Image Analysis

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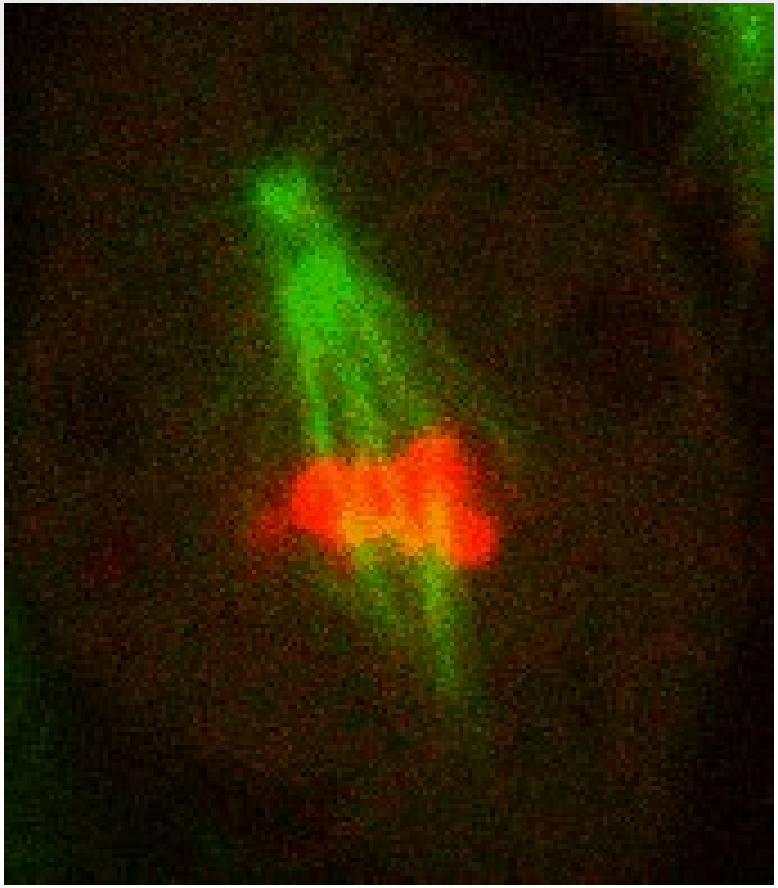
Overview

1. Digital image
2. Image Analysis
3. Point Operations
4. Local Filtering
5. Filtering in the frequency domain
6. Image Restoration
7. Segmentation
8. Geometrical Transformations
9. Visualization
10. Colocalization
11. Filament Tracing
12. Particle Tracking
13. Cell Tracking
14. Software Tools

What is a digital image - examples

Example 1: Fly Brain example (ImageJ)

Example 2: Mitosis (ImageJ)



Example 3: Embryonic Zebrafish Heart Development

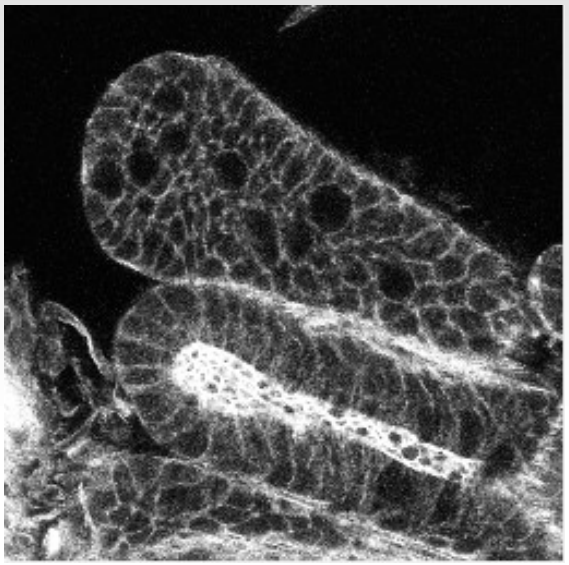
What is a digital image – mathematical point of view

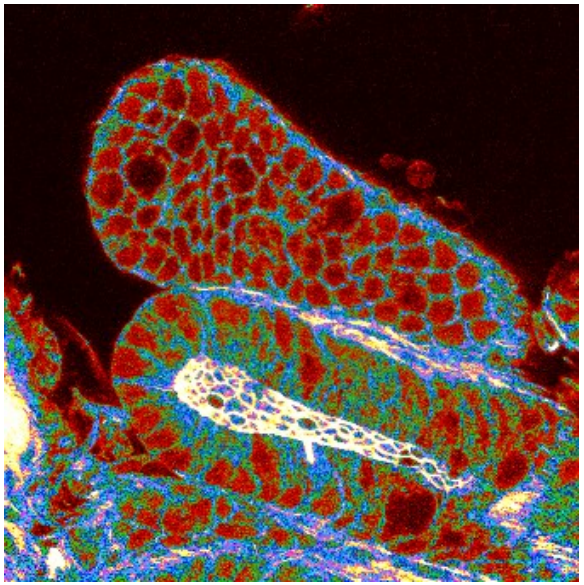
- Matrix of sample values
  - finite number of samples
  - finite number of values per sample
- Image dimensions
  - 1D, 2D, 2D + t, 3D, 3D + t, 3D + t + multispectral
  - $I_{(x,y,z,t)} \in W^n$

0	0	0	0	0	2	3	7	10	12	13	14	11	5	1	0	0	0	0
0	0	0	1	1	7	14	17	25	30	30	29	26	16	7	2	0	0	0
0	0	0	4	8	18	26	37	48	52	52	53	41	30	18	9	3	0	0
0	0	3	8	19	29	44	60	72	76	73	67	61	45	30	19	7	0	0
0	0	5	14	27	45	61	79	94	102	98	88	70	59	43	26	13	5	0
0	1	7	18	35	56	79	99	111	114	108	94	80	67	53	36	19	8	0
0	4	12	23	40	62	87	105	123	124	111	97	83	73	59	45	28	12	2
0	4	12	23	41	62	89	108	120	117	103	96	88	75	63	47	29	13	2
0	3	10	21	37	54	80	102	108	103	96	88	80	67	56	41	21	6	0
0	2	8	17	28	44	62	75	84	88	87	80	62	53	43	27	11	3	0
0	0	4	12	19	31	43	52	63	65	67	56	49	41	28	15	5	0	0
0	0	1	6	9	16	25	34	39	45	40	38	32	25	15	5	0	0	0
0	0	0	1	4	8	13	18	22	20	22	18	16	8	3	1	0	0	0
0	0	0	0	1	2	4	5	9	6	7	5	3	0	0	0	0	0	0

What is a digital image – displayed by the computer

- mapping between sample values and display colors
  - bright means high values
  - bright means low values
  - brightness / contrast adjustments
  - lookup tables

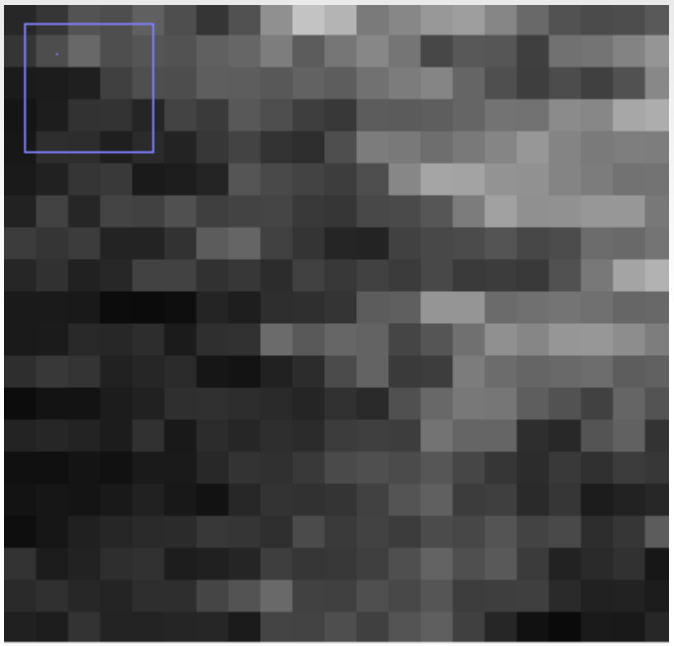




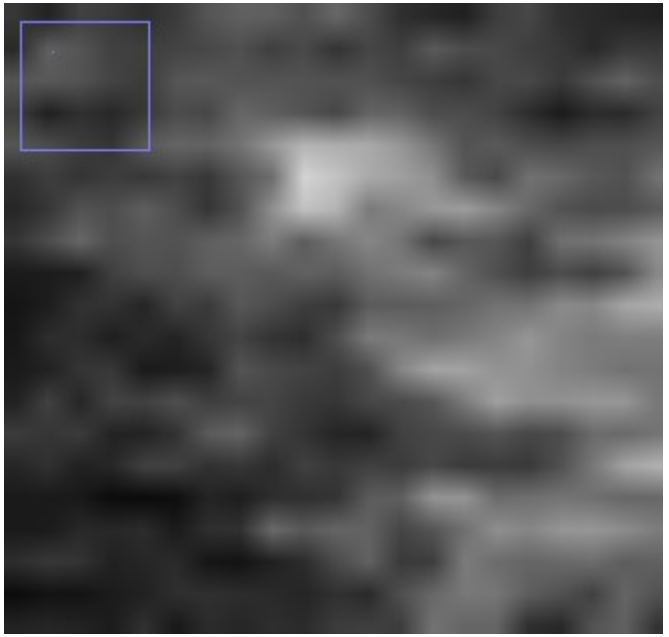
When I use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean—neither more nor less.

L. Carroll, Through the Looking-Glass

What is a digital image – displayed by the computer



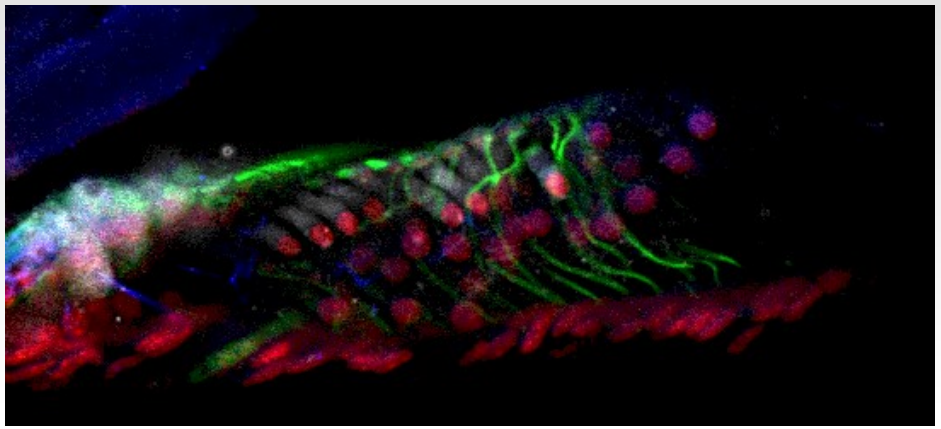
- mapping between sample grid and display grid
  - homogenous rectangles
  - interpolation

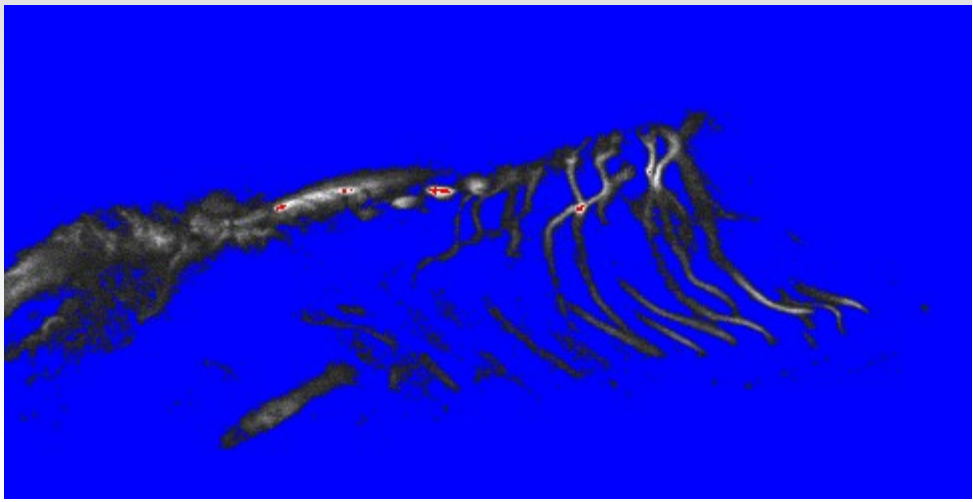


What is a digital image – represented in memory

Formats	Values	Interpretation
8-bit	0-255	unsigned integer
16-bit	0-65535	unsigned integer
32-bit	-3.4×10^{38} - $+3.4\times10^{38}$	precision 6-7 decimal digits, special values like NaN for “Not a Number”, Infinity and -Infinity
8-bit + lookup table	0-255	indexed color
24-bit	3 times 0-255	RGB
hyperstack	n channels of 8, 16 or 32 bit	3d + time + n channels

What is a digital image – convertion traps





- look at green channel
- multiply by ten
- convert both to 8-bit
- compare total intensity before and after

Label	Mean	Min	Max	IntDen
green	100.9	0	4095	13774198
10 x green	1009.0	0	40950	137741980
green 8bit	6.3	0	255	861340
10 x 8bit	6.3	0	255	861340

- conversion is done by linearly scaling from min–max to 0–255

What is a digital image – stored on a disk

- data (sample values) + meta-data in header
- different organization of data and meta-data
- different possibilities / restraints

format	name	provider	properties
tiff	Tagged image file format	Adobe	lossless / metadata
ome-tiff	Open microscopy environment-tiff	OME	tiff with ontology for microscopy metadata
jpeg exif	Joint Photographic Experts Group - exchangable image file format	ISO	lossy data compression / minimal metadata
lsm, stk	Laser scanning microscope file	Zeiss	extensions of tiff
lif	Leica image file format	Leica	can contain multiple images in one file

What is a digital Image – stored on a disk

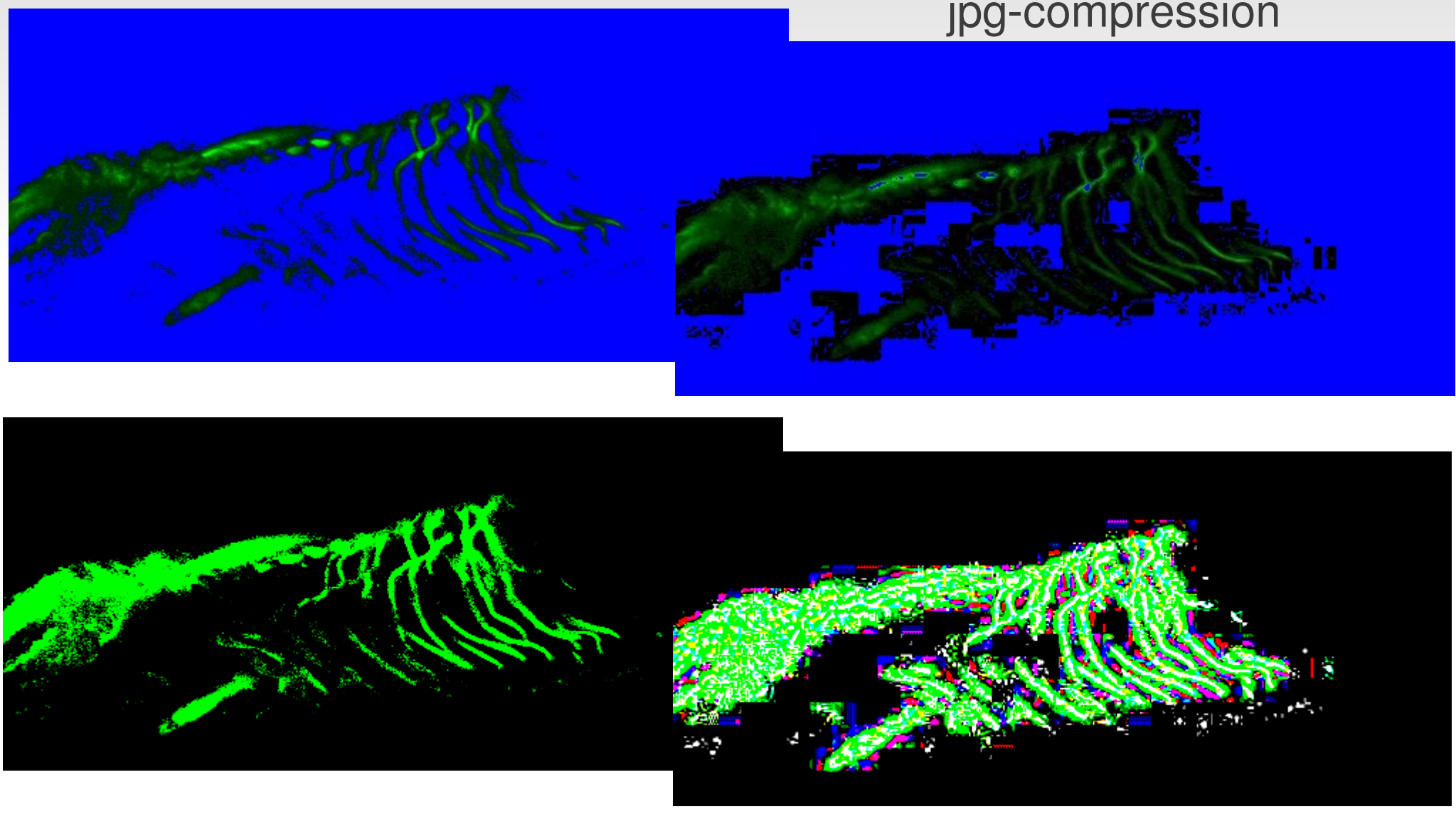
- some lsm-metadata

BitsPerPixel	8
DimensionOrder	XYCZT
IsInterleaved	false
IsRGB	false
LittleEndian	true
PixelType	uint8
Series 0 Name	cafe
SizeC	2
SizeT	1
SizeX	1320
SizeY	1320
SizeZ	1
BeamSplitter #1 Acquire	true
BeamSplitter #1 Filter	None
BeamSplitter #1 Filter Set	FW1
BeamSplitter #1 Name	FW1

DC#1 Pinhole Diameter	896.0
DC#1 Pinhole Name	PH1
DC#1 SPI Wavelength End	798.88
DC#1 SPI Wavelength Start	456.48
...	

What is a digital Image – stored on a disk

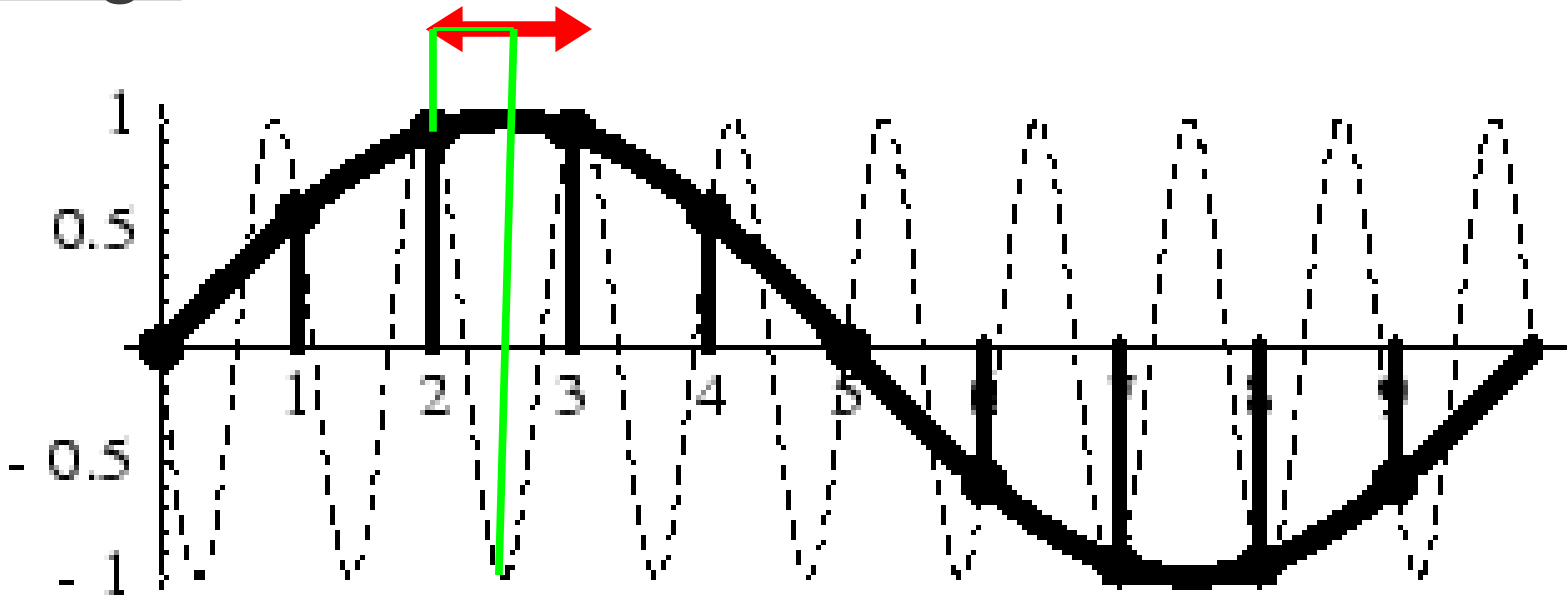
- artefacts from jpg-compression



What is a digital image - the image and the real world

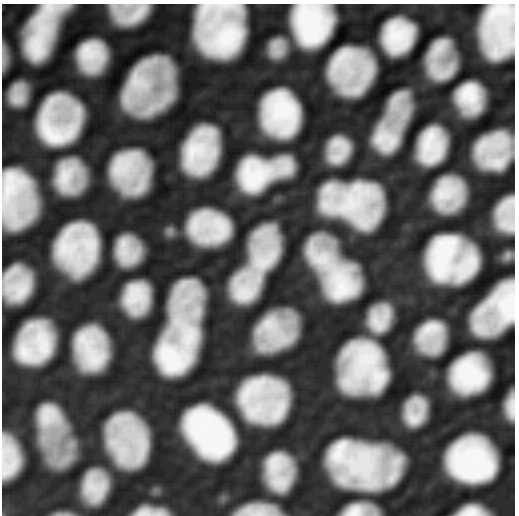
- sampling and resolution
- digital image – finite number of samples
- Nyquist-Shannon sampling theorem:

  The sampling interval must be smaller than one-half the size of the smallest resolvable feature of the optical image



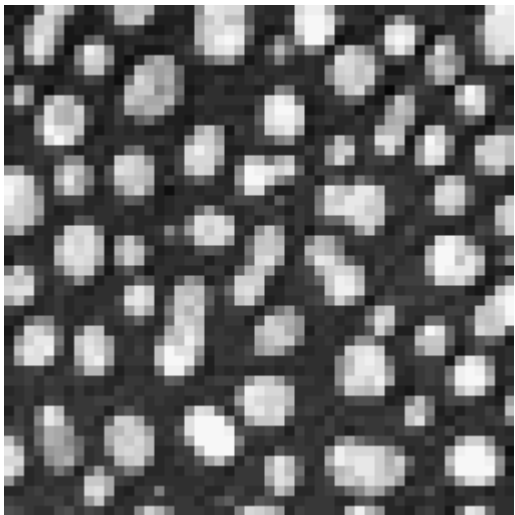
What is a digital image - the image and the real world

- sampling and resolution
- resolution of an optical system
  - the smallest distance at which two objects can still be distinguished
  - given by the Rayleigh criterion $r = \frac{0.61 * \lambda}{NA}$
- therefore the pixel size must be



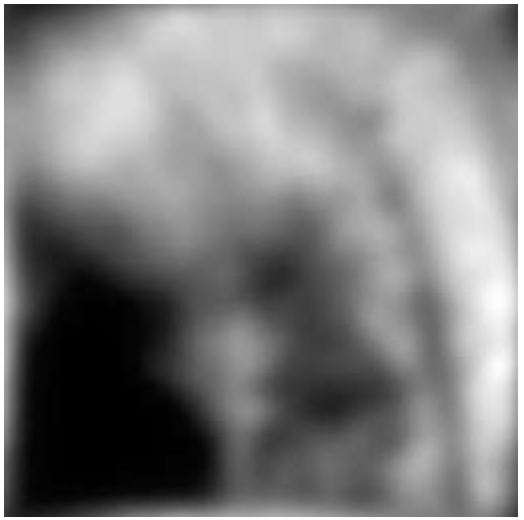
$$\Delta x < \frac{\lambda_{em}}{4 * NA}$$ for widefield

$$\Delta x < \frac{\lambda_{ex}}{8 * NA}$$ for confocal



What is a digital image - the image and the real world

- point spread function
  - the way an optical system images one point
    - a point = an object at the limit of the resolution
  - acquired image = object function convolved with psf



