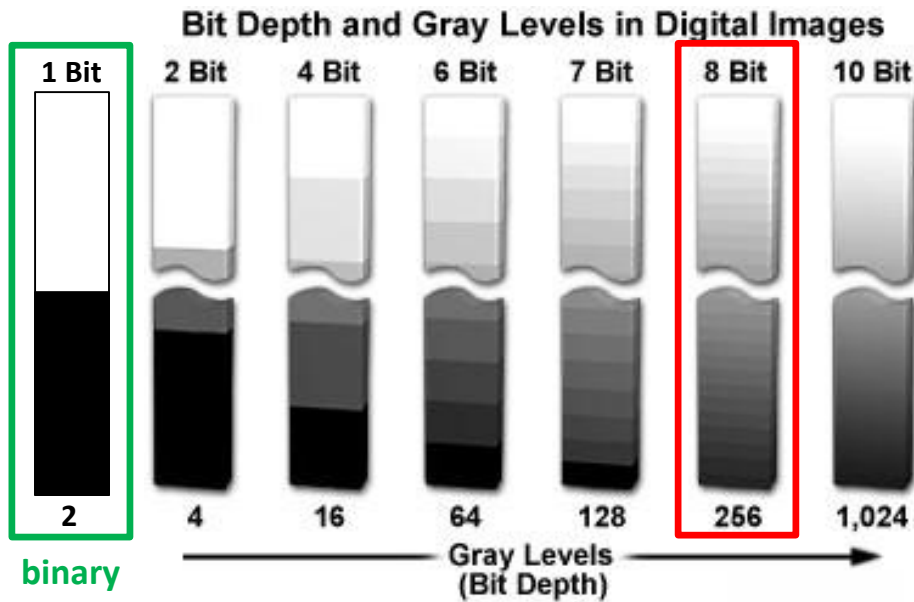
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31/03/2026



SEMMELWEIS
UNIVERSITY 1769

Greyscale



our eyes are sensitive to ~200-300 shades of gray

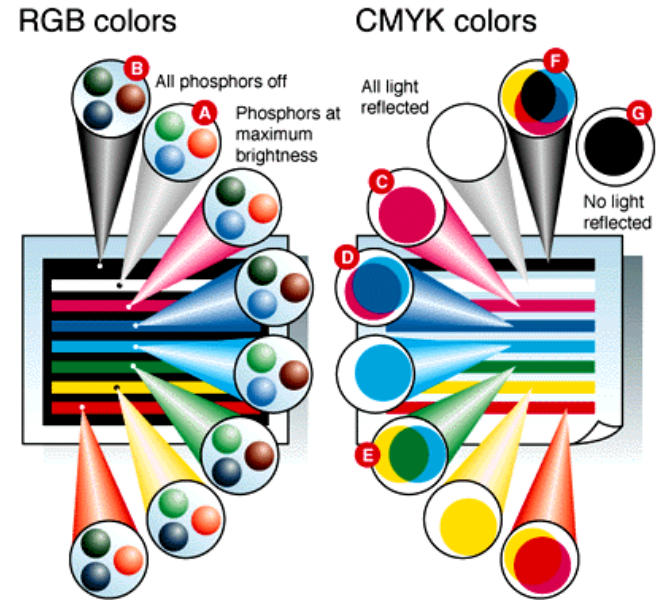
$$1 \times 2^3 \quad 1 \times 2^2 \quad 0 \times 2^1 \quad 1 \times 2^0$$

$$1 \quad 1 \quad 0 \quad 1$$

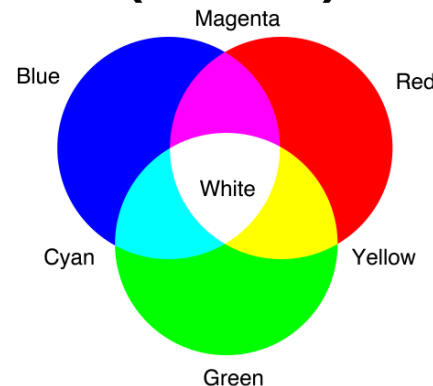
$$8 \quad 4 \quad 0 \quad 1 = 13$$

1 byte = 8 bits

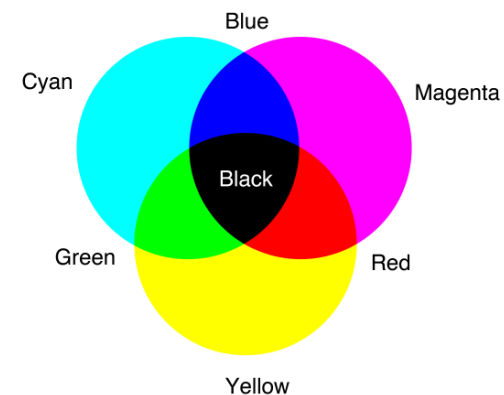
Color



(additive)