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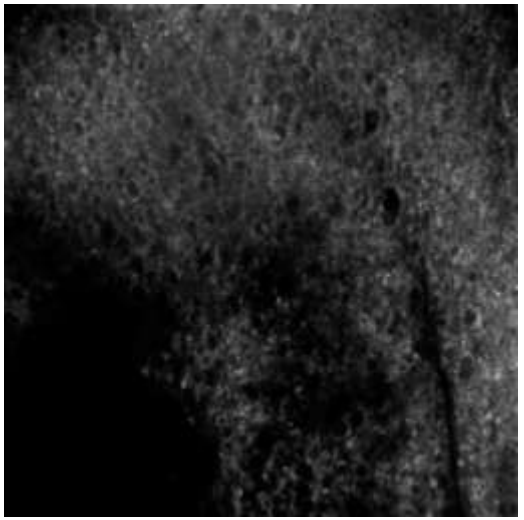

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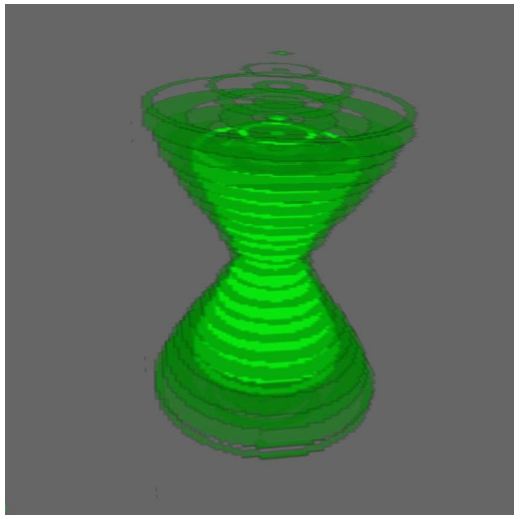
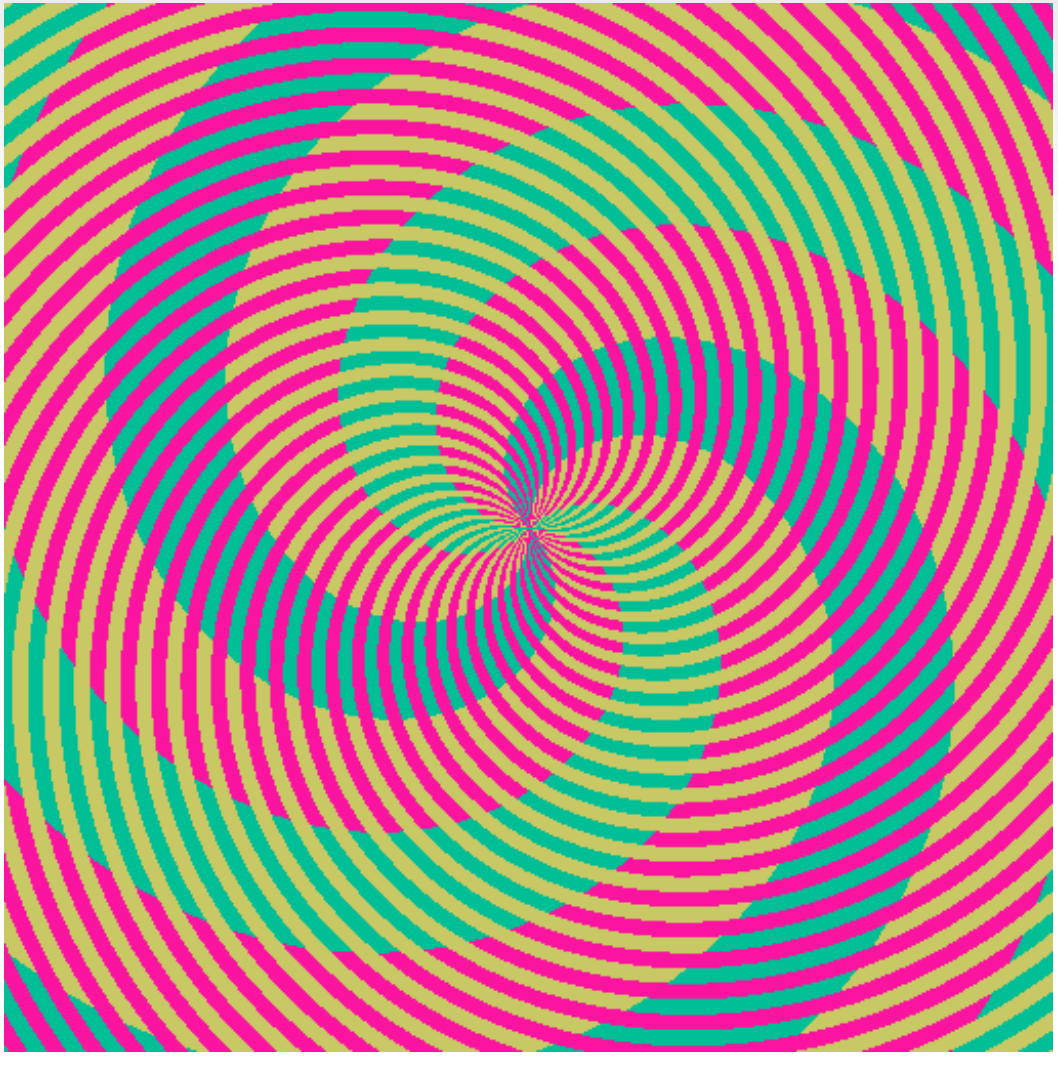
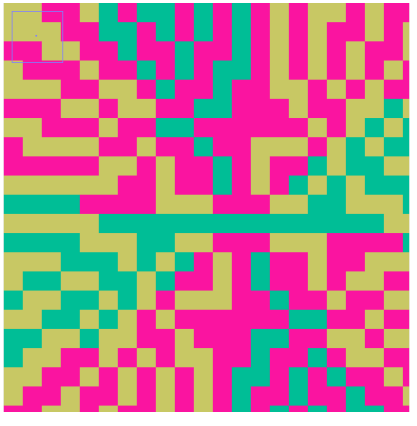


What is a digital image - image and perception

- How many colors do you see?

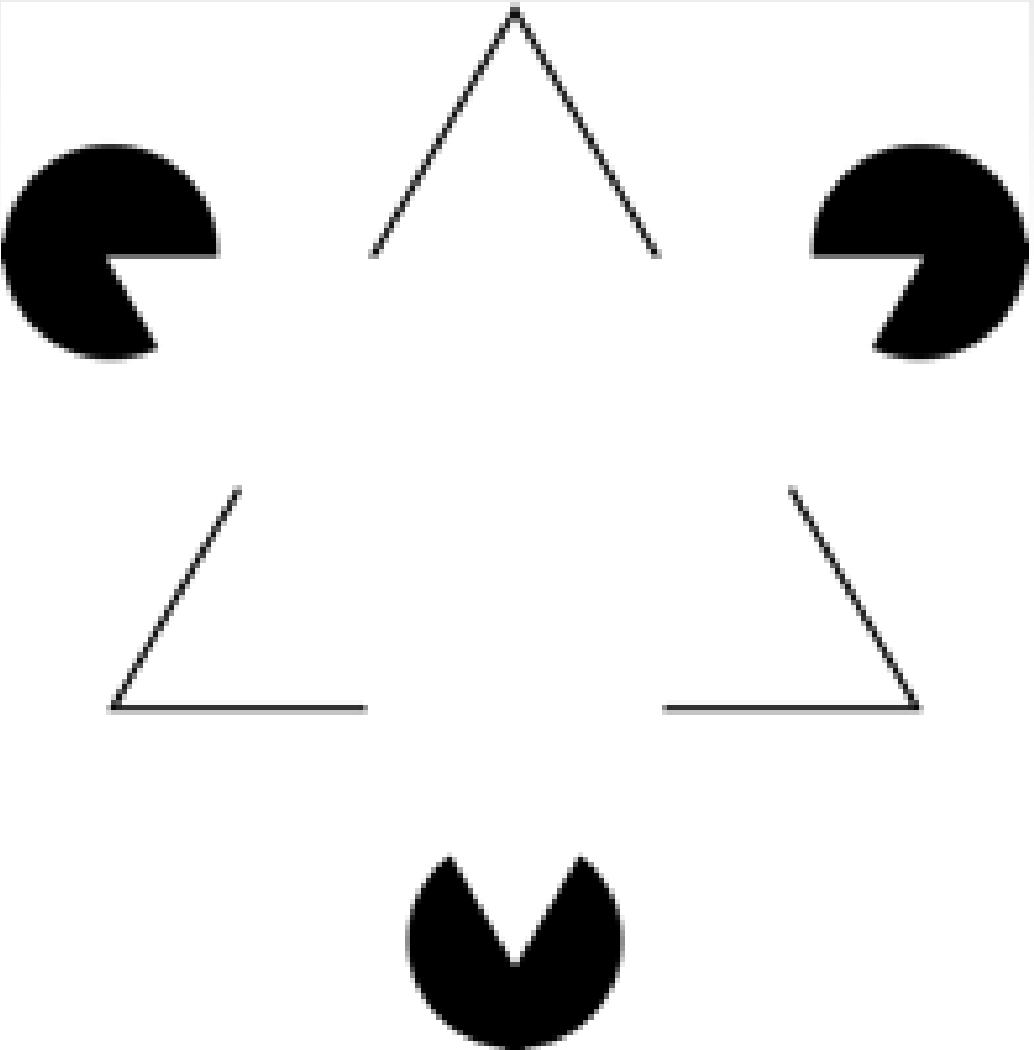


- the image contains 3 different colors
- the brain interprets color according to the background

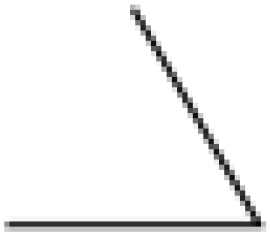


What is a digital image - image and perception

- Can you see the white triangle, standing on its head?

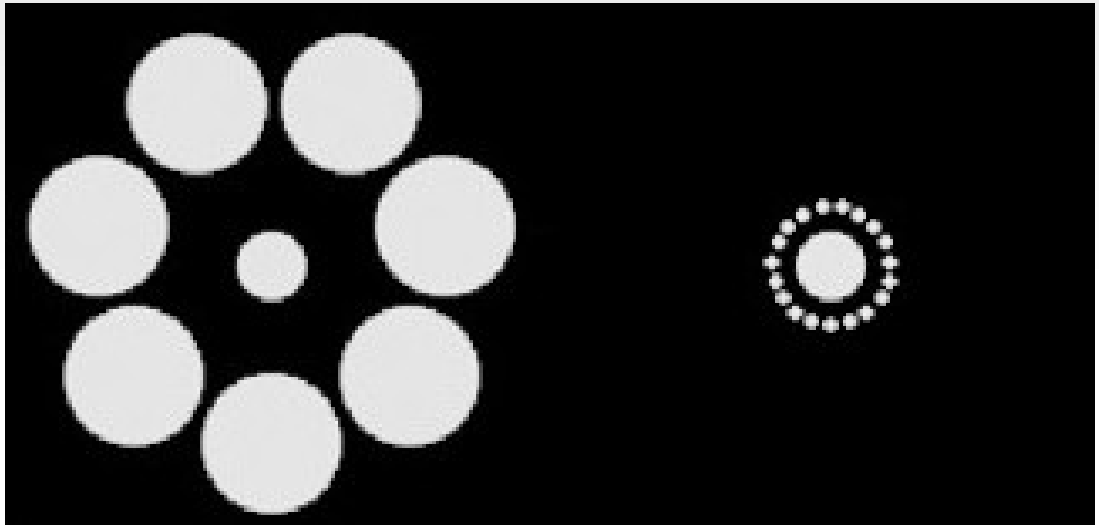


- the borders of the triangle don't exist
- the brain connects the points and interprets the scene as one triangle on top of another one



What is a digital image - image and perception

- Which of the two central spots is bigger?

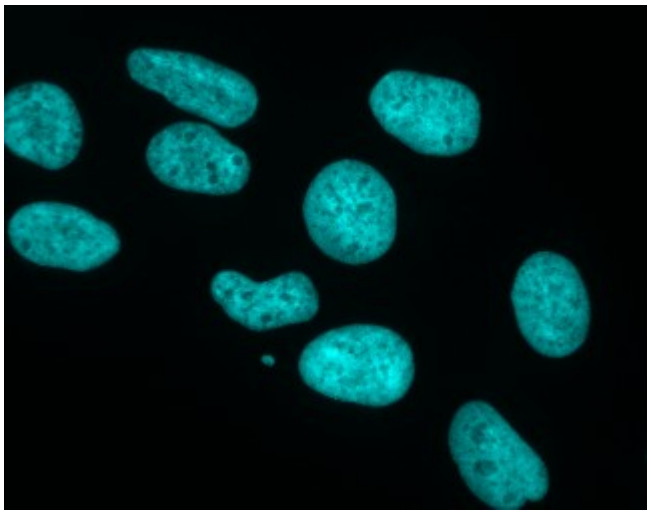


- both have the same size
- again the interpretation is relative to the environment

- conclusions
  - we can not always trust our senses when comparing images
  - quantification needed

What is image analysis?

- Wikipedia
  - ”Image analysis is the extraction of meaningful information from images; mainly from digital images by means of digital image processing techniques.”

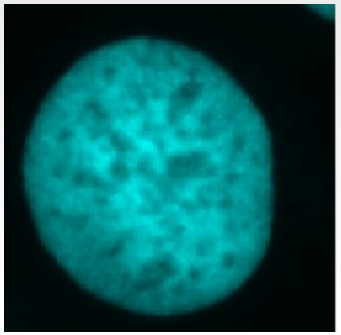


	Area	Perim.	
1	6101	353.061	
2	7047	329.120	
3	5455	292.392	
4	7524	328.191	
5	5653	300.978	
6	6178	304.392	
7	4583	296.392	
8	7312	333.120	
9	6820	343.345	

- IMAGE IN – FEATURES OUT

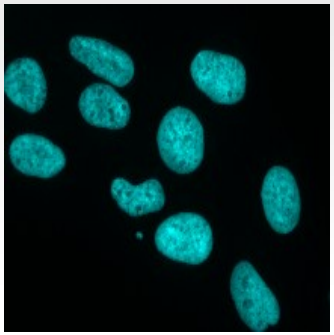
Image analysis and related concepts

image acquisition



object in → image out

image processing



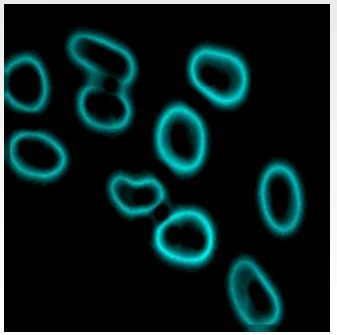
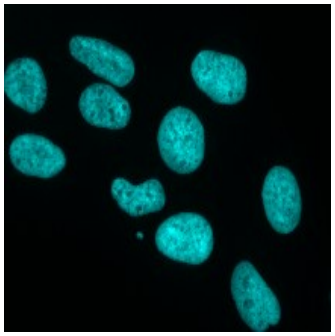


image in → image out

image analysis



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6	6178	304.392
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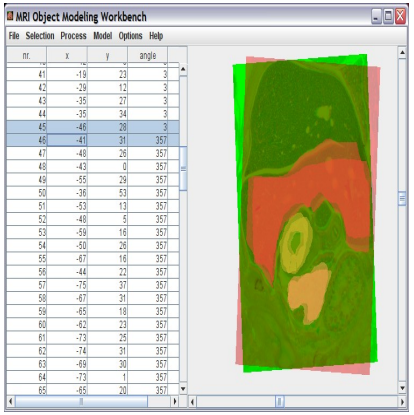
8	7312	333.120
9	6820	343.345

image in → features out

visualization



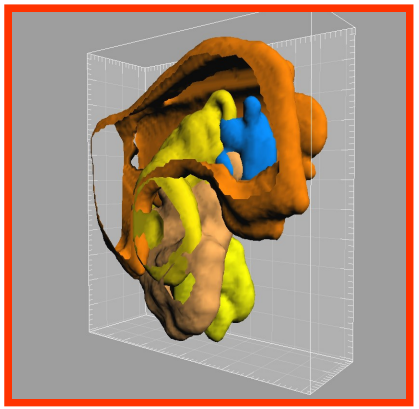
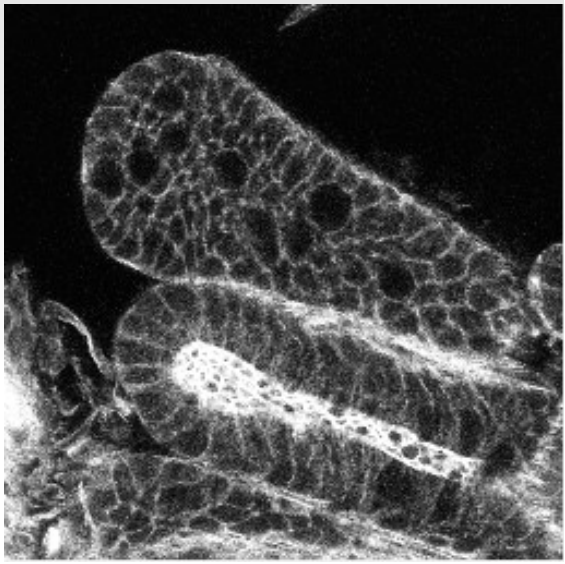


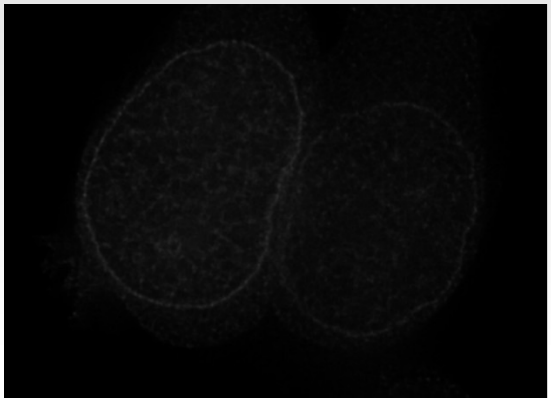
image in → representation out

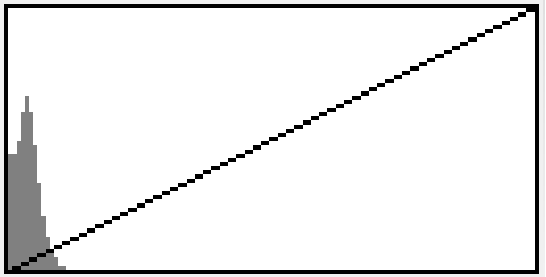
Point operations

- global intensity transformations
  - intensity inversion
  - contrast and brightness adjustment
    - linear
    - gamma function
    - histogram equalization
  - pseudo-coloring
  - intensity thresholding



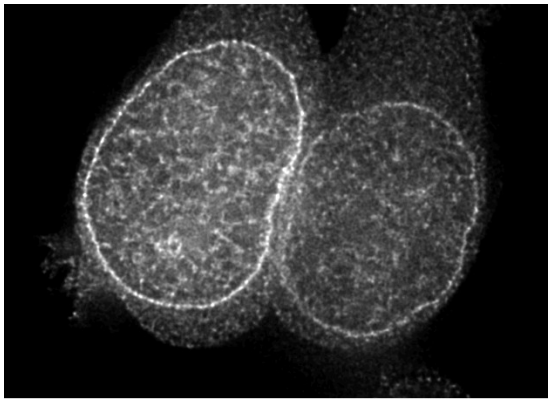
Point operations – contrast stretching

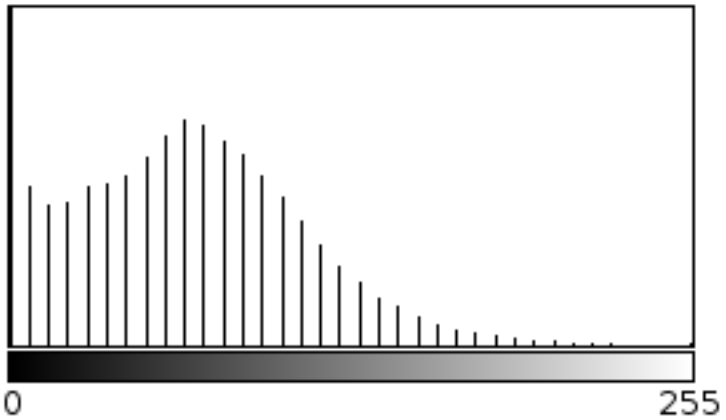




Count: 282048
Mean: 6.968
StdDev: 6.906

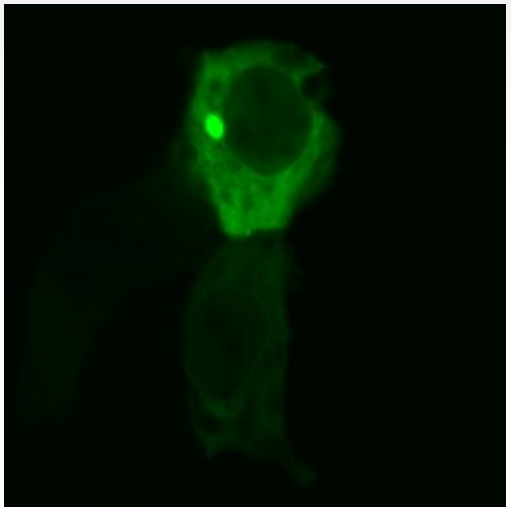
Min: 0
Max: 48
Mode: 0 (89140)

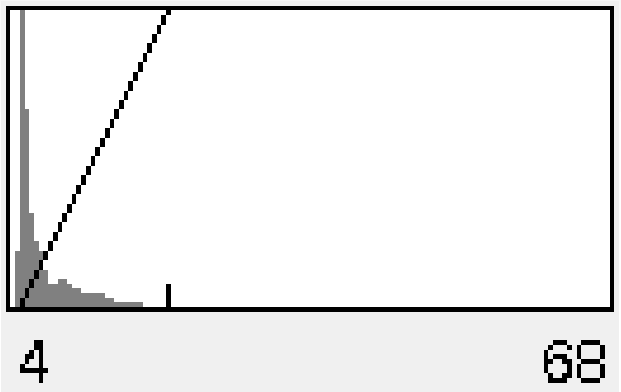


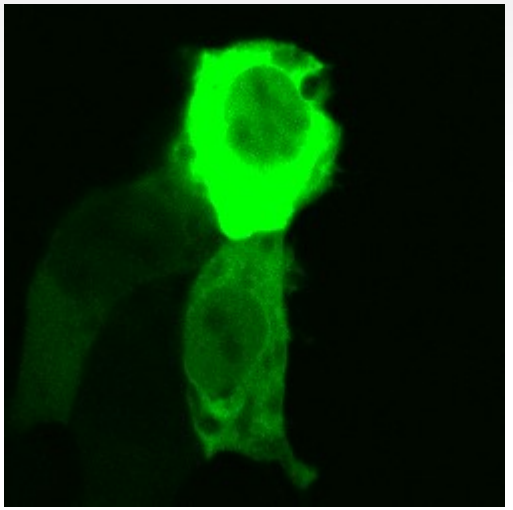


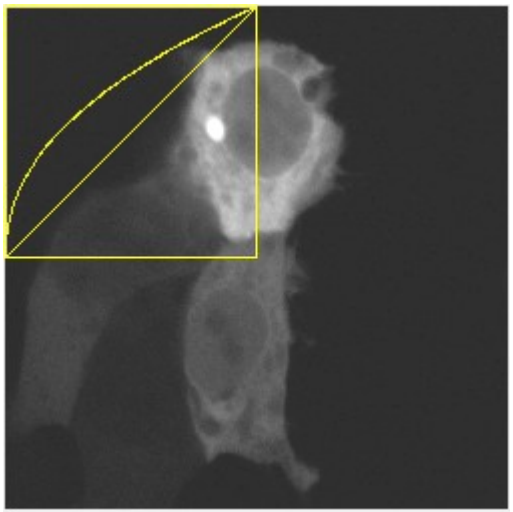
Point operations – gamma function

- linear function
  - changes small and high values in the same way



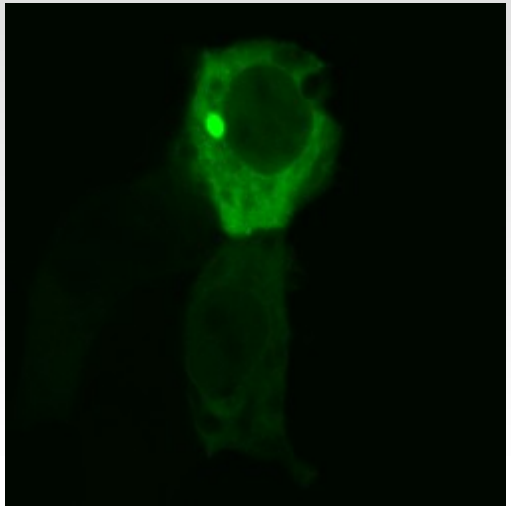


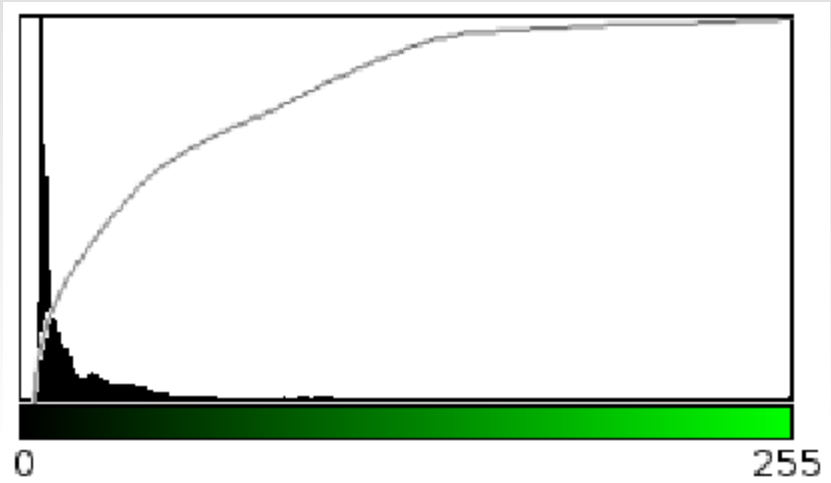


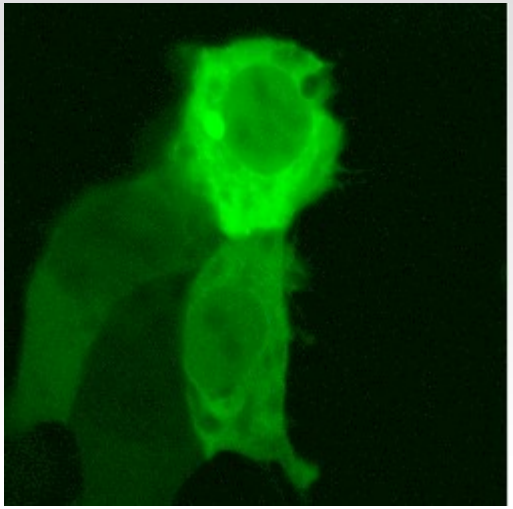


$$f(i) = \left(\frac{i}{255}\right)^{\frac{1}{\gamma}} \cdot 255$$

Point operations – histogram equalization

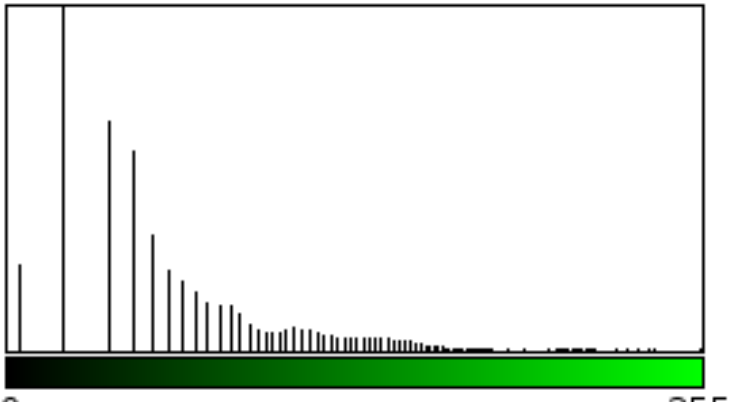




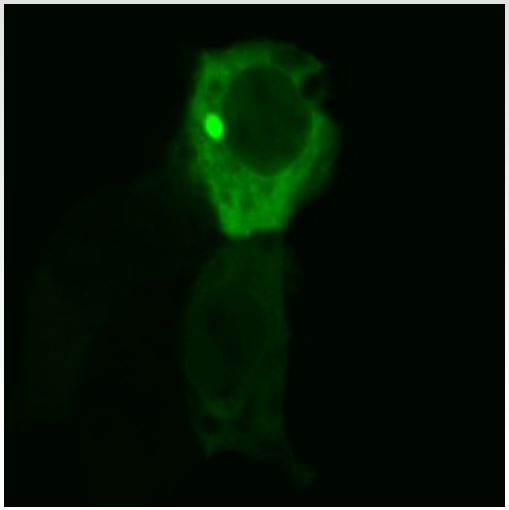


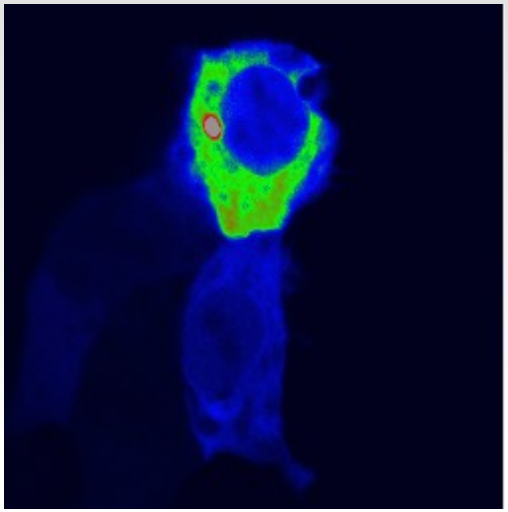
- calculate cumulative histogram
- normalize to range 0-255

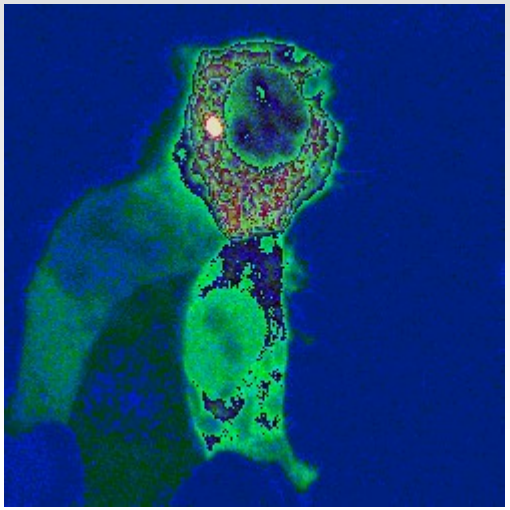
$$h'(n) = \sum_{i=0}^{n} h(i)$$



Point operations – lookup tables

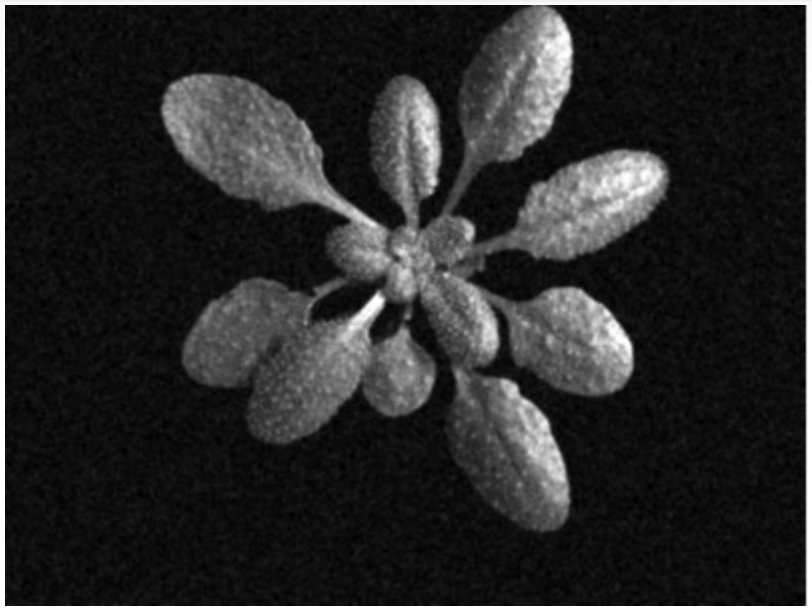


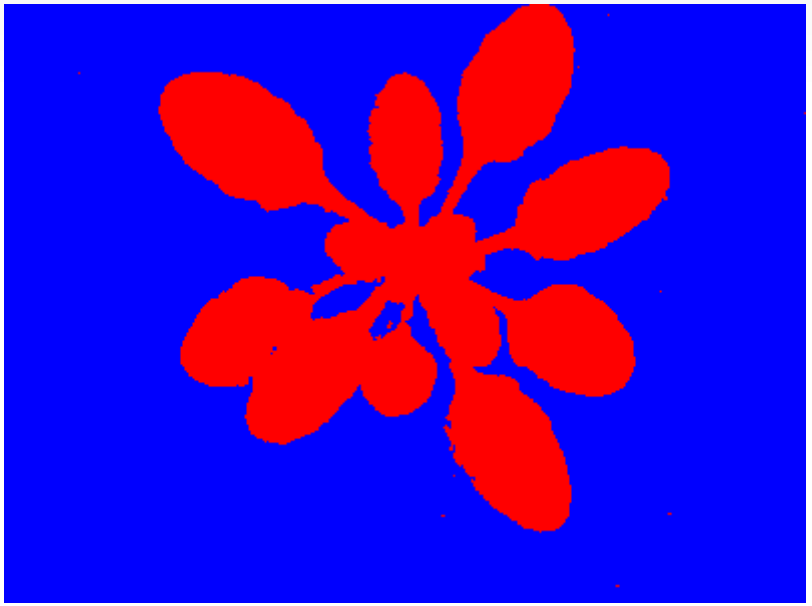




Index	Red	Green	Blue
0	0	0	0
1	0	0	5
2	0	0	10
3	0	1	15
4	0	1	20
5	0	1	25

Point operations – thresholding





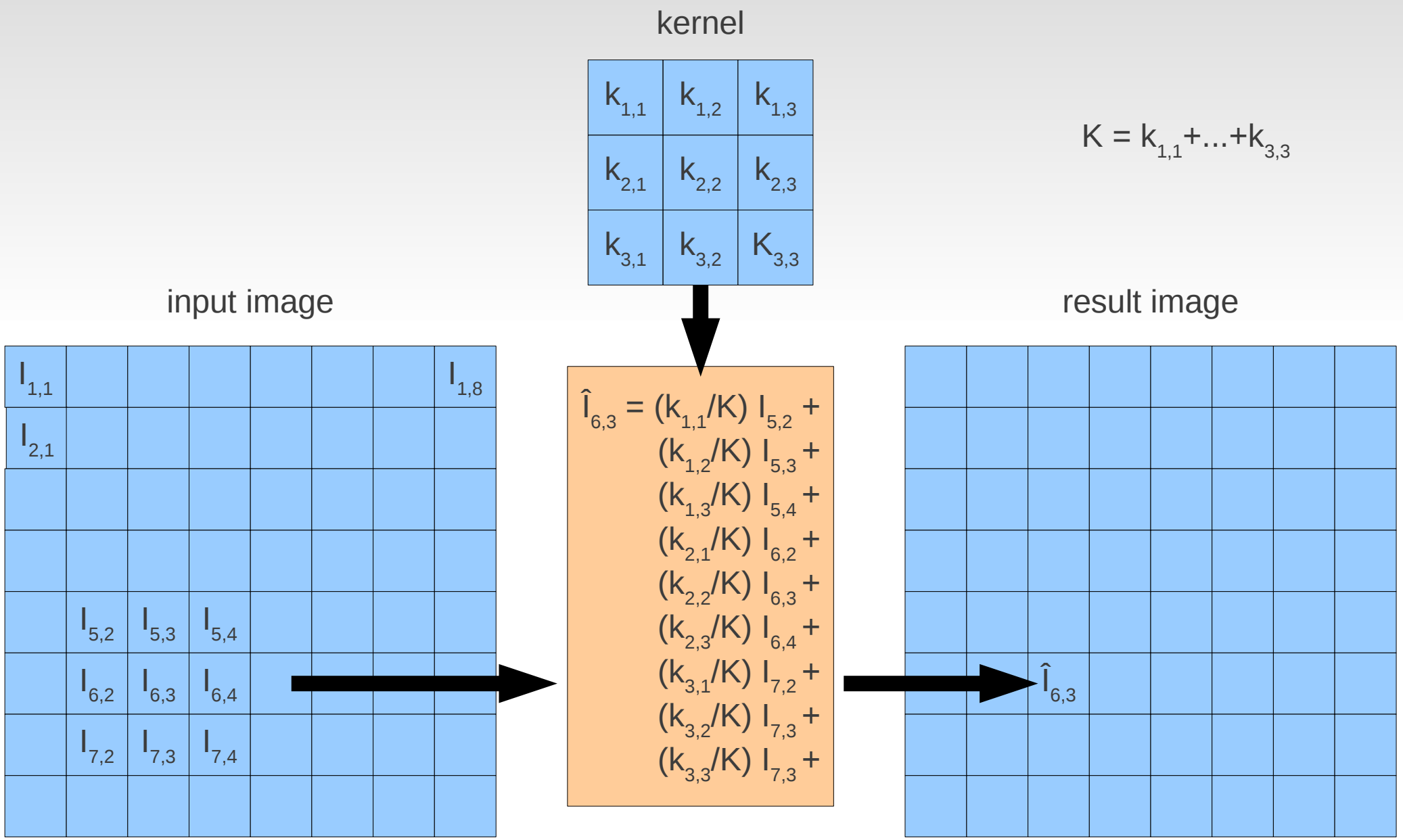
- segmentation – separate objects from background
- can be done by applying a global threshold
- what threshold value?
- the same for all images?

Local Filtering

- convolution filter (linear filtering)
  - smoothing
    - mean filter
    - gaussian blur filter
  - edge detection
    - sobel filter
  - spot detection
    - Laplacian of Gaussian (Mexican Hat Filter)
- ranking filter
  - median, min, max
- mathematical morphology
  - post processing
    - erode, dilate, open, close, top hat, granulometry

The new value of a pixel is calculated from the values in the local neighborhood of the pixel