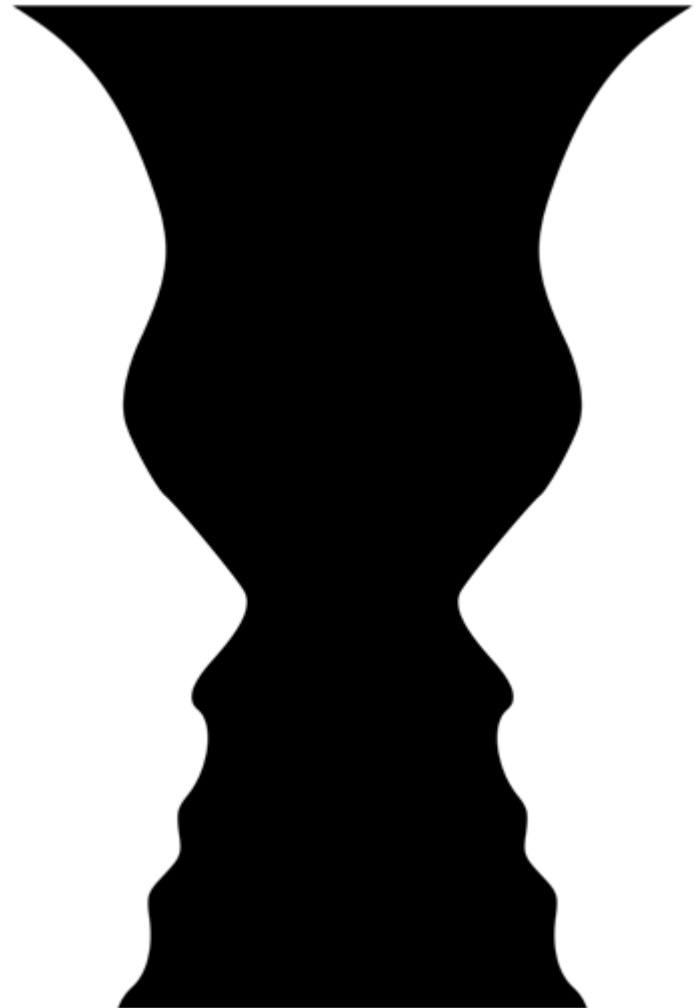
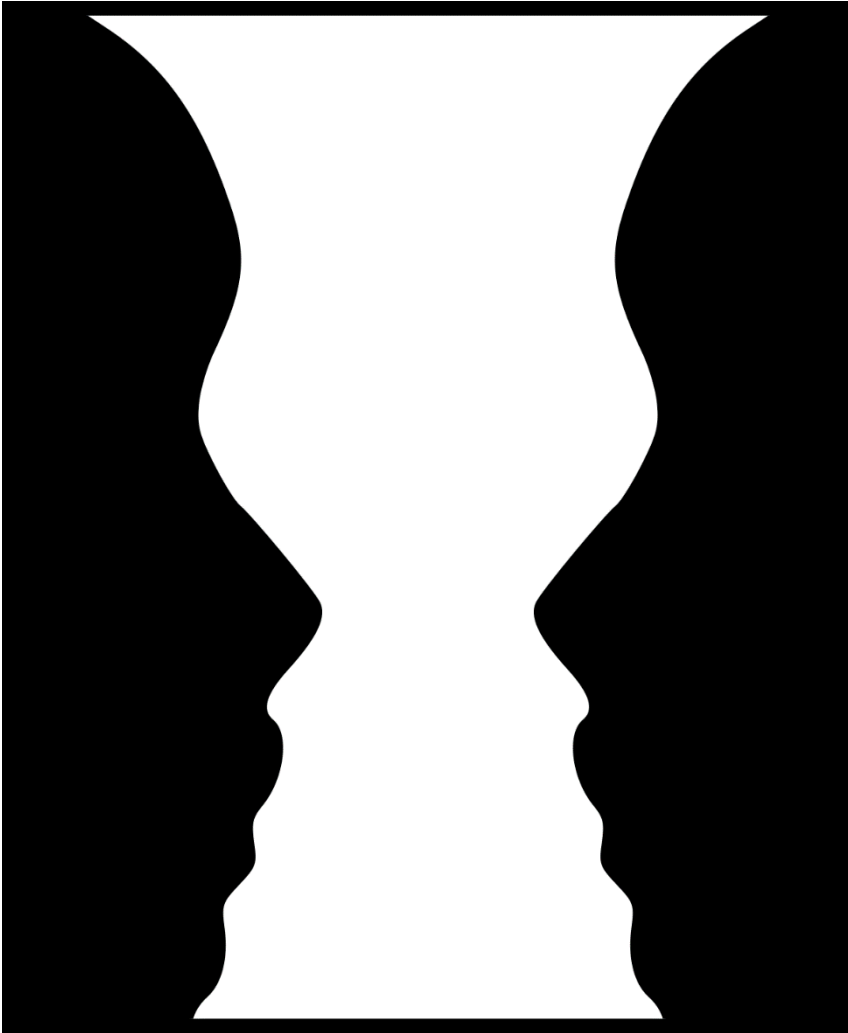