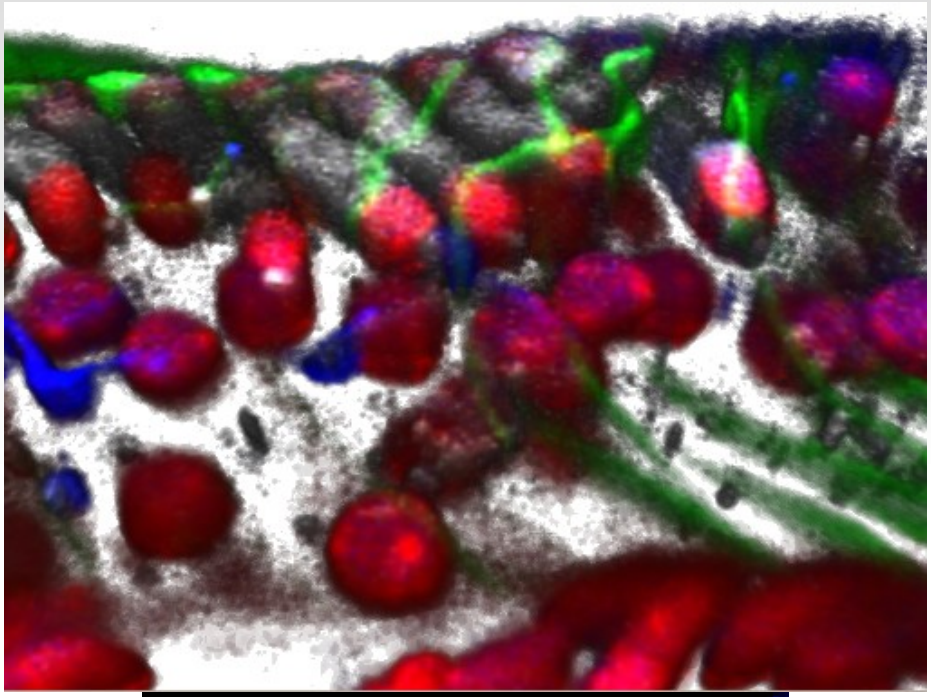
Local Filtering convolution filter

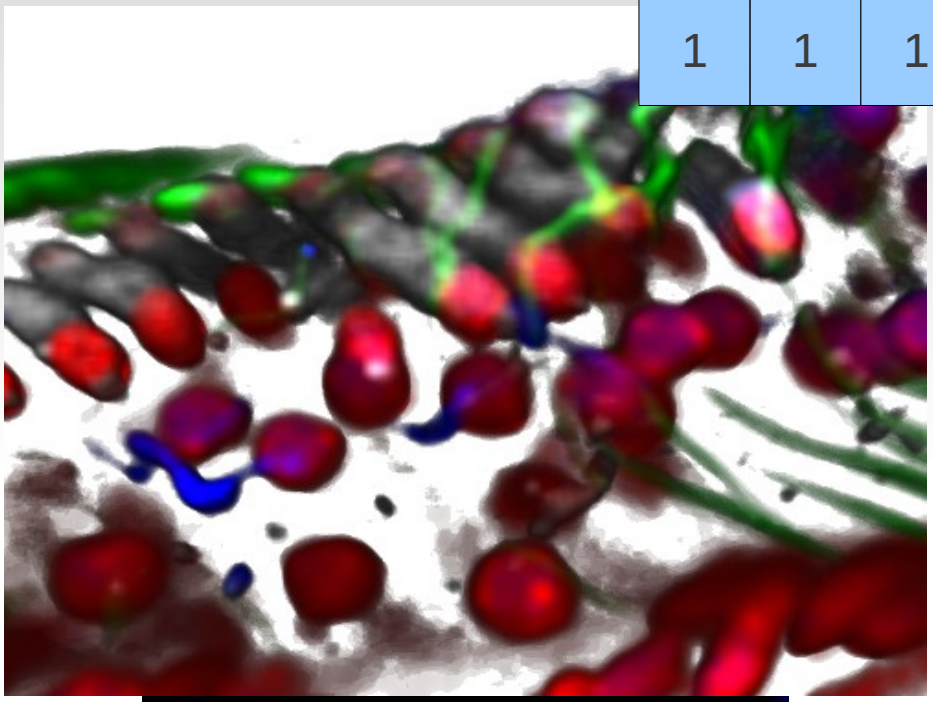


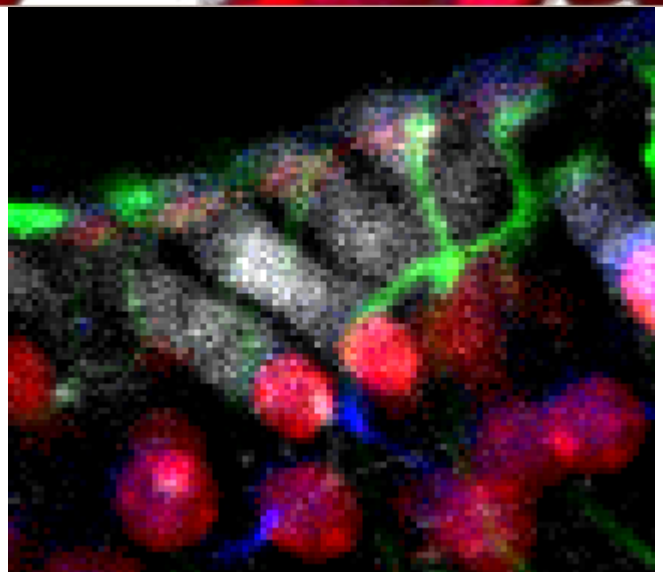
Convolution filter - smoothing

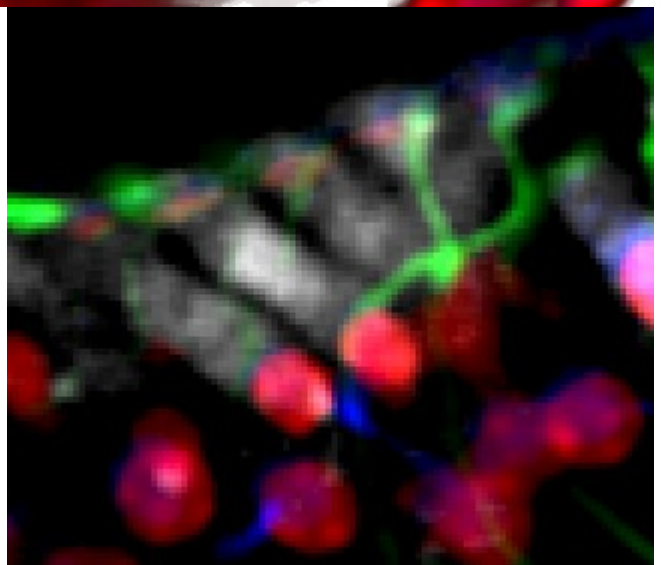
mean

1	1	1
1	1	1
1	1	1

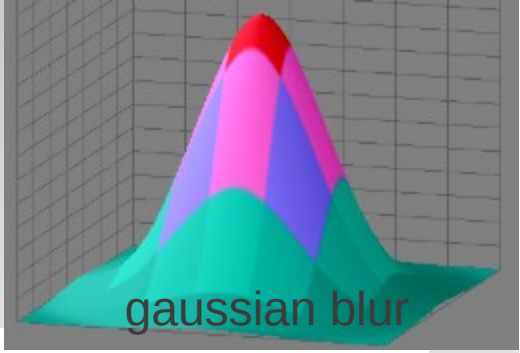


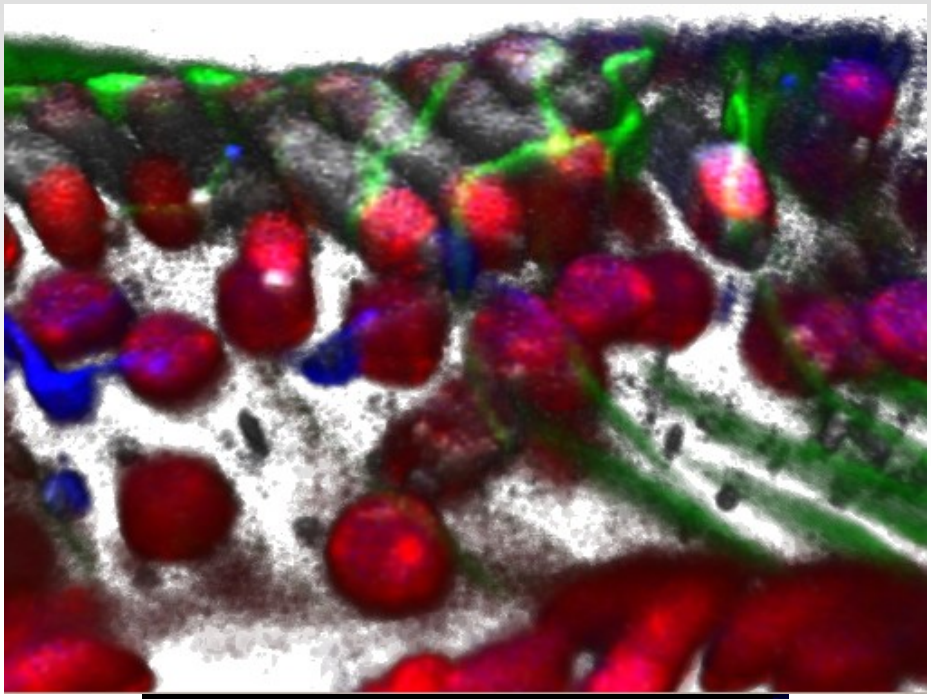


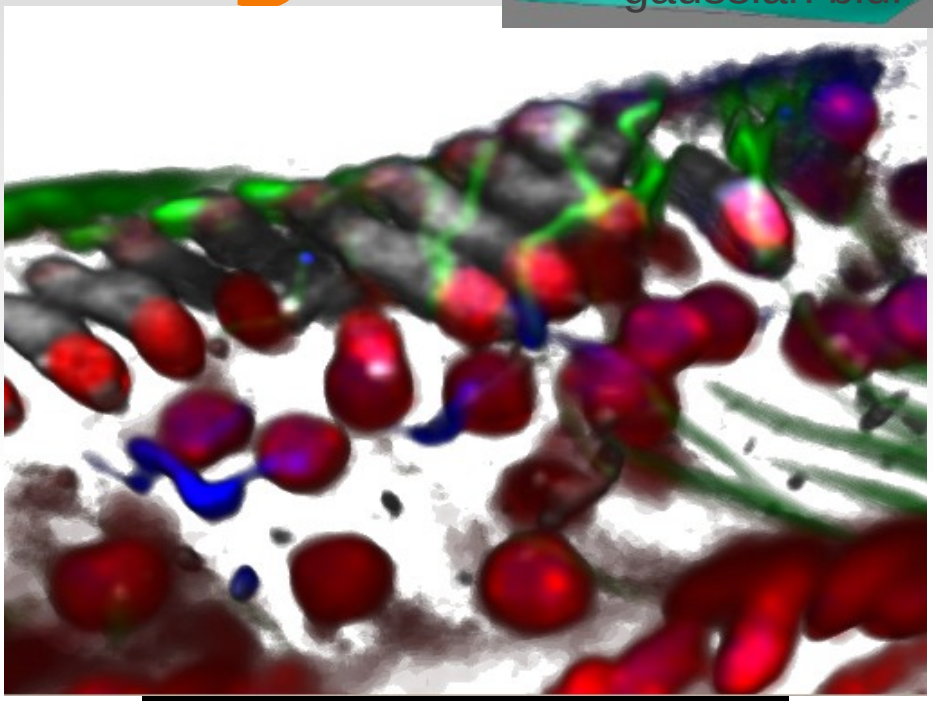


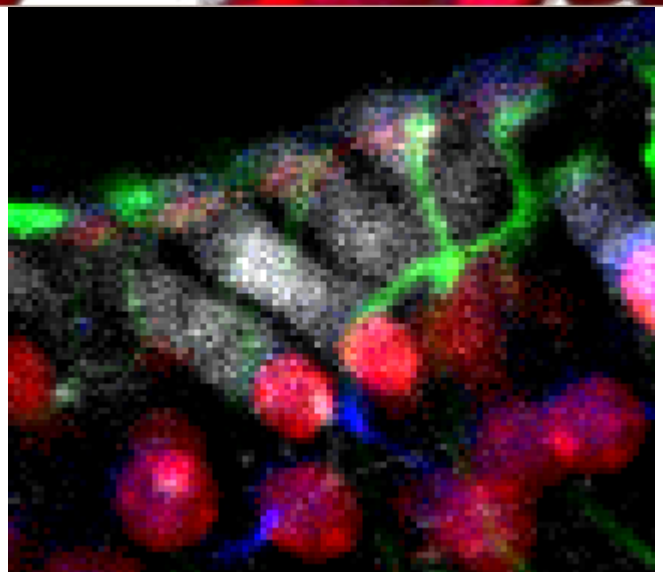


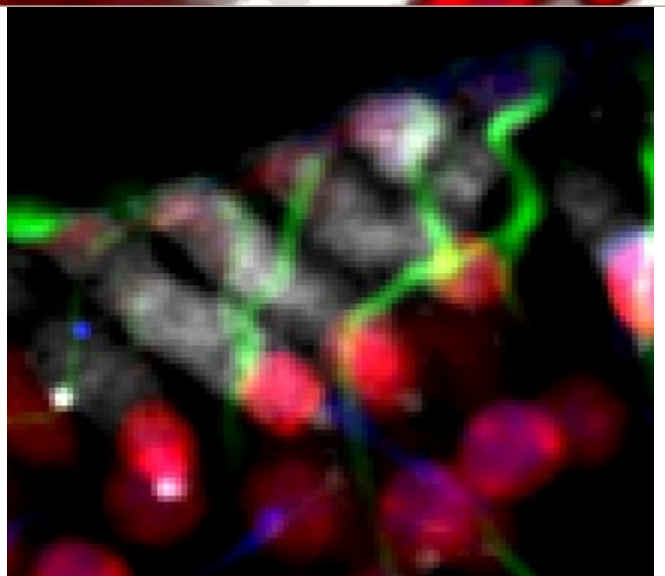
Convolution filter smoothing











x-derivative

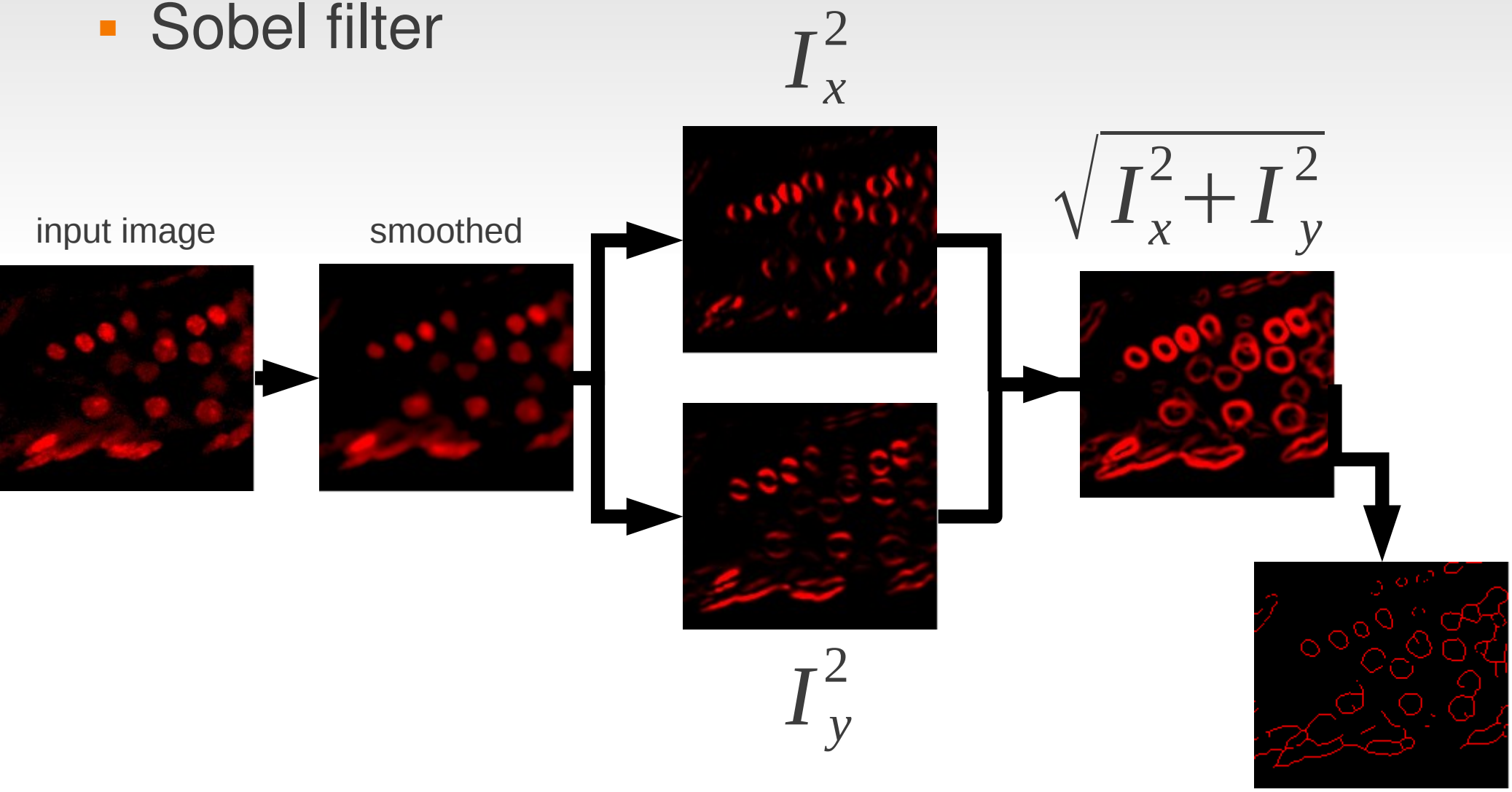
1	0	-1
2	0	-2
1	0	-1

Convolution filter - edge detection

y-derivative

1	2	1
0	0	0
-1	-2	-1

- Sobel filter

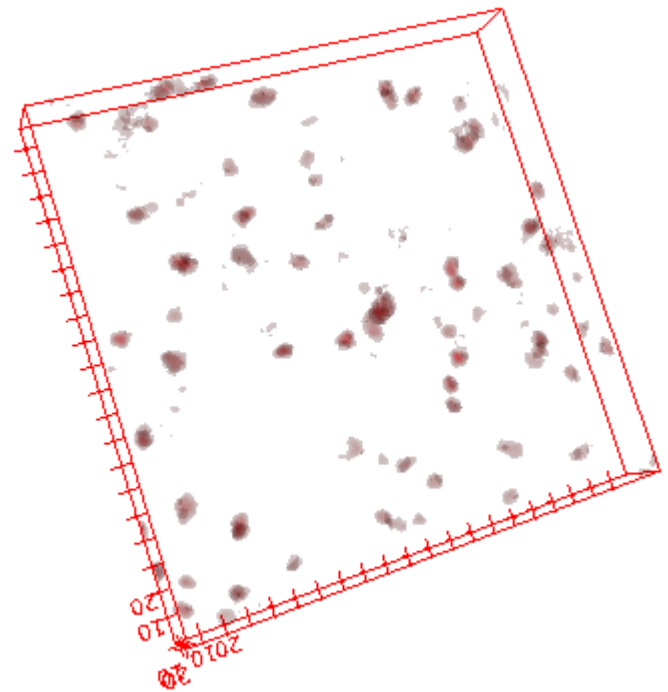


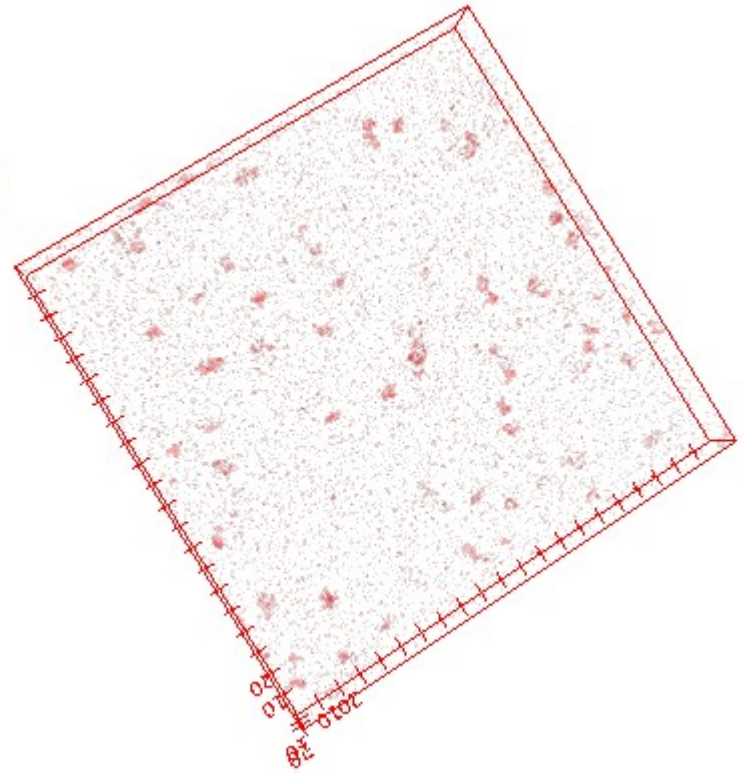
Convolution filter - spot detection

laplacian

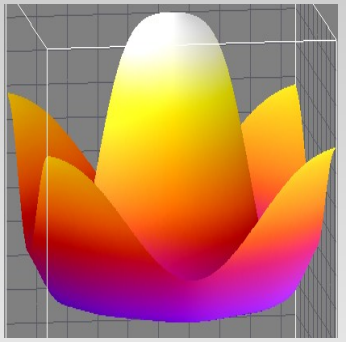
-1	-1	-1
-1	8	-1
-1	-1	-1

- Laplacian filter enhaces spots but augments noise
- use 'Laplacian of Gaussian (LoG)' to enhance spots in noisy images

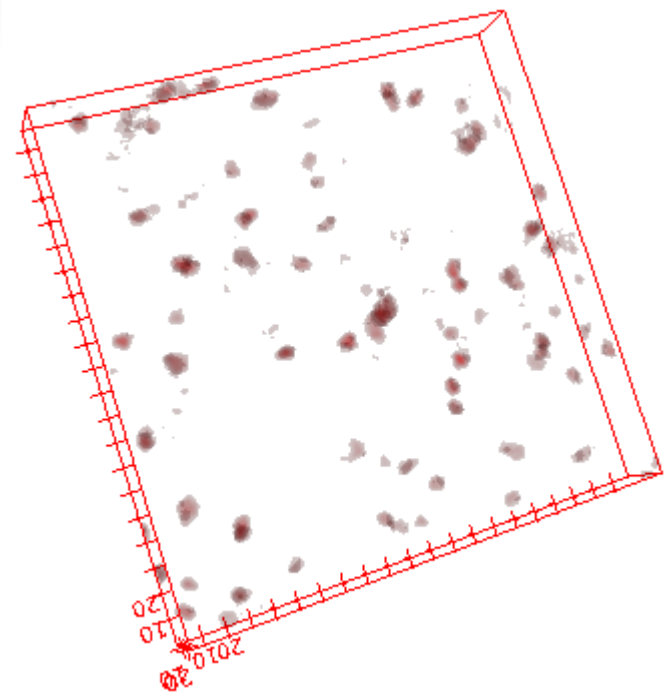


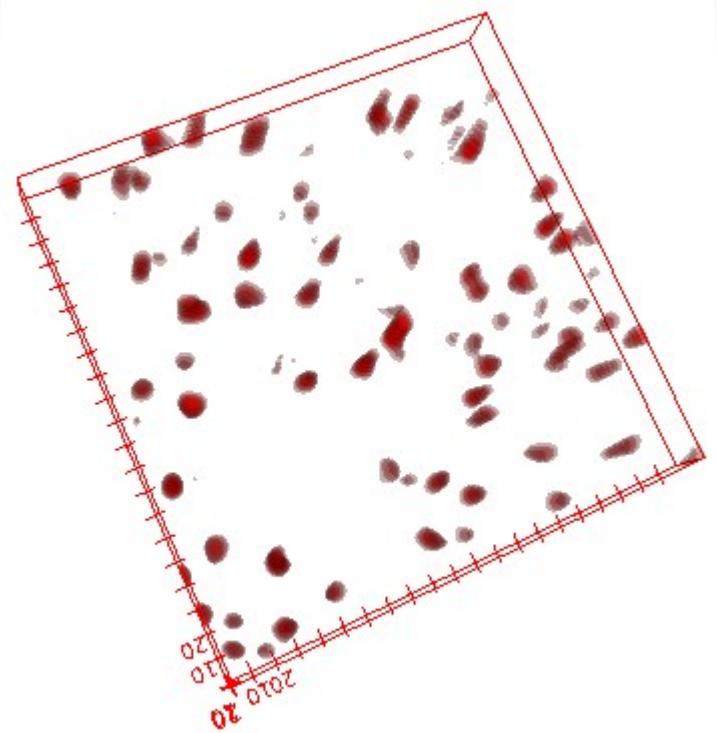


Convolution filter - spot detection



- Laplacian filter enhaces spots but augments noise
- use 'Laplacian of Gaussian (LoG)' to enhance spots in noisy images





Local Filtering - Ranking filter

- for each pixel:
  - sort the values in the neighborhood
  - take the value at a given position
    - first = min filter — enlarge dark regions
    - middle = median filter — filter noise
    - last = max filter — enlarge bright regions

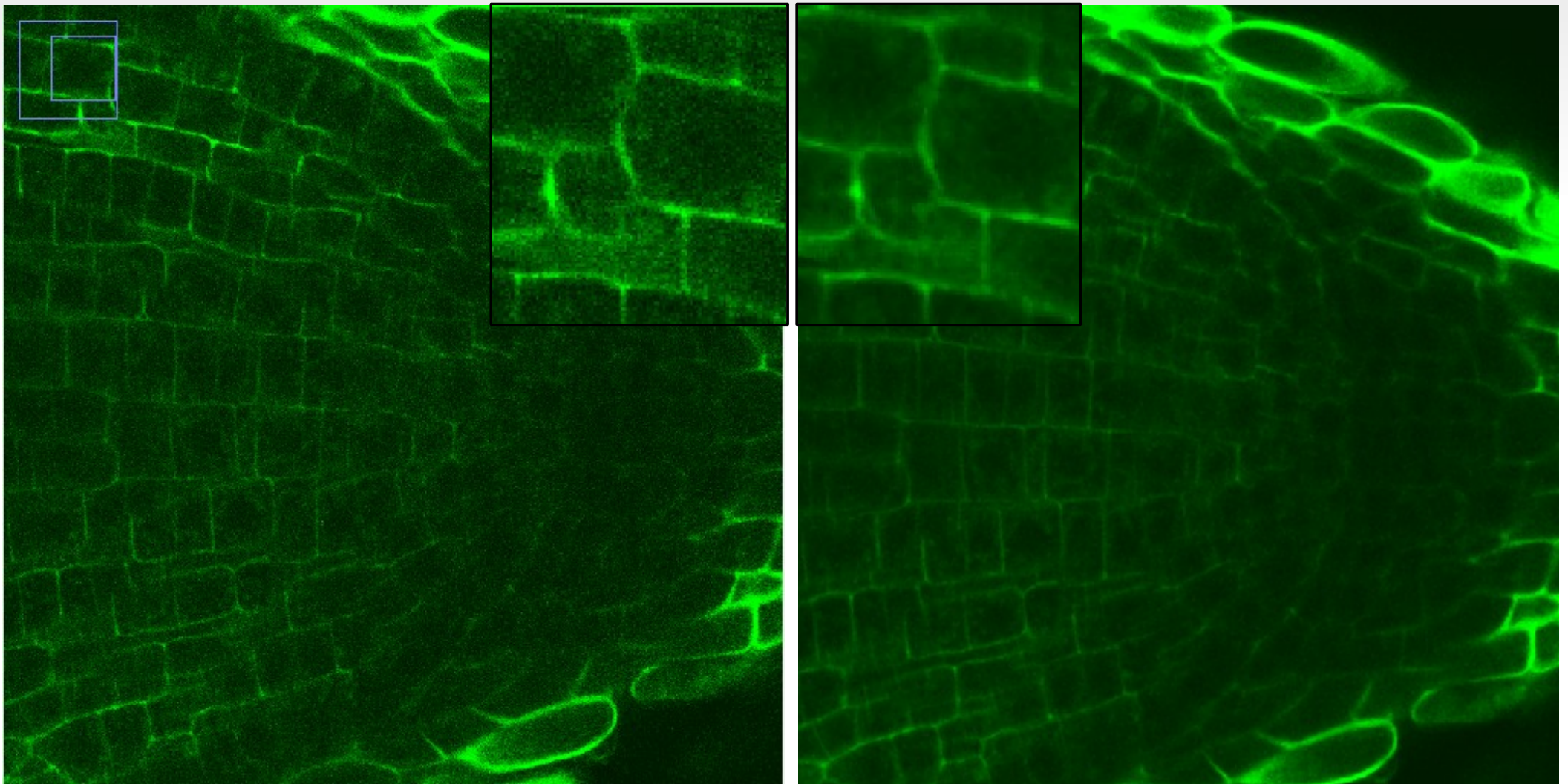
15	18	14
29	27	13
12	19	21

15	18	14
29	18	13
12	19	21

12, 13, 14, 15, **18**, 19, 21, 27, **29**

Ranking filter - median filter

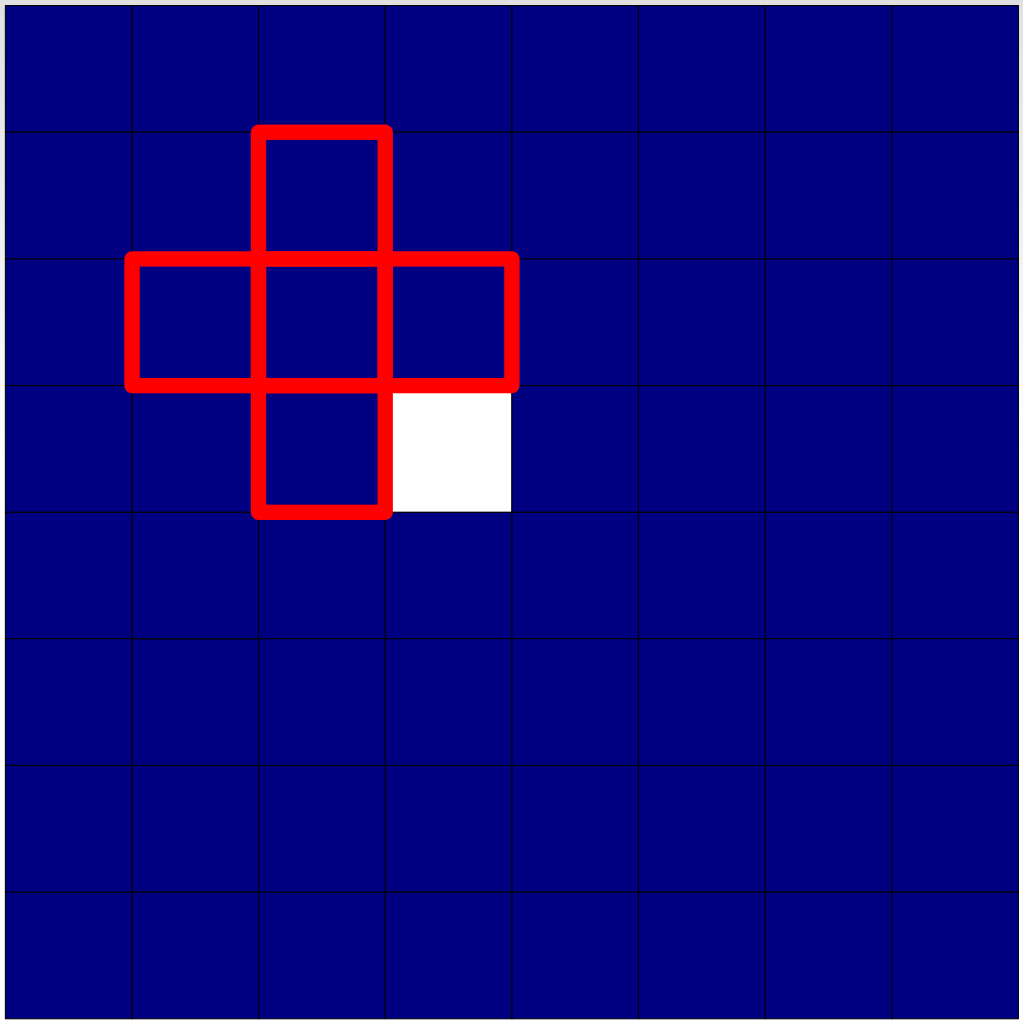
- + stable against outliers
- - can be long to calculate