(subtractive)

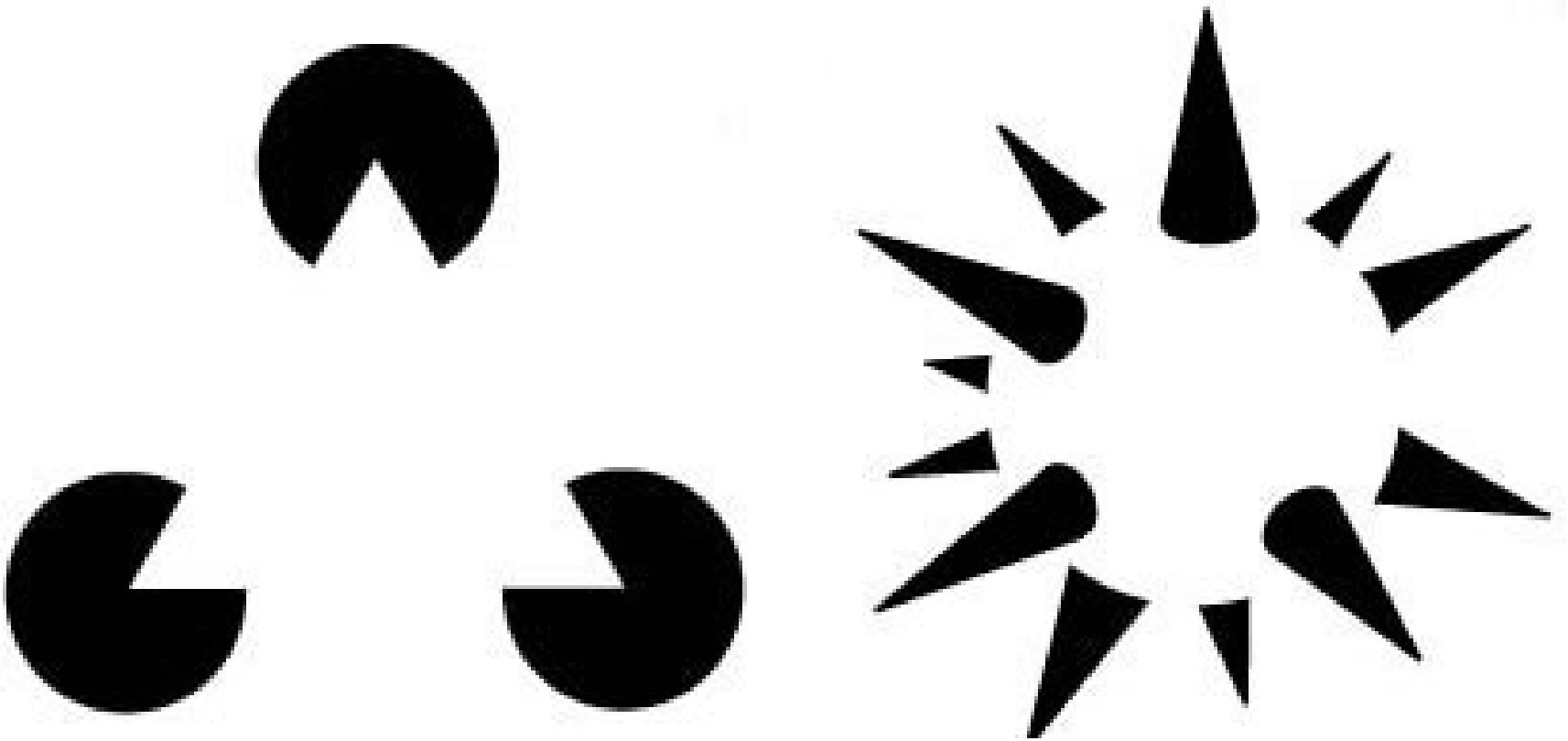


Foreground-background optical illusion

The essence of thresholding and segmentation is to divide the image into areas based on certain criteria. They are also called "Foreground/Background" separation operations, which refers to the fact that the procedure focuses on a specific feature of the image and discards the rest. The "foreground/background" procedure is particularly relevant to the eye. The human visual system is not able to focus on different information content of the image at the same time.



Optical illusion with binary images



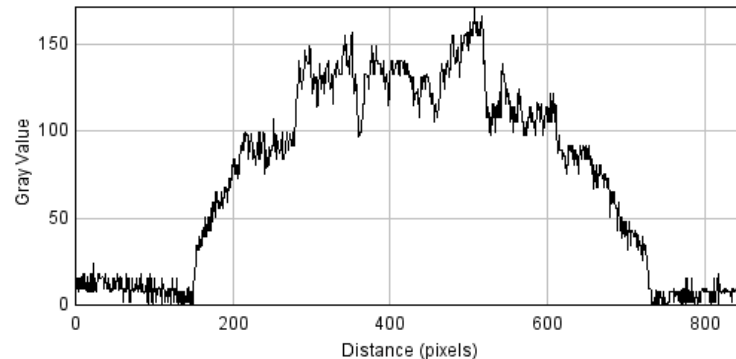
The existence of a white triangle can easily be imagined on the left image while your brain can also easily create the existence of a white sphere in the image on the right.