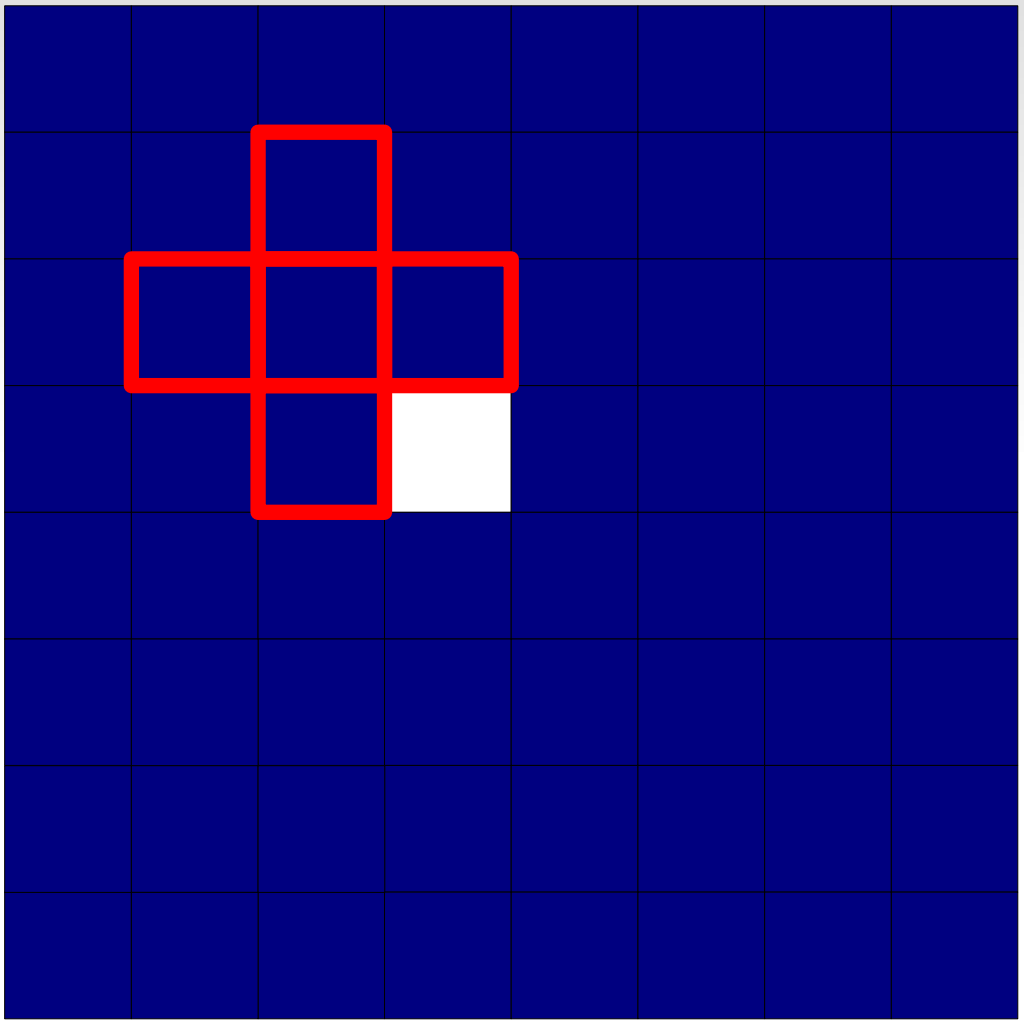


Local Filtering
binary morphology

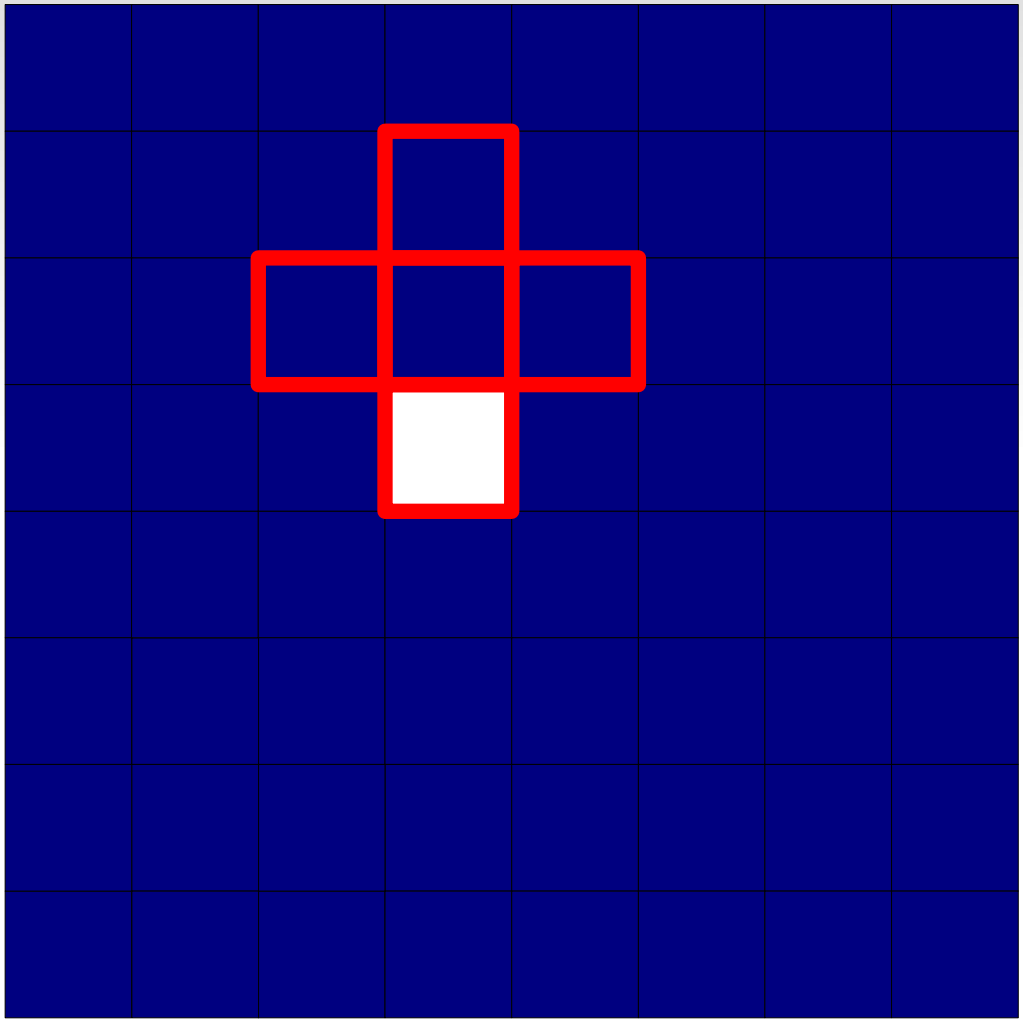
- correct segmentation, measure features, granulometry, edge detection, skeletonization, reconstruct objects
- work on a mask (a binary image)
- move the structuring element along the image
- two basic operations
  - dilate (enlarge objects):
    - current pixel is 1 if the SE touches a 1 in the image
  - erode (shrink objects):
    - current pixel is 1 if no 1 in the SE touches a zero in the image