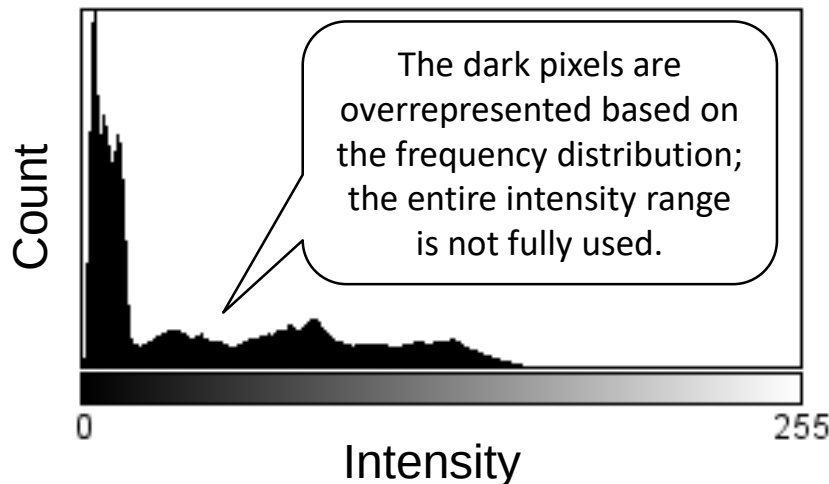
Victor Vasarely born **Vásárhelyi Győző**, 9 April 1906, Pécs - 15 March 1997, Paris was a Hungarian French artist whose work is generally seen as aligned with Op-art. His work entitled **Zebra**, created by Vasarely in the 1930s, is considered by some to be one of the earliest examples of Op-art. Vasarely eventually went on to produce art and sculpture mainly focused around the area of optical illusion.

Intensity-Histogram

Plot profile: Intensity values as a function of the distance:



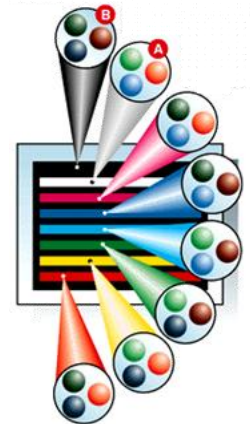
Histogram: Frequency distribution of the intensity values of the entire image or just the subset of it (ROI, region of interest):



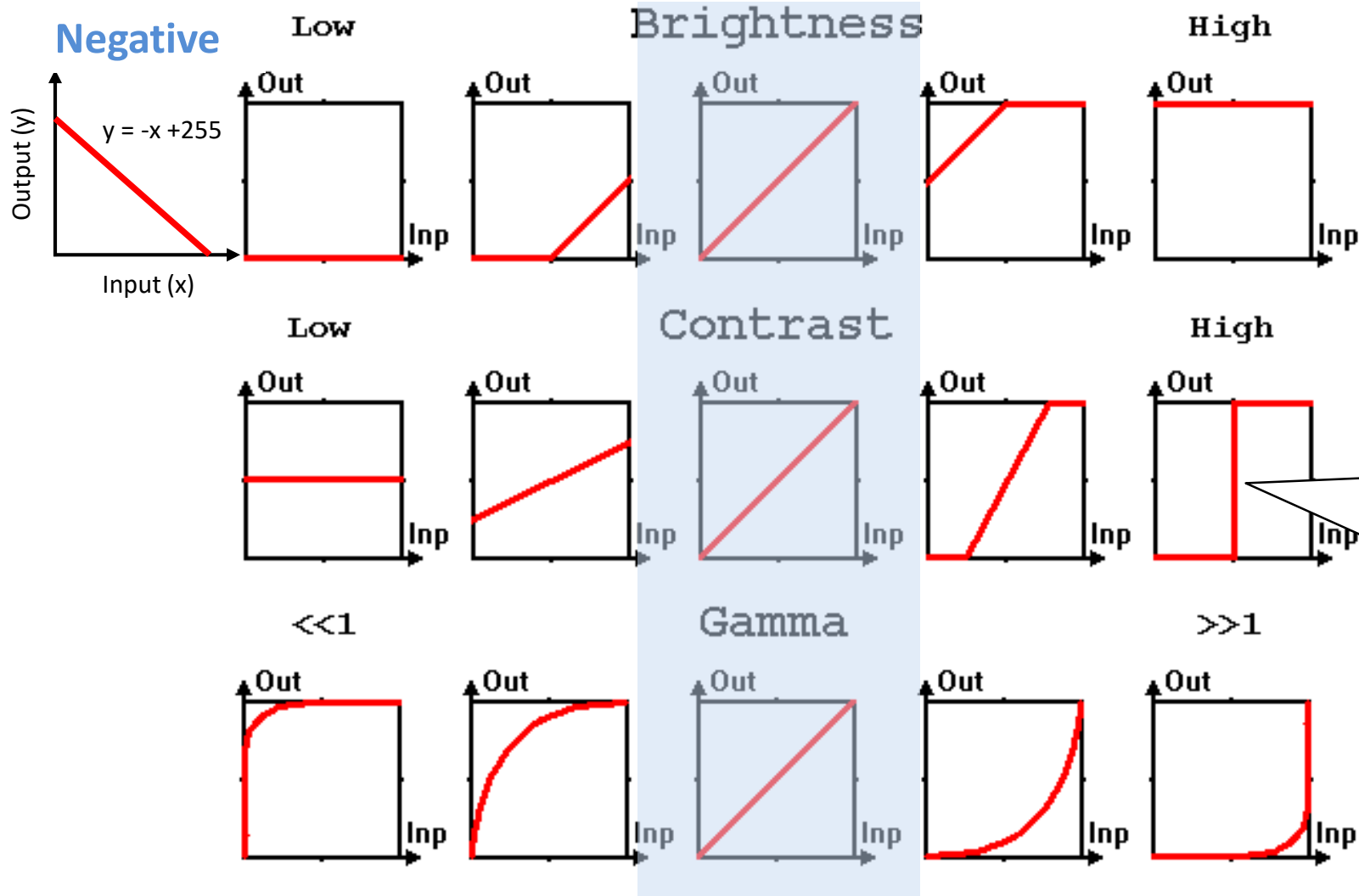
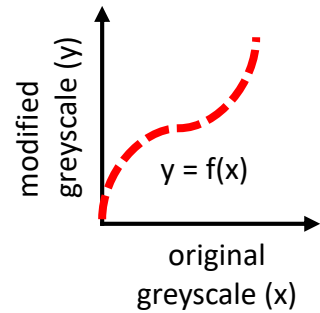
greyscale (8-bit):

- „0”: black
- „255”: white

Encoding of color images: additive mixing of **R (red)**, **G (green)** and **B (blue)** channels: $2^{24} \approx 16$ million different colors.