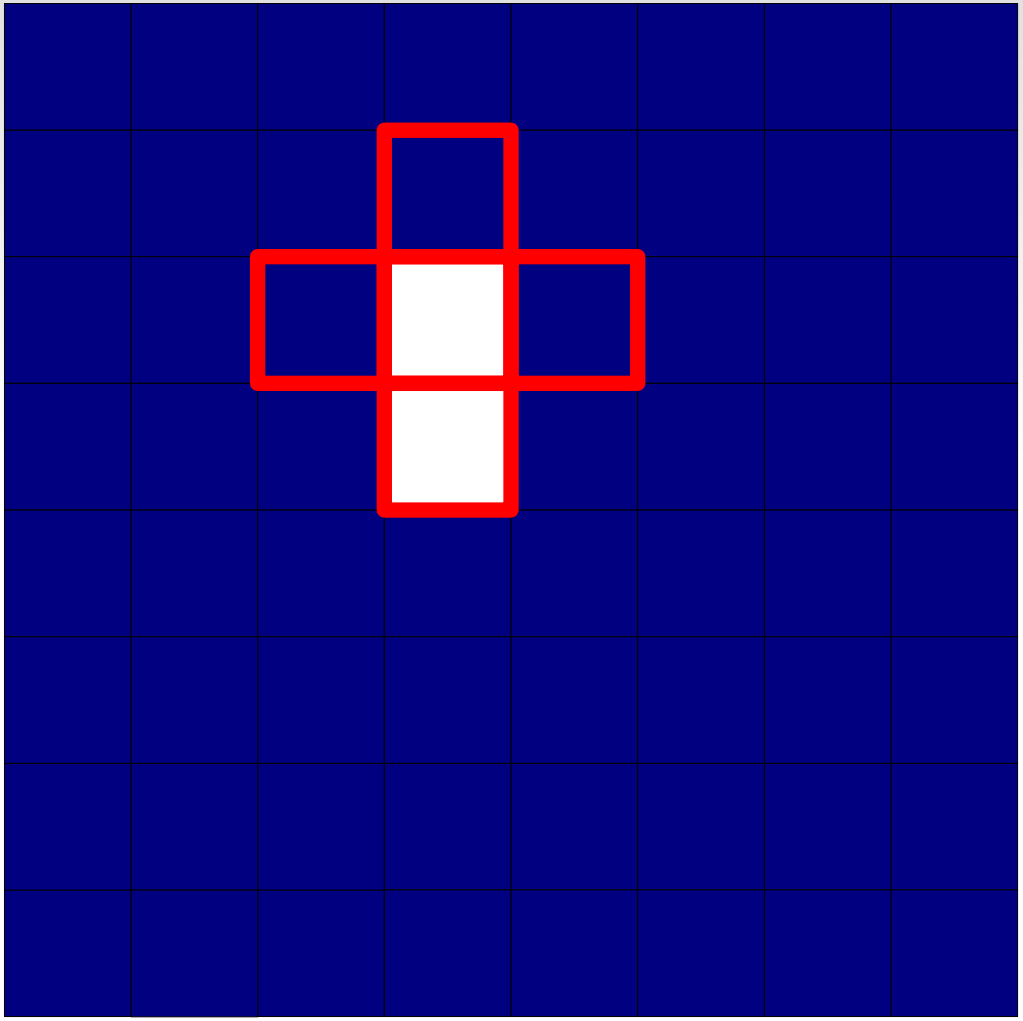
Binary Morphology - dilation



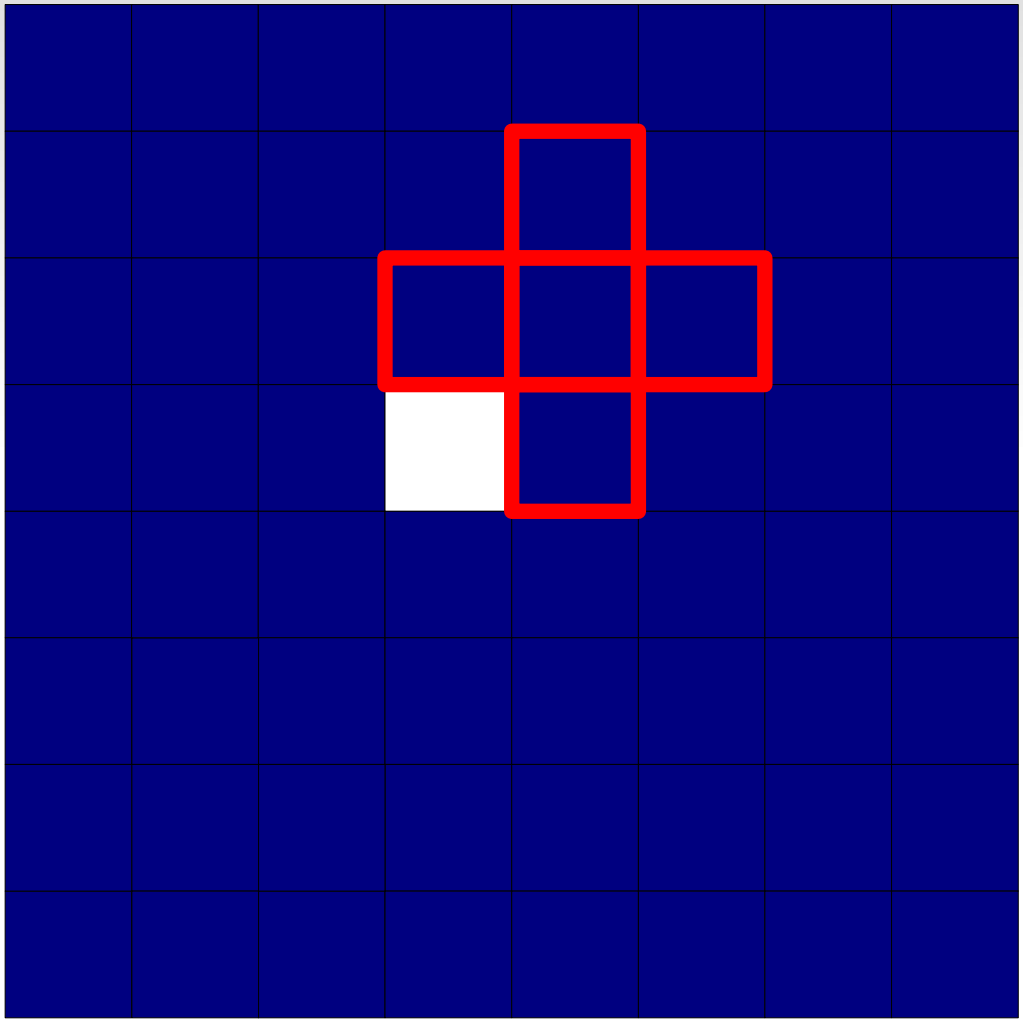


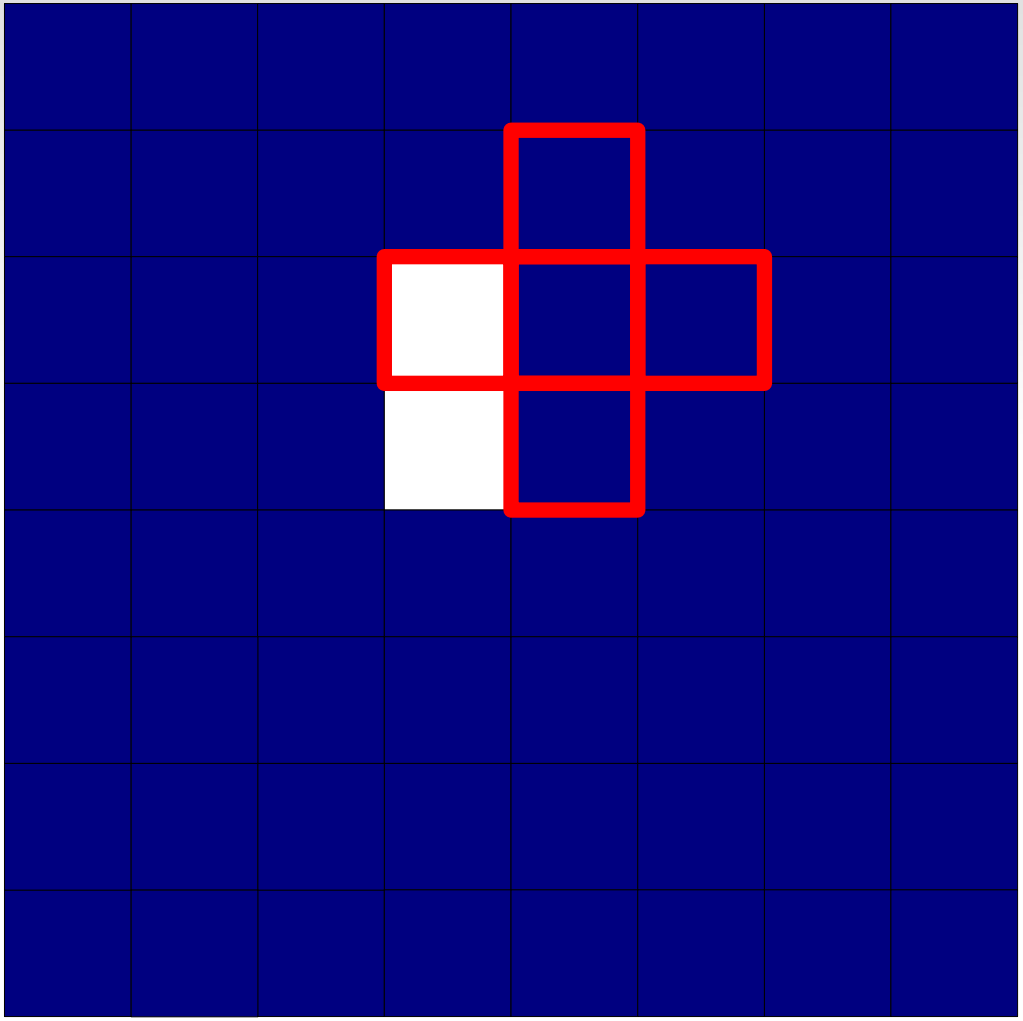
Binary Morphology - dilation



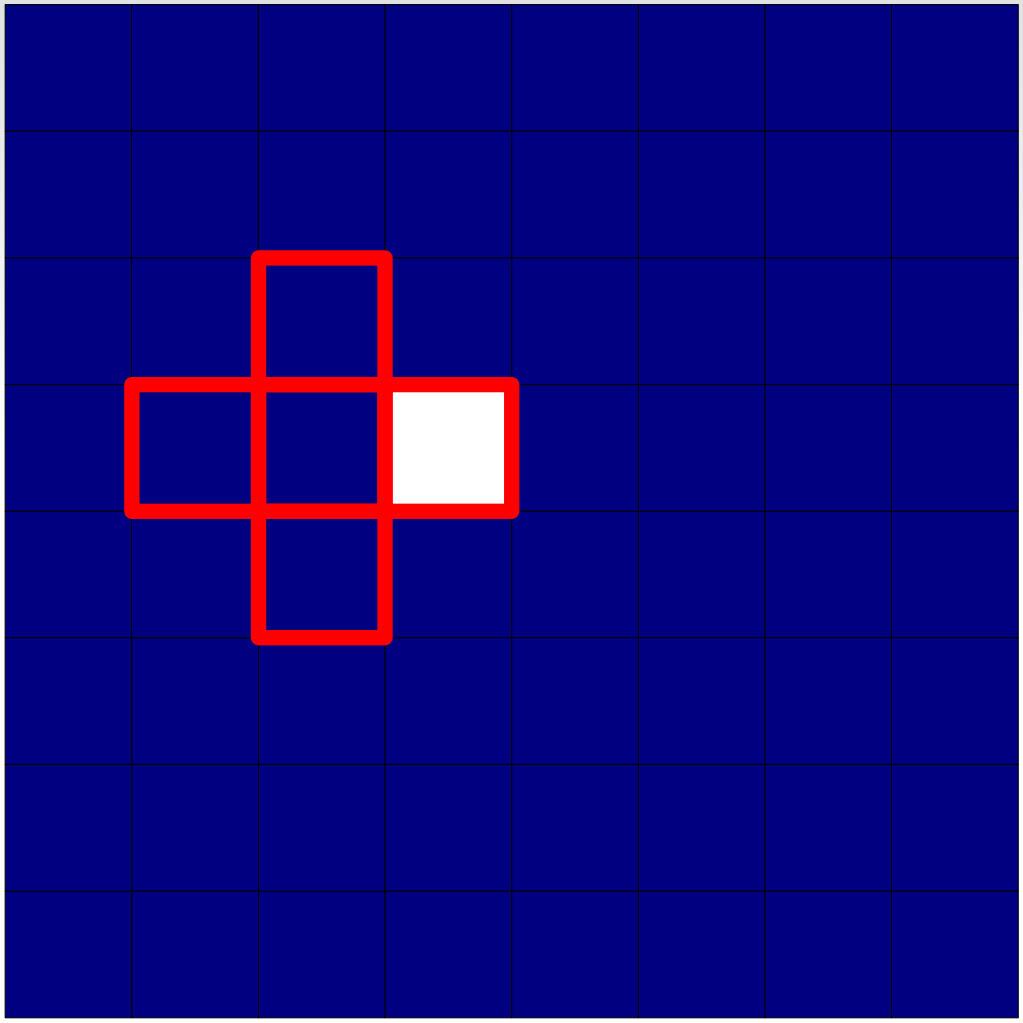


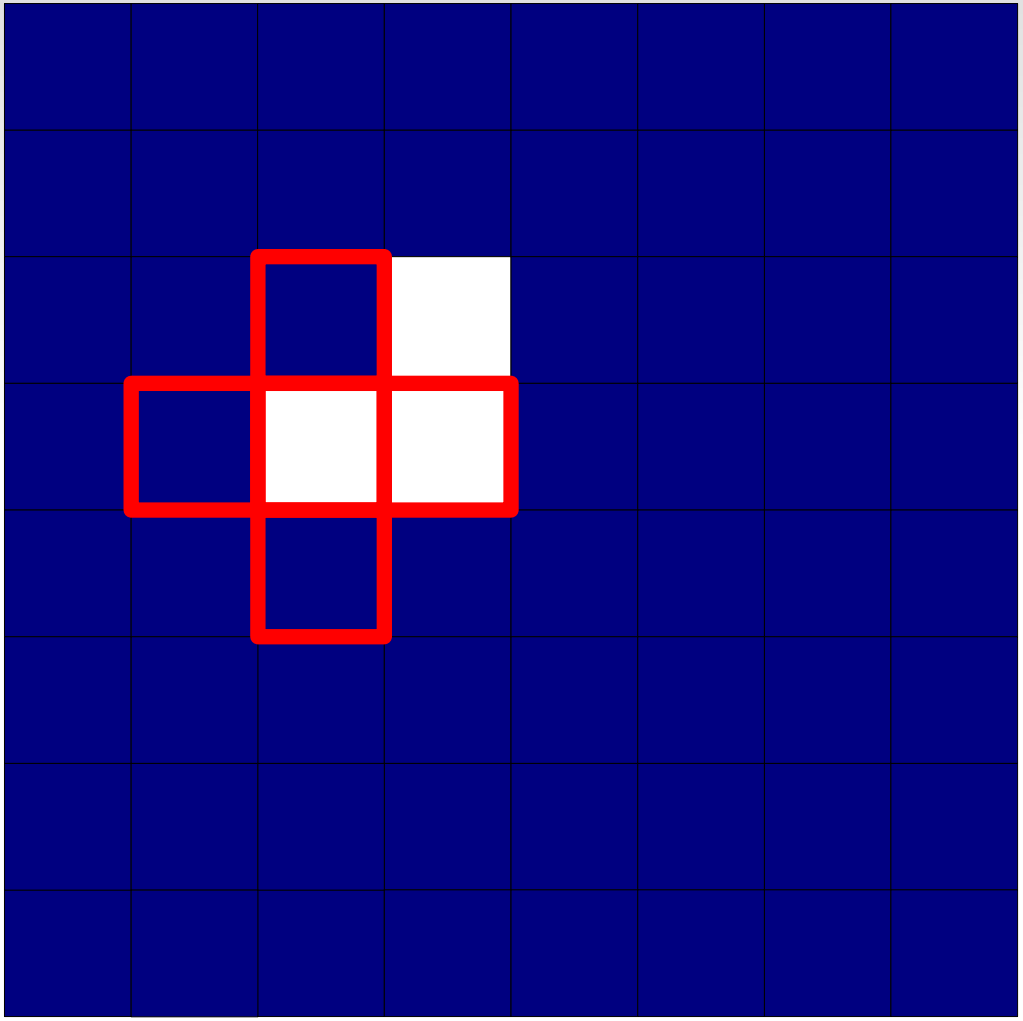
Binary Morphology - dilation



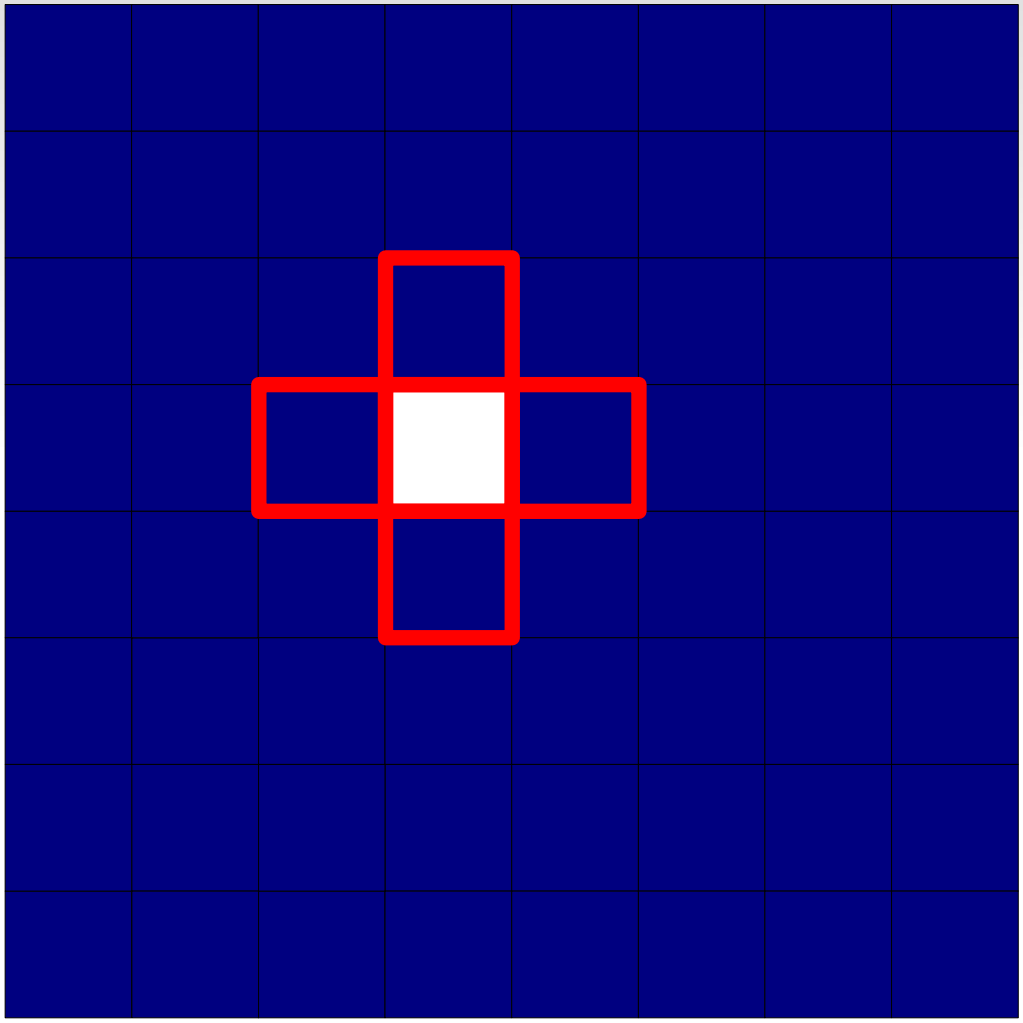


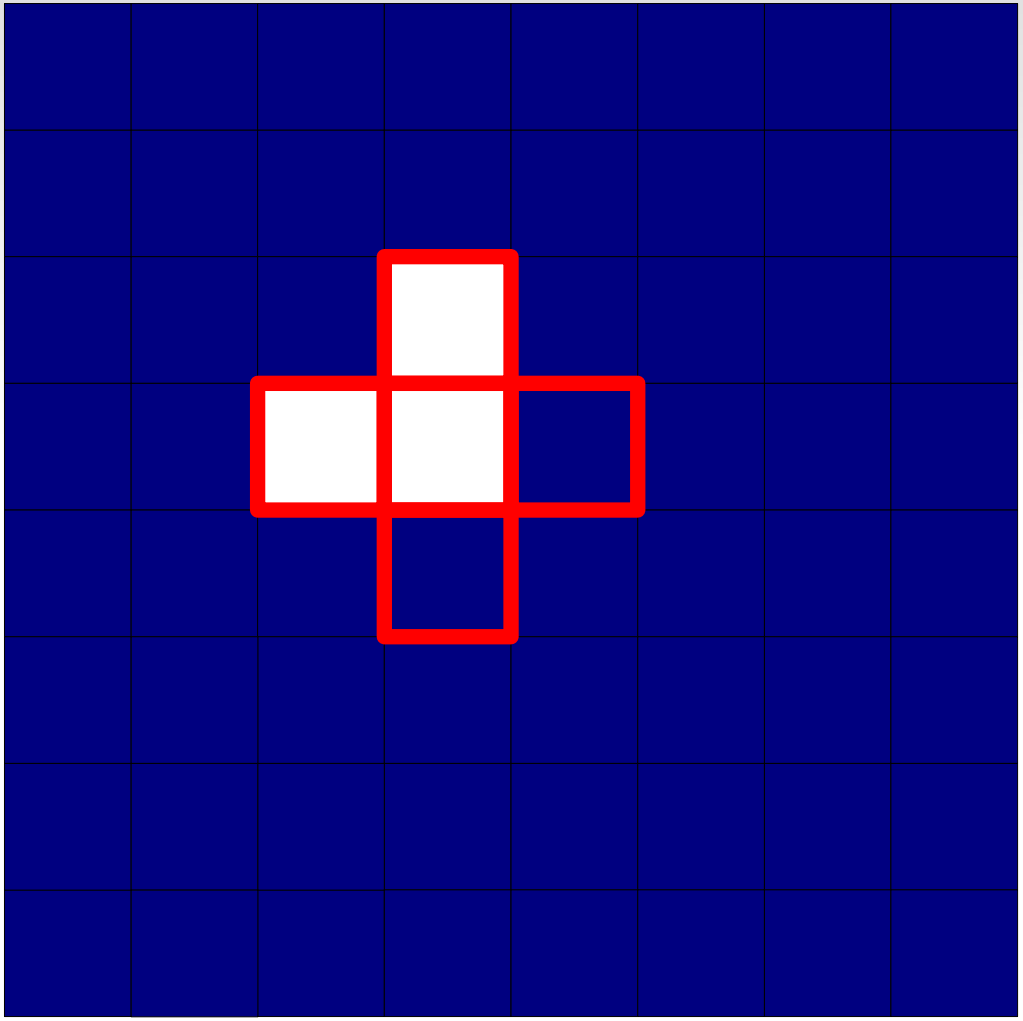
Binary Morphology - dilation



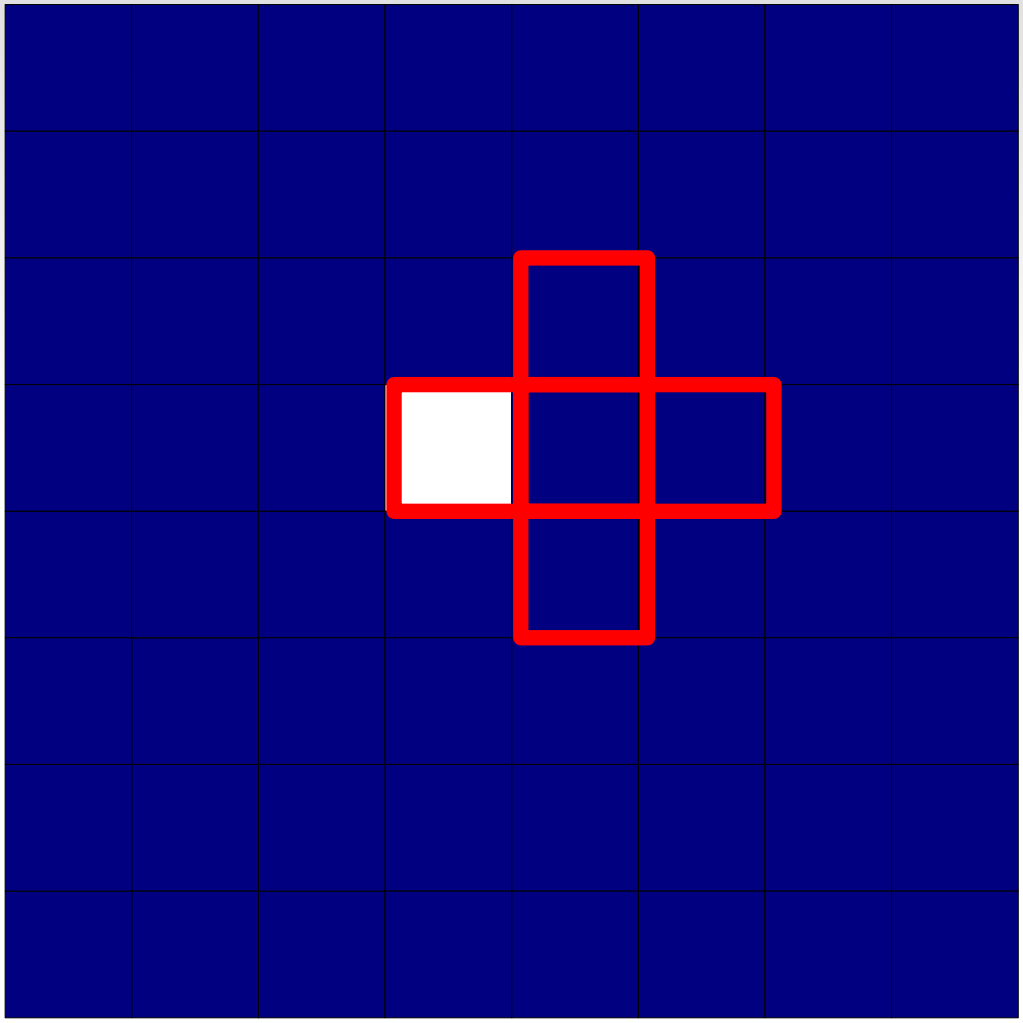


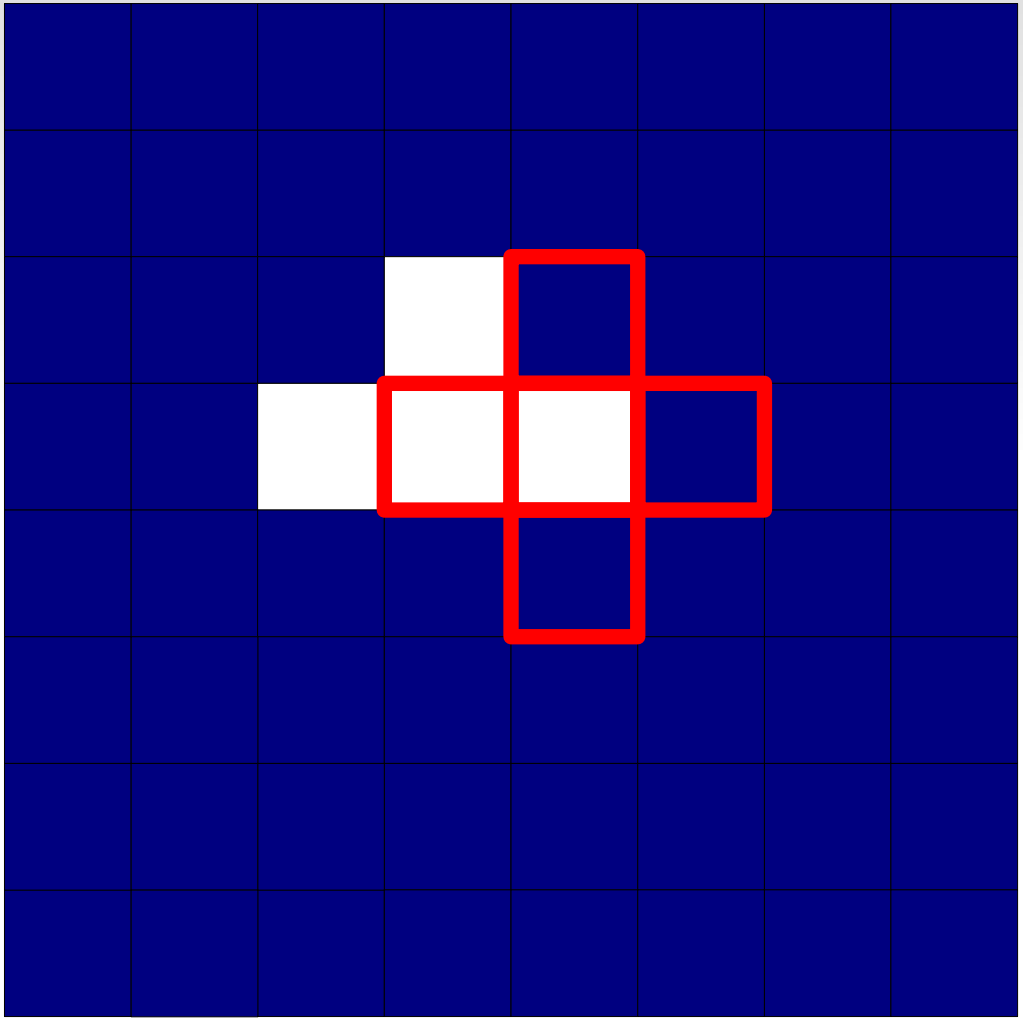
Binary Morphology - dilation



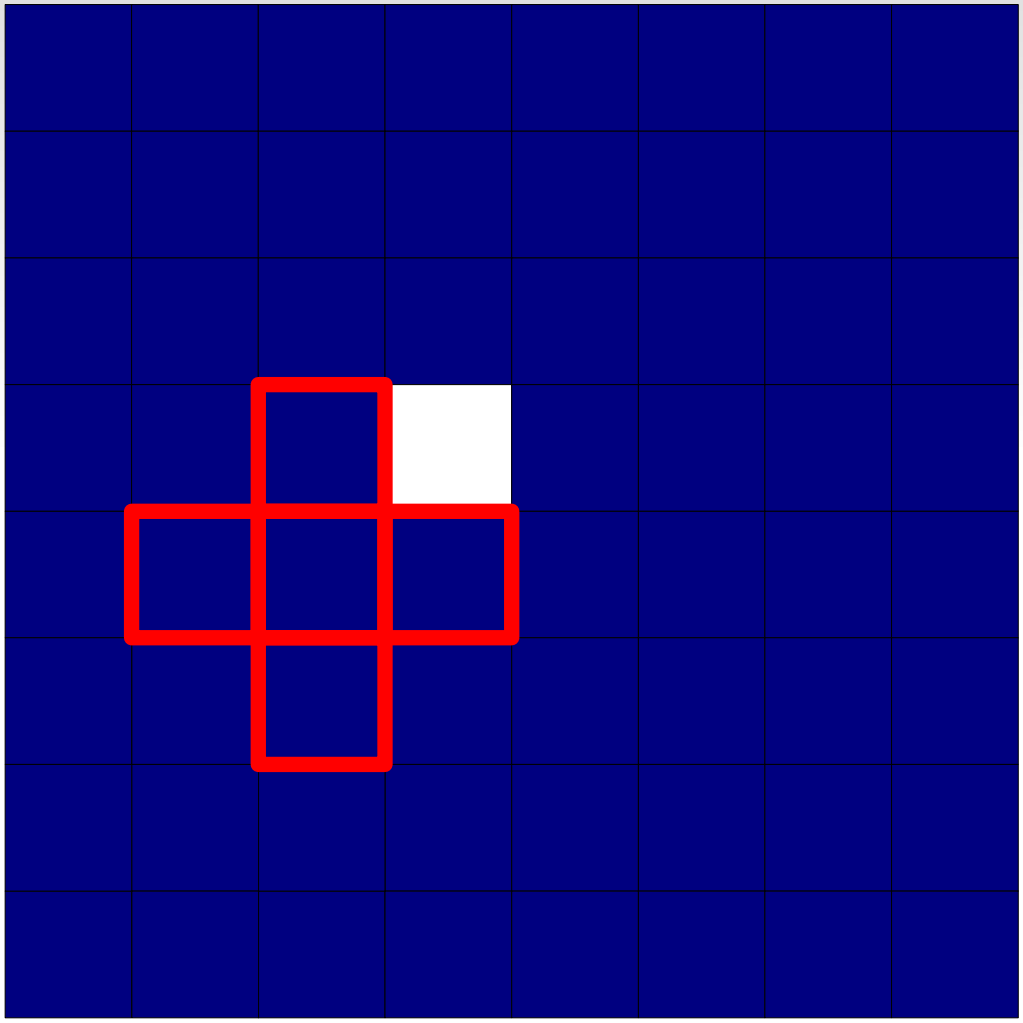


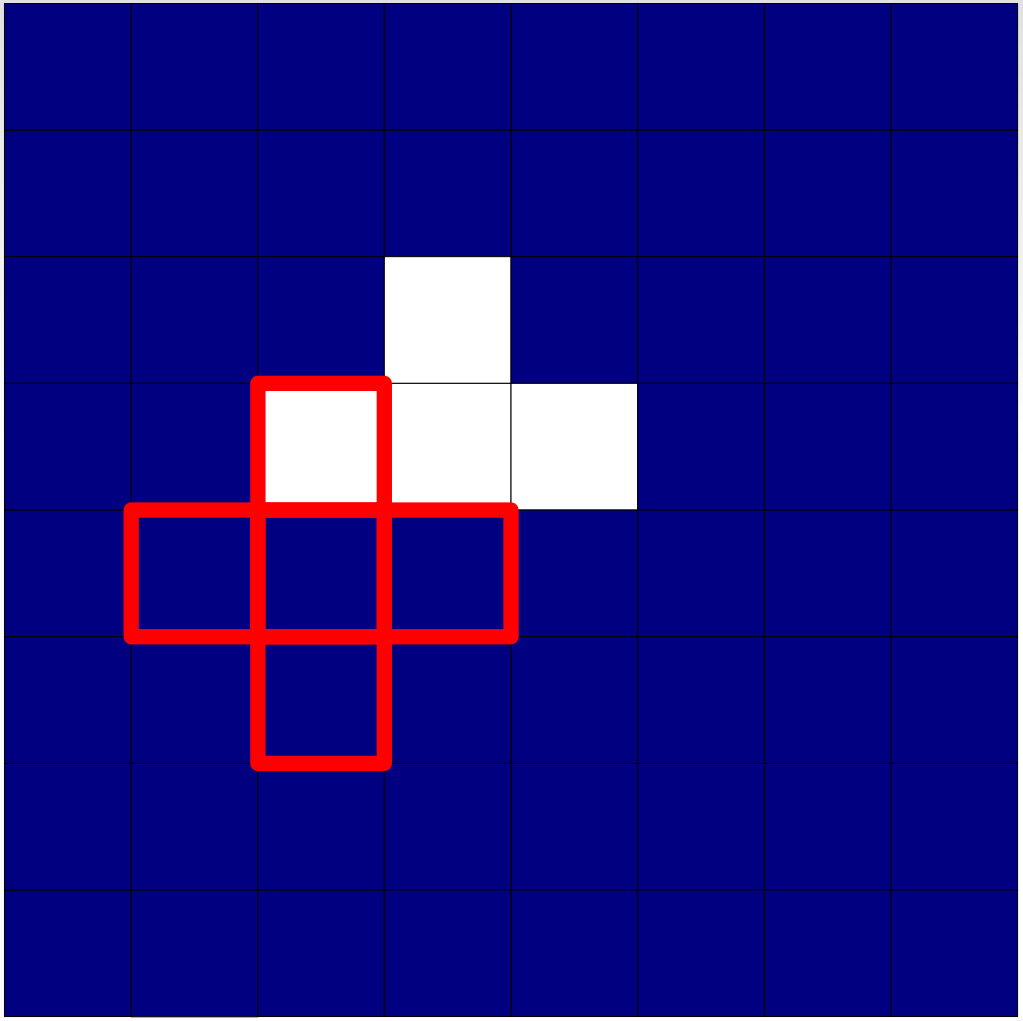
Binary Morphology - dilation



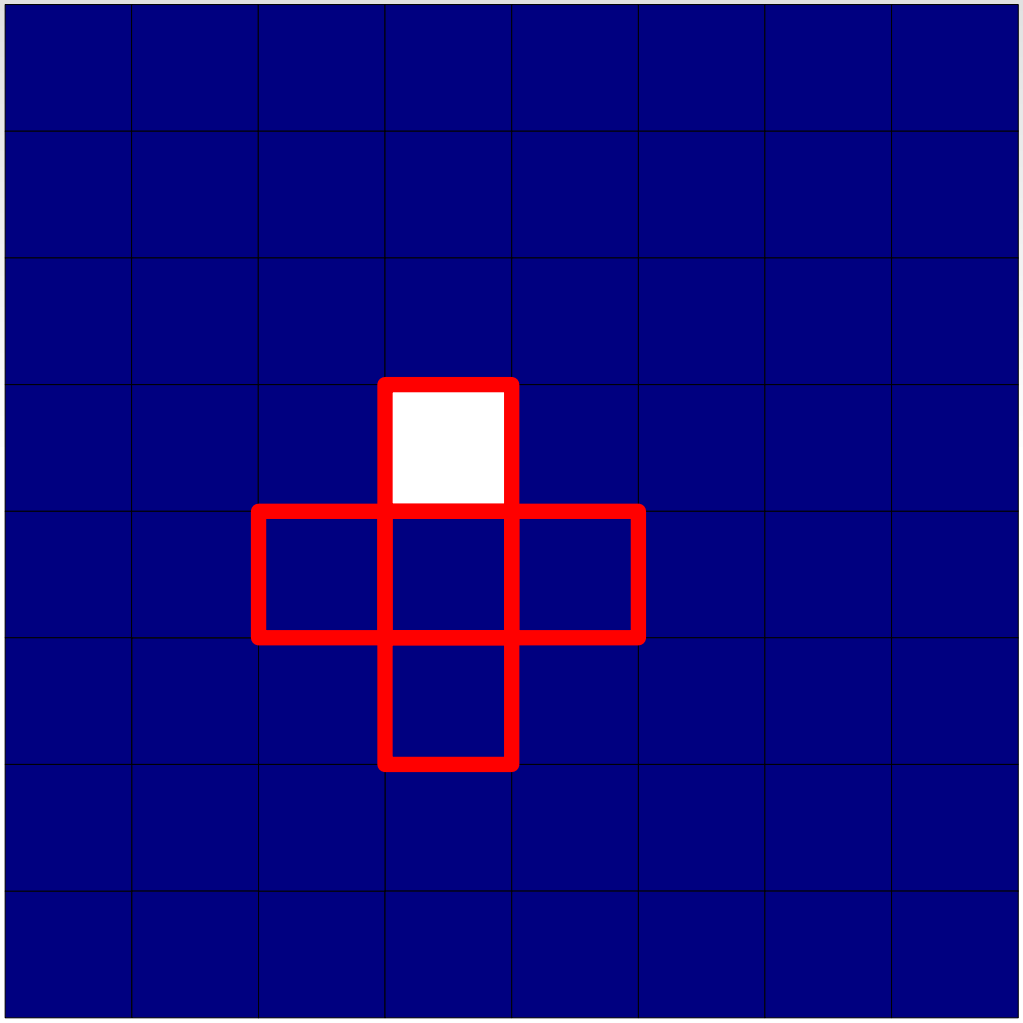


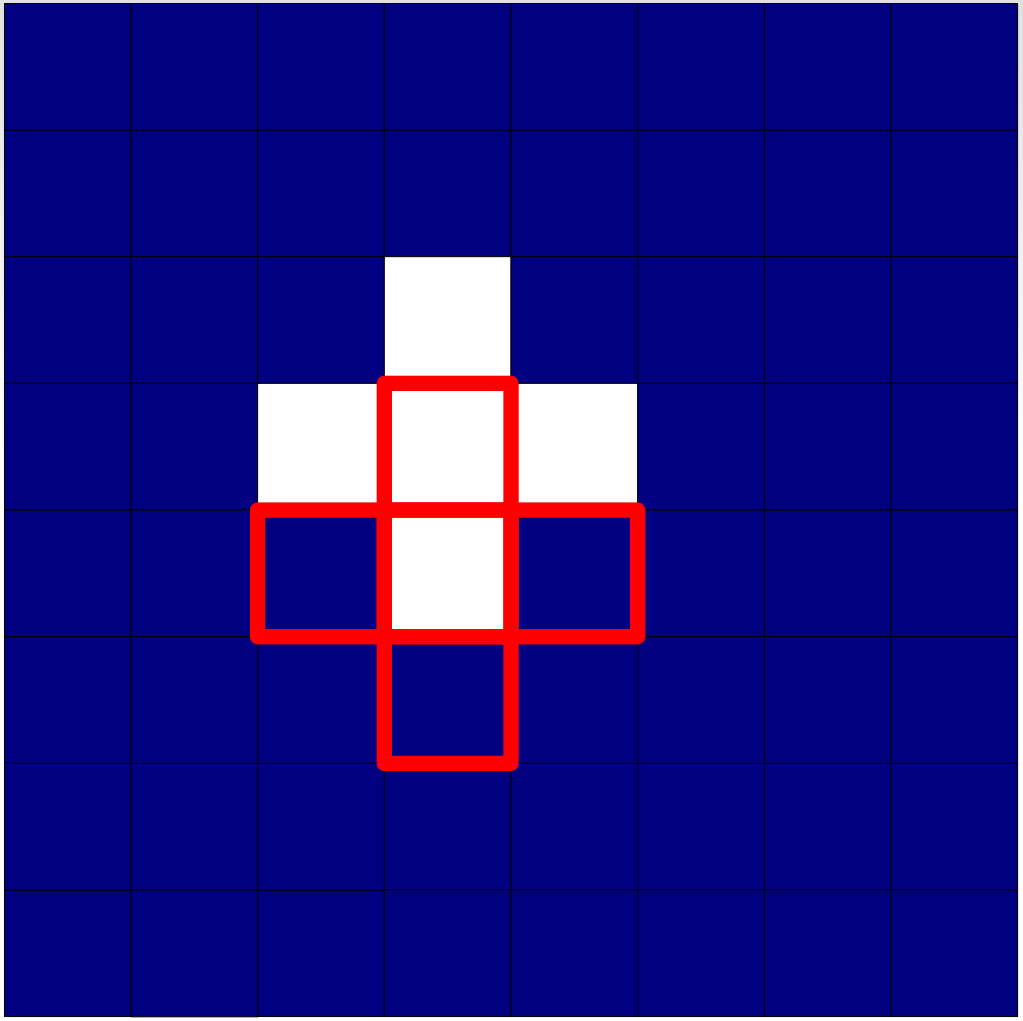
Binary Morphology - dilation



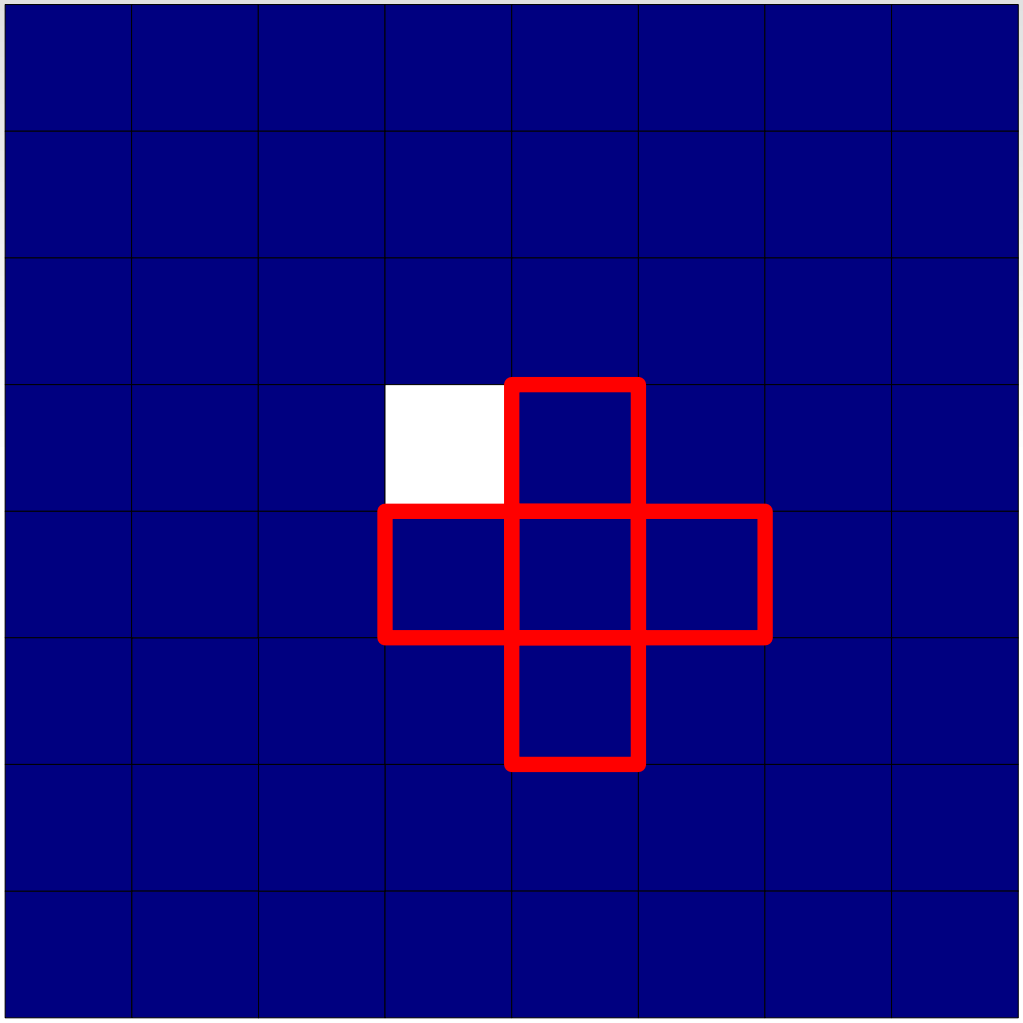


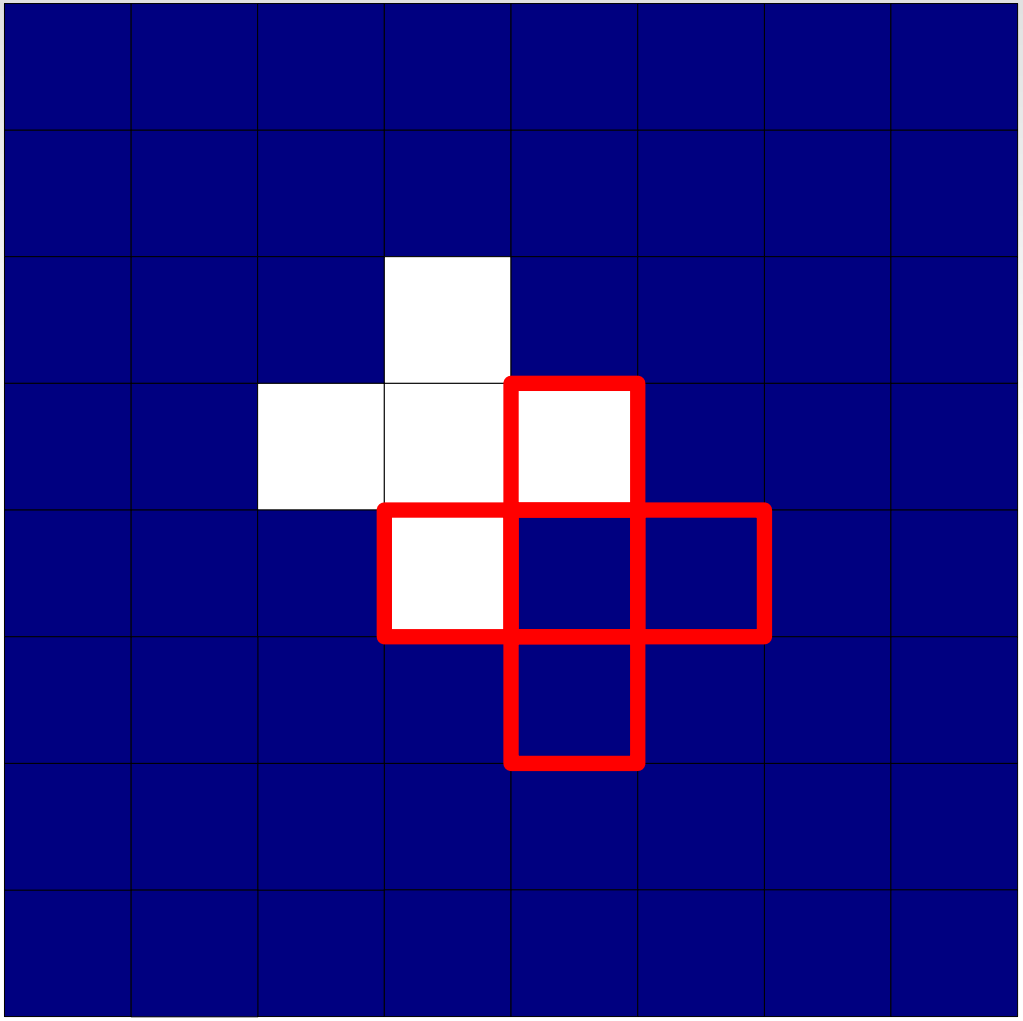
Binary Morphology - dilation



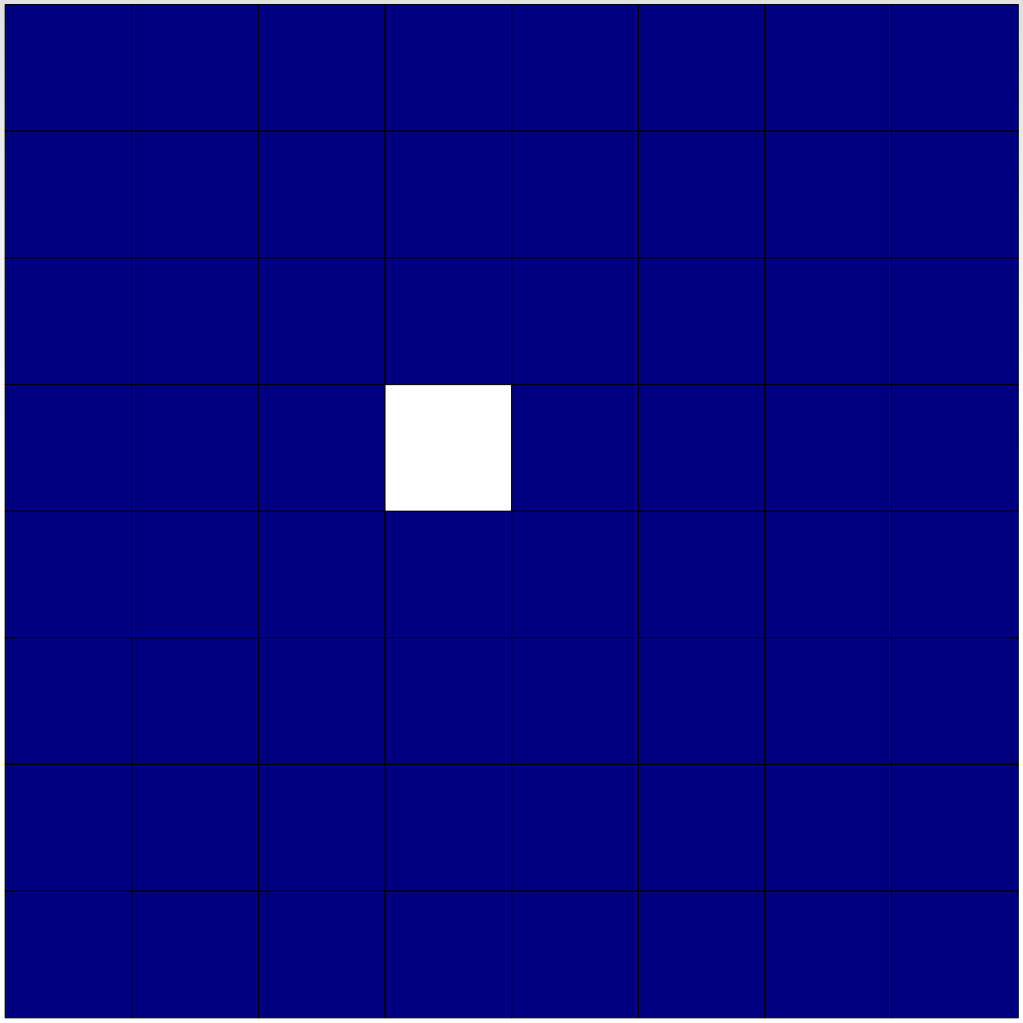


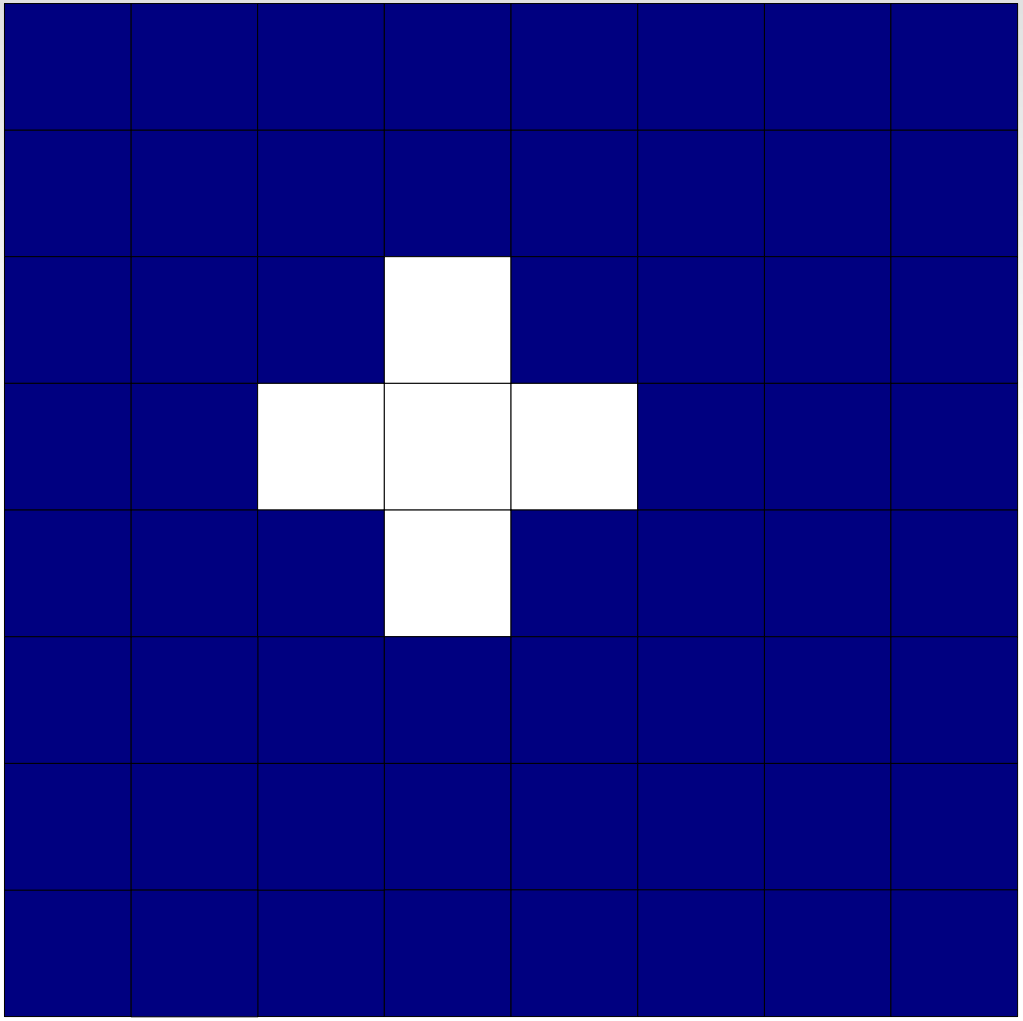
Binary Morphology - dilation



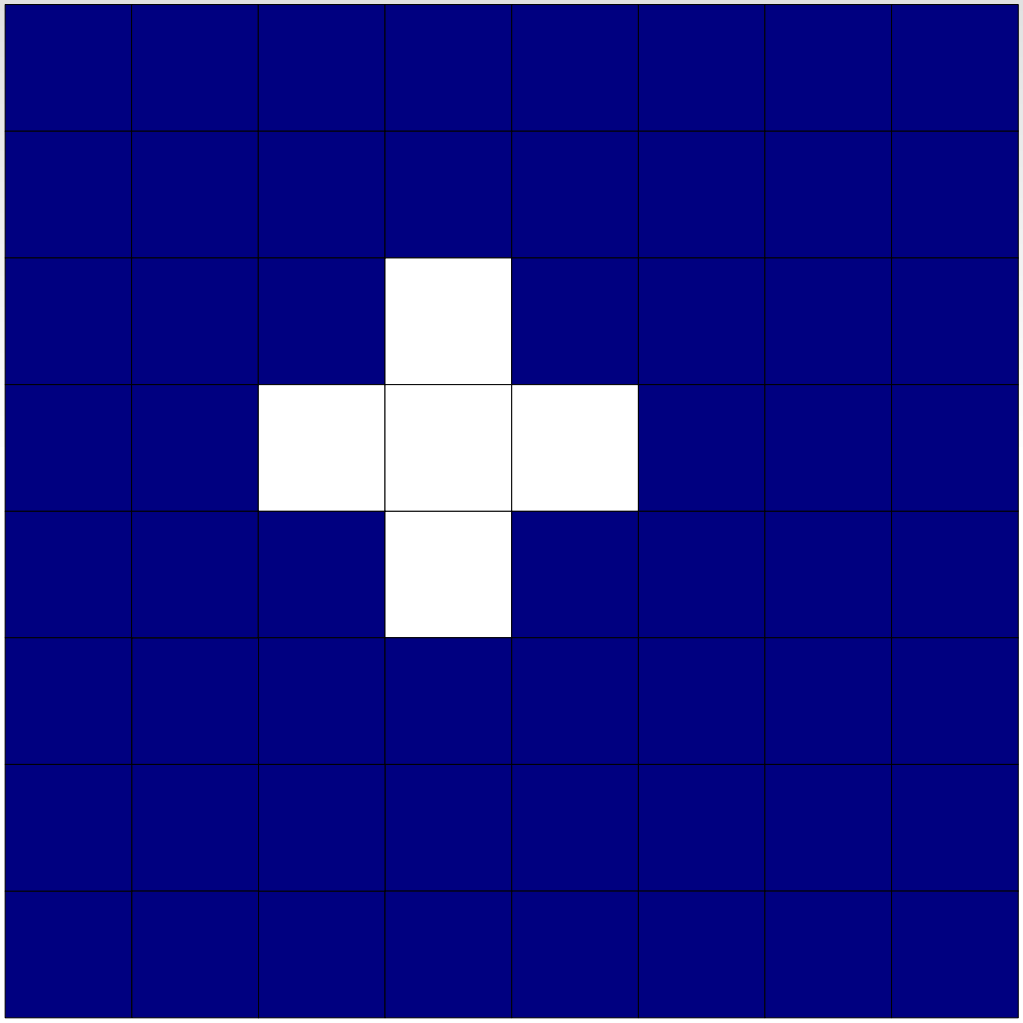


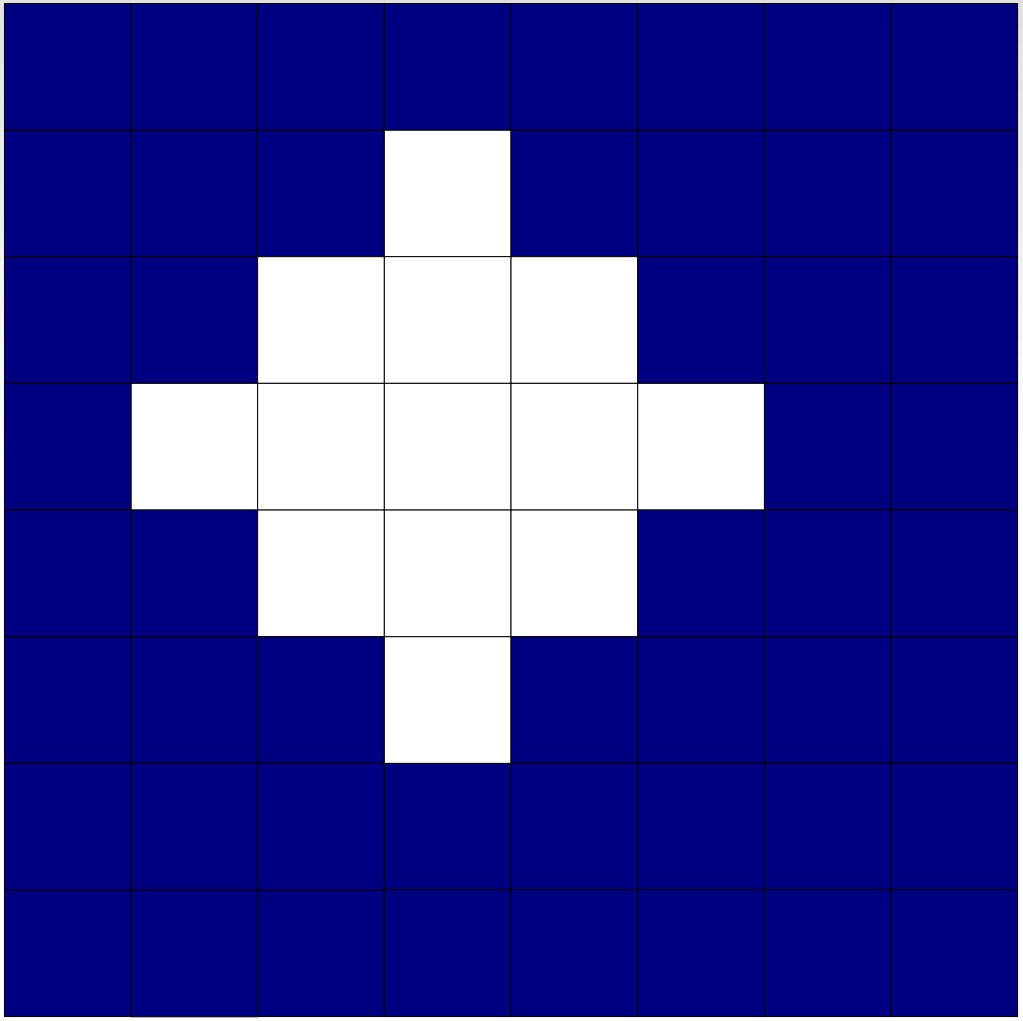