Transfer functions



Thresholding:
pixels below
threshold:
black, pixels
over threshold:
white.

No difference, no manipulation: „Input = Output”

Essence and implementation of the thresholding

1. We select a certain gray intensity range of the image
2. the pixels in this range form the "foreground",
3. the other pixels form the "background"

The result: a **binary image**

The foreground is either white or black (usually)

Thresholding can be used for:

1. texture analysis
2. edge enhancement
3. feature enhancement
4. image preparation for further measurements

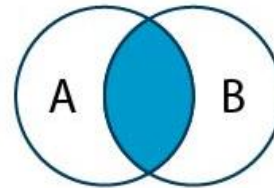


Analysis of binary images

Binary image: an image containing only two different pixel values. It can be generated by thresholding.

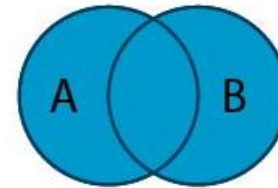
Boolean logic operations

A AND B



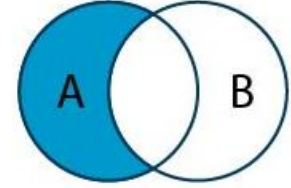
Both terms

A OR B

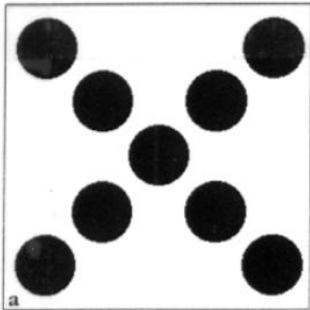


Either term

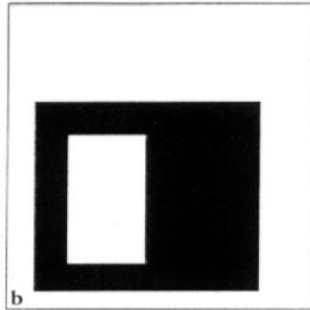
A NOT B



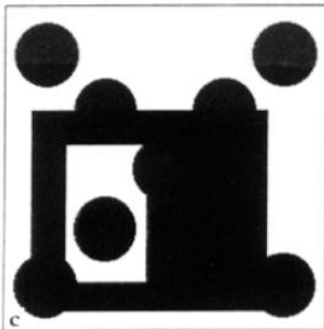
Just one term



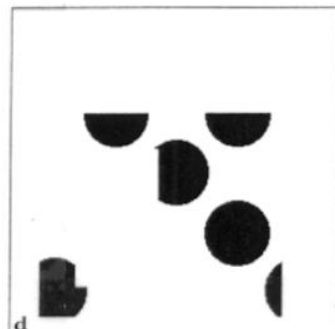
A



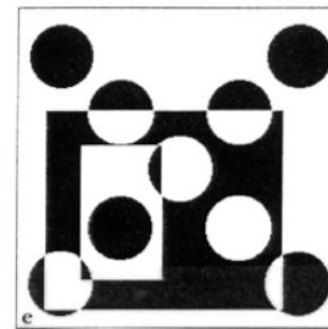
B



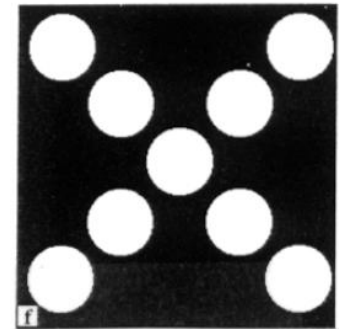
A OR B
the union of
images A and B



A AND B
the intersection of
images A and B



A NOR B
the union -
intersection of
images A and B



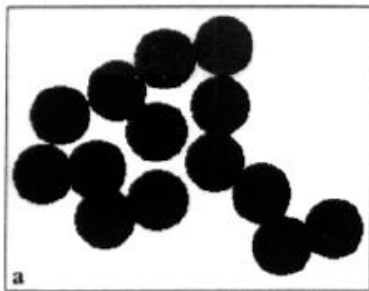
NOT A
the inverse of
image A

Erosion

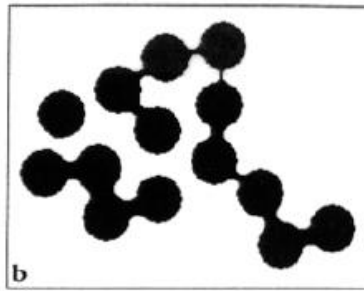
Belongs to the group of „neighborhood operations“. Operations on individual pixels take into account the properties of neighboring pixels.

Erosion: removes pixels that are in the foreground and moves them to the background. "Classic" erosion removes pixels that are in contact with pixels that are part of the background.

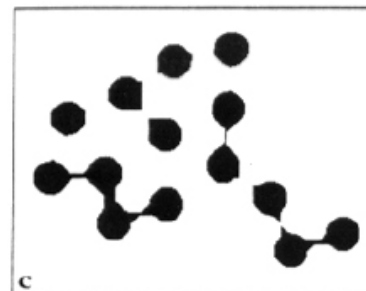
Effect: removes a layer of pixels from the periphery of the image object.



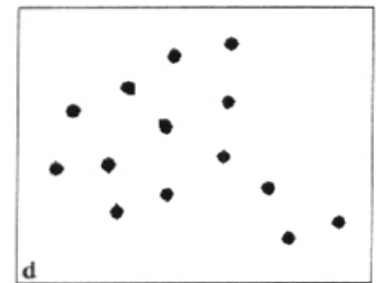
original
image



2



4

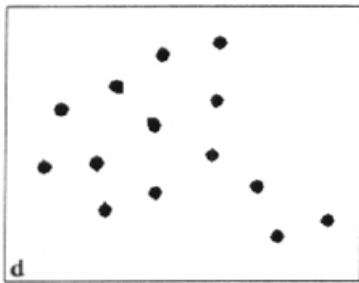


7
cycles of erosion

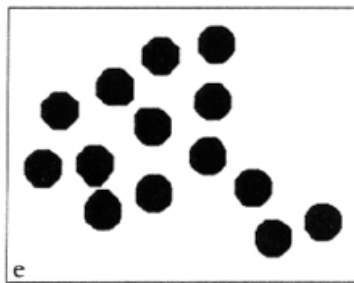
Dilation

Dilation: the opposite of erosion. Brings background pixels that are in contact with pixels of the image object to the foreground.

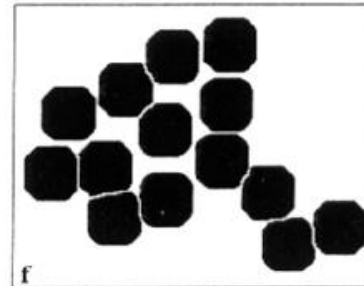
Effect: adds a layer of pixels to the periphery of the image object.



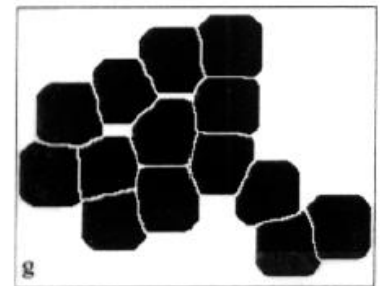
original
image



4



7



9
cycles of dilation

Opening and closing

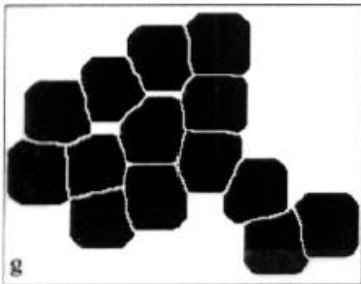
Combinations of erosion and dilation.

Opening: erosion + dilation (the order is important!)

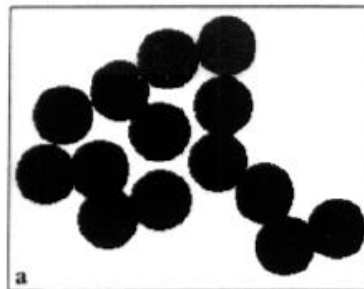
Effect: opens the space between the currently touching image objects.

Closing: dilation + erosion

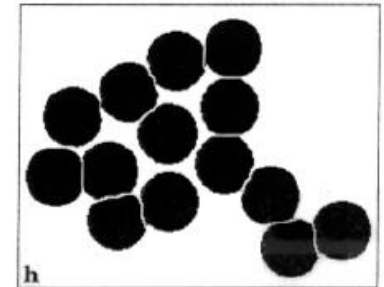
Effect: closes isolated holes, gaps.



AND



=

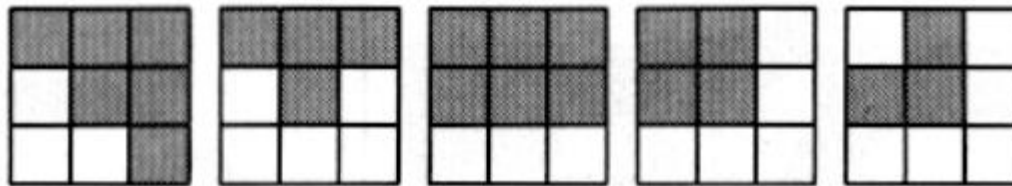


Skeletonization

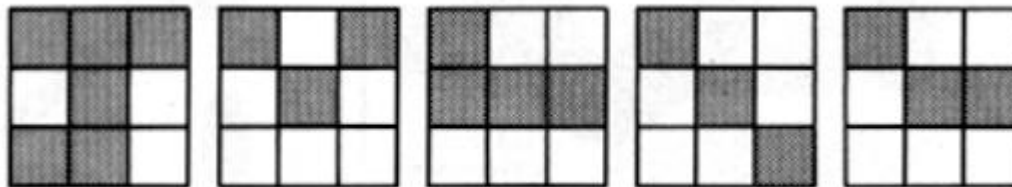
A special form of erosion. **Repeated erosion** is performed by following certain rules. The rule concerns the relationship between neighboring pixels that are in contact with each other.

Namely, if the neighboring (contacting) pixels do not form a continuous group, then the central pixel cannot be removed.

Effect: the skeleton of the image object is drawn.



Patterns for which the central pixel can be removed.



Patterns for which the central pixel cannot be removed.

Outline

draws the outline of a binary image object



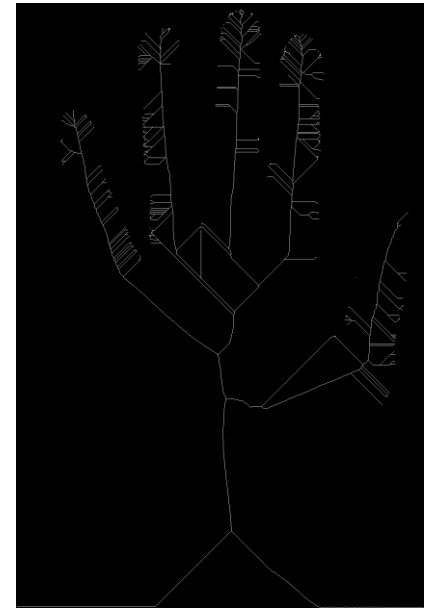
original



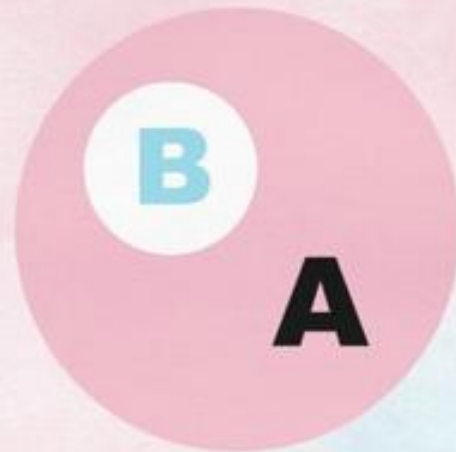
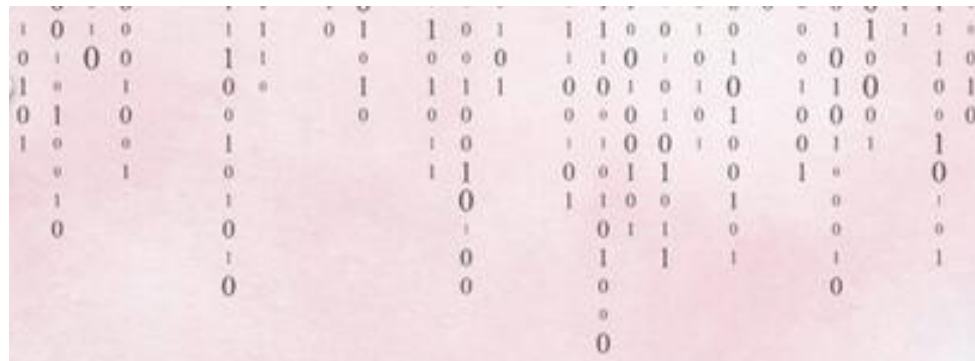
Thresholding



Outline



Skeletonization



**The best thing about a boolean
is even if you are wrong**

you are only off by
a bit.