Binary Morphology - dilation



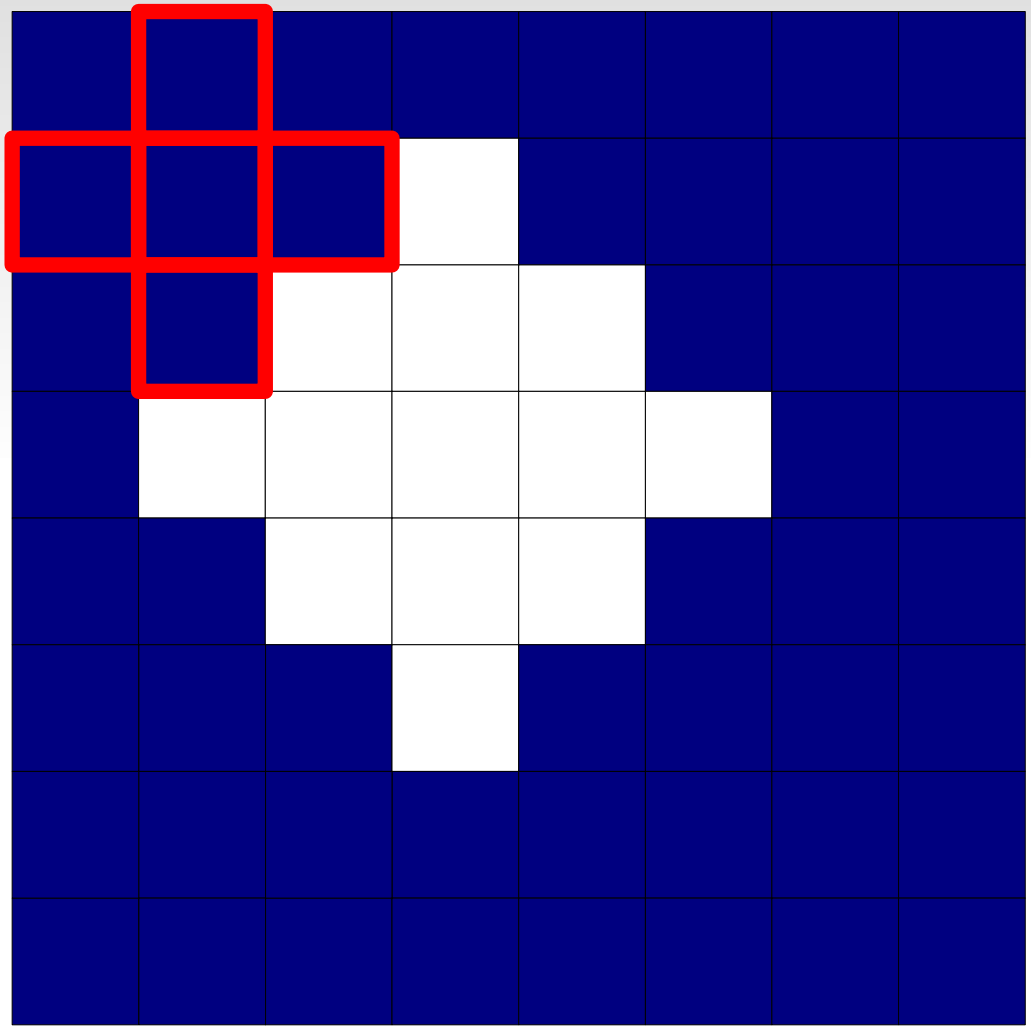


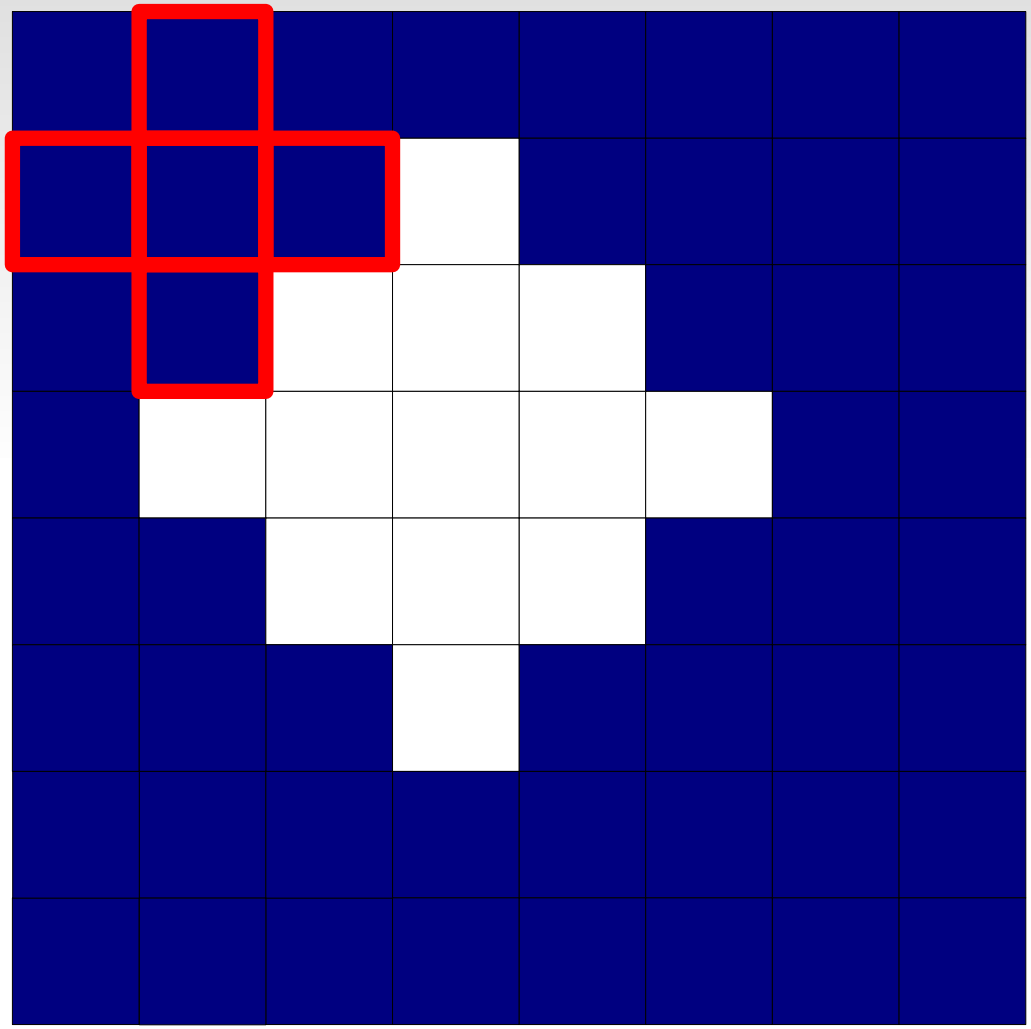
Binary Morphology - dilation



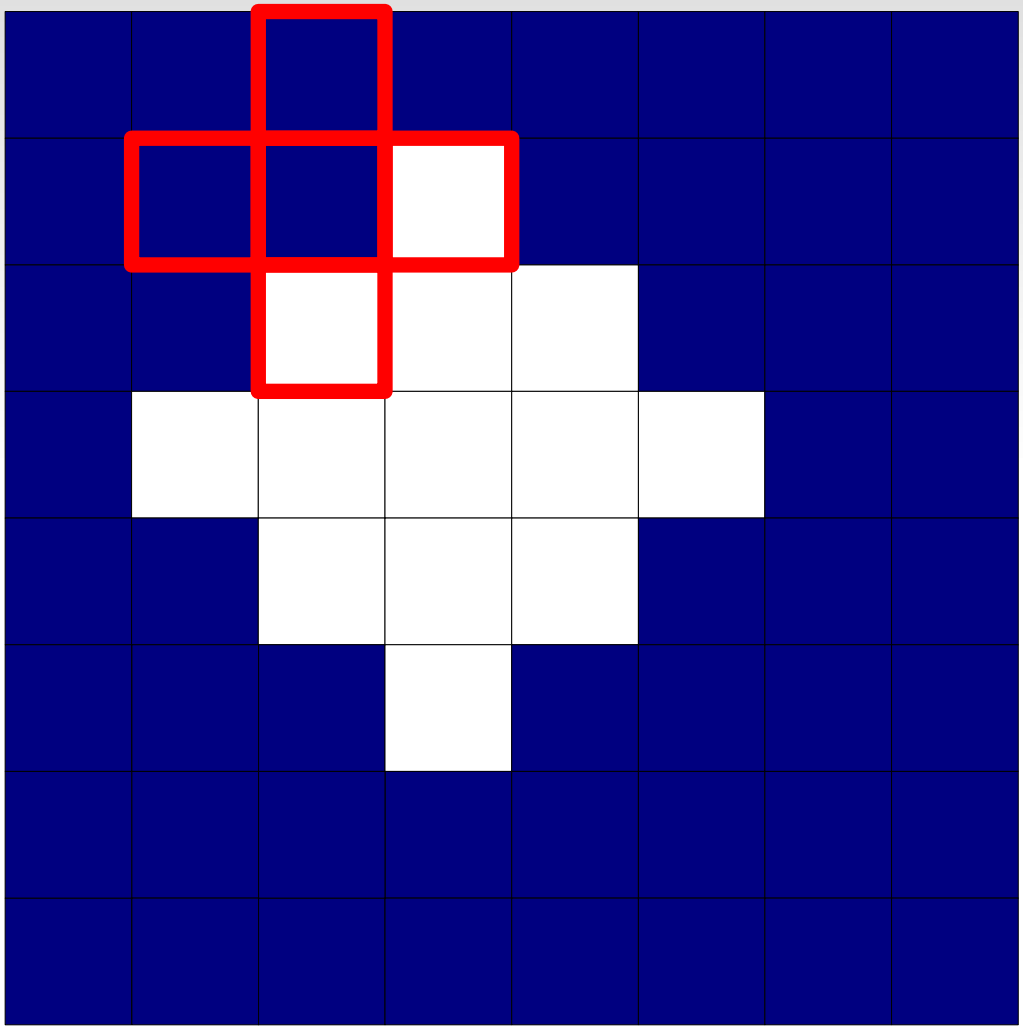


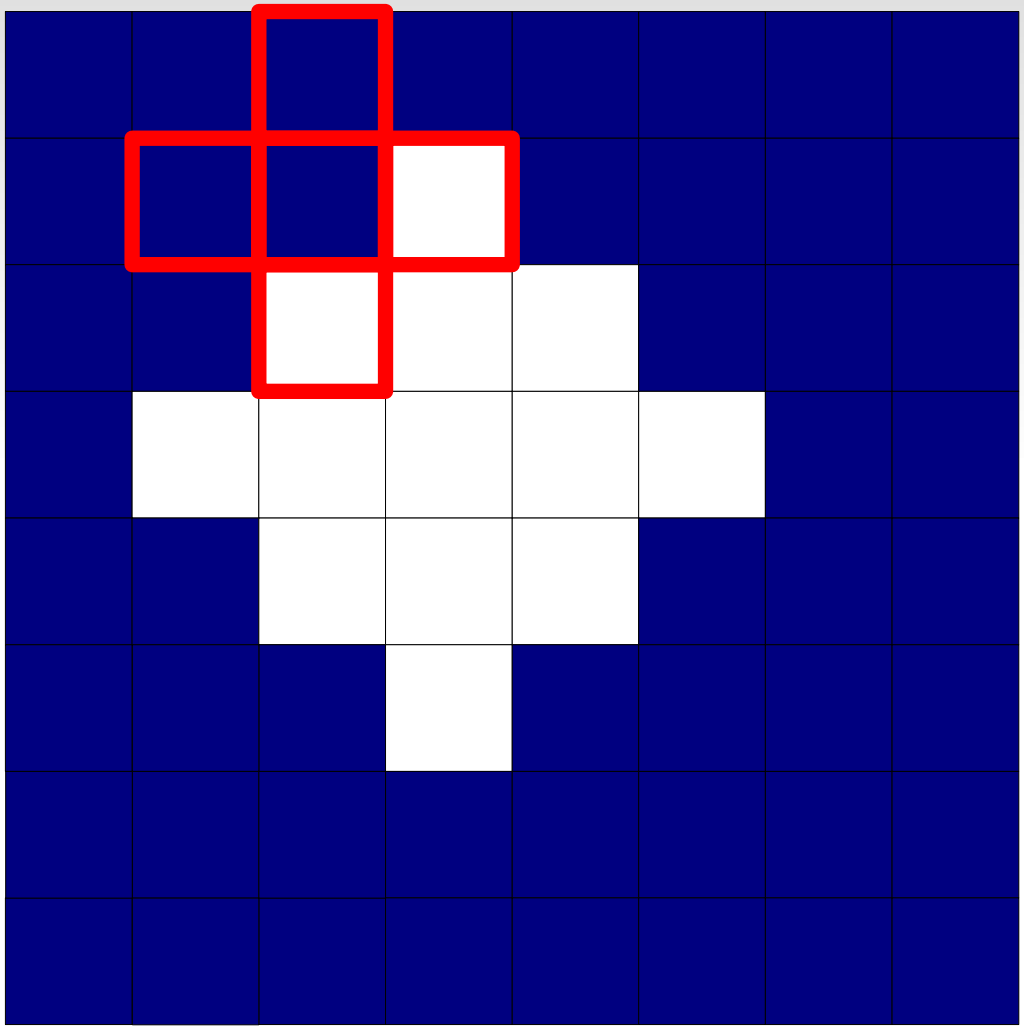
Binary Morphology - erosion



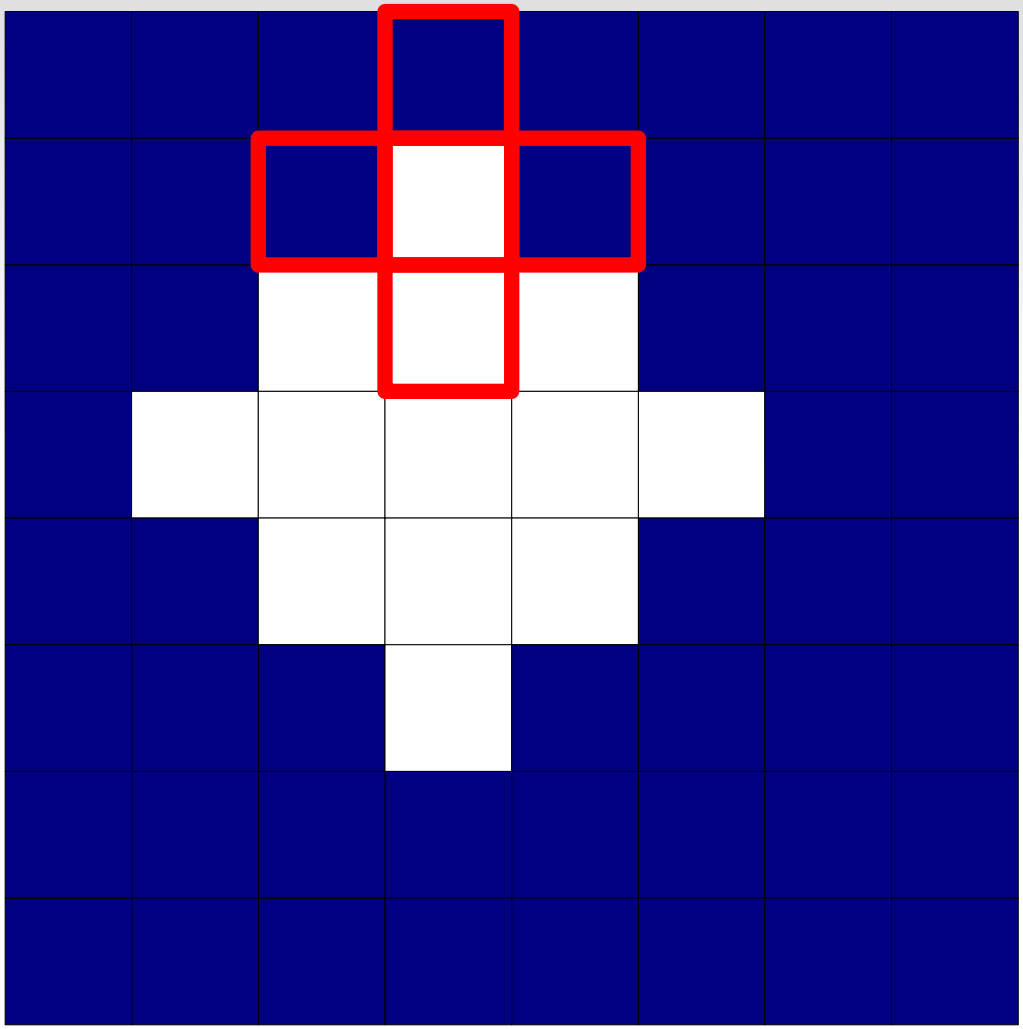


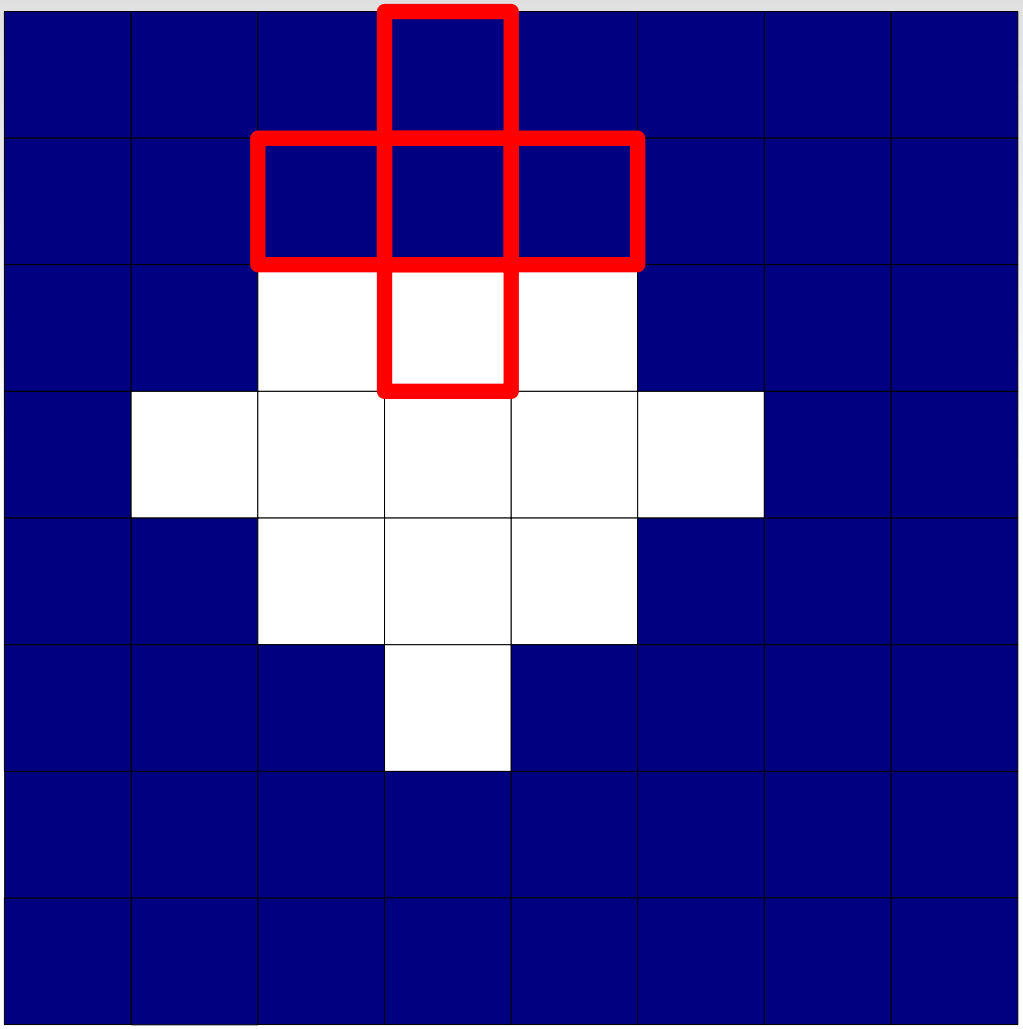
Binary Morphology - erosion



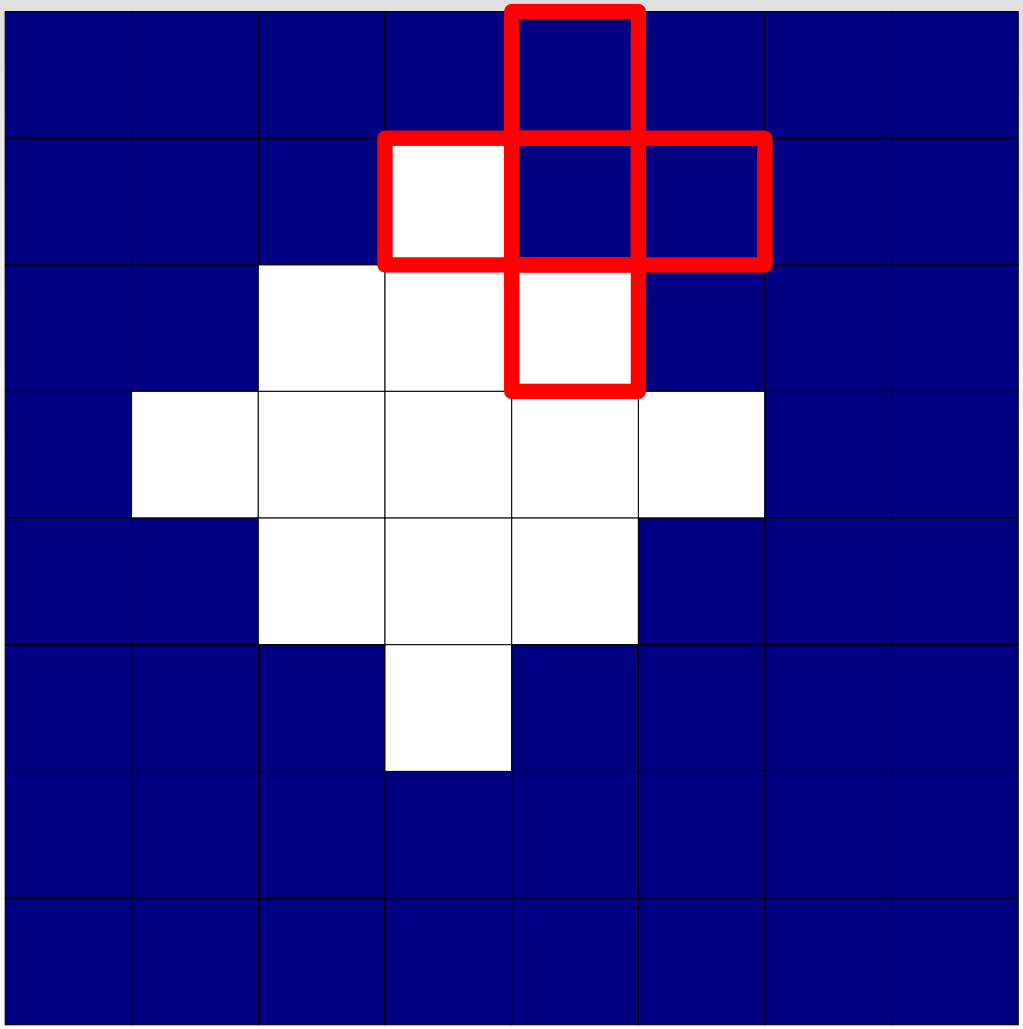


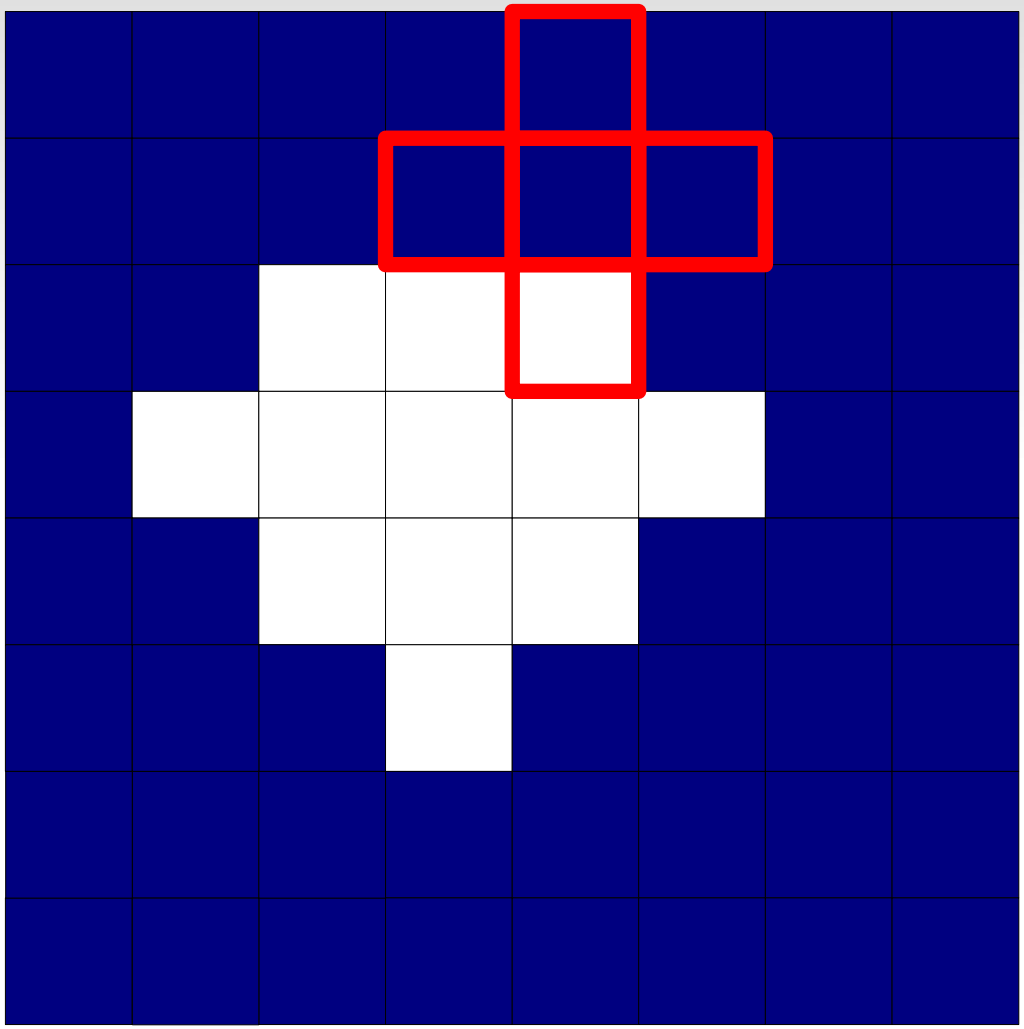
Binary Morphology - erosion



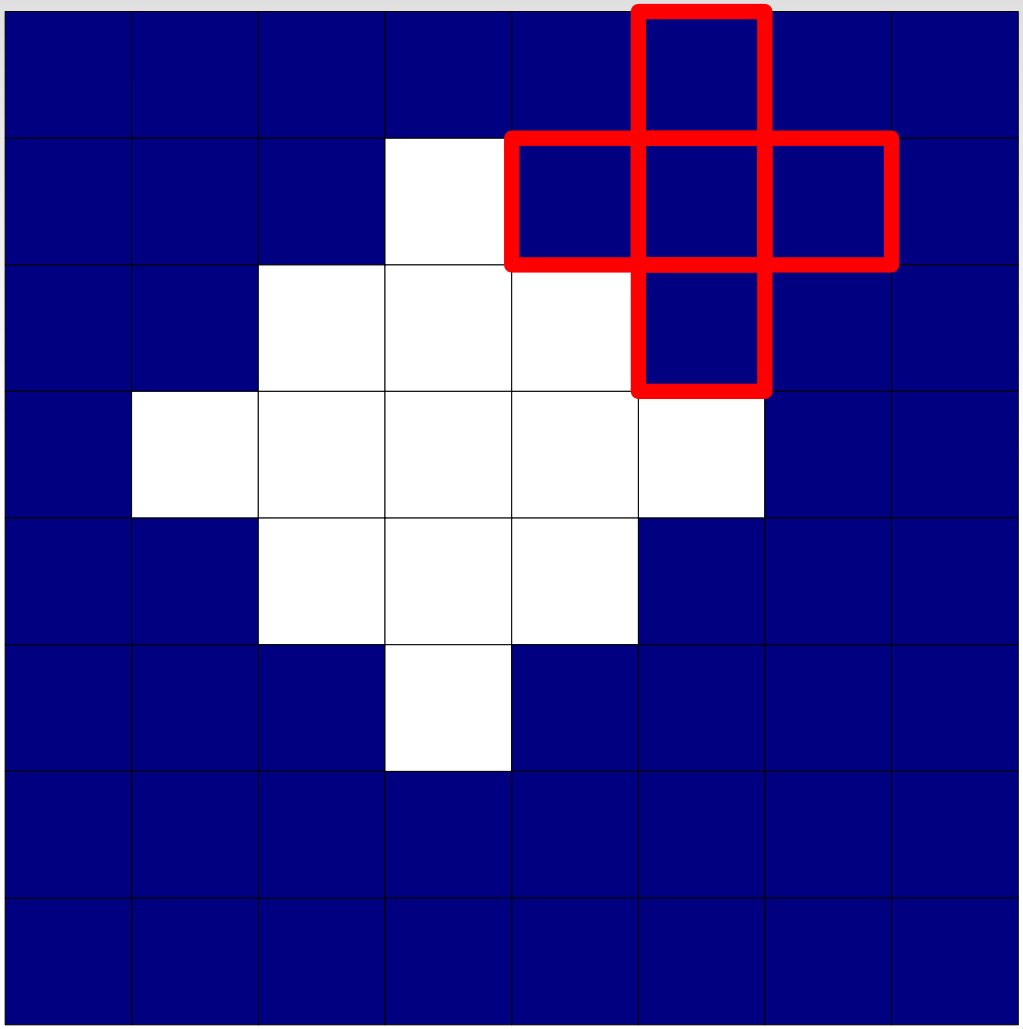


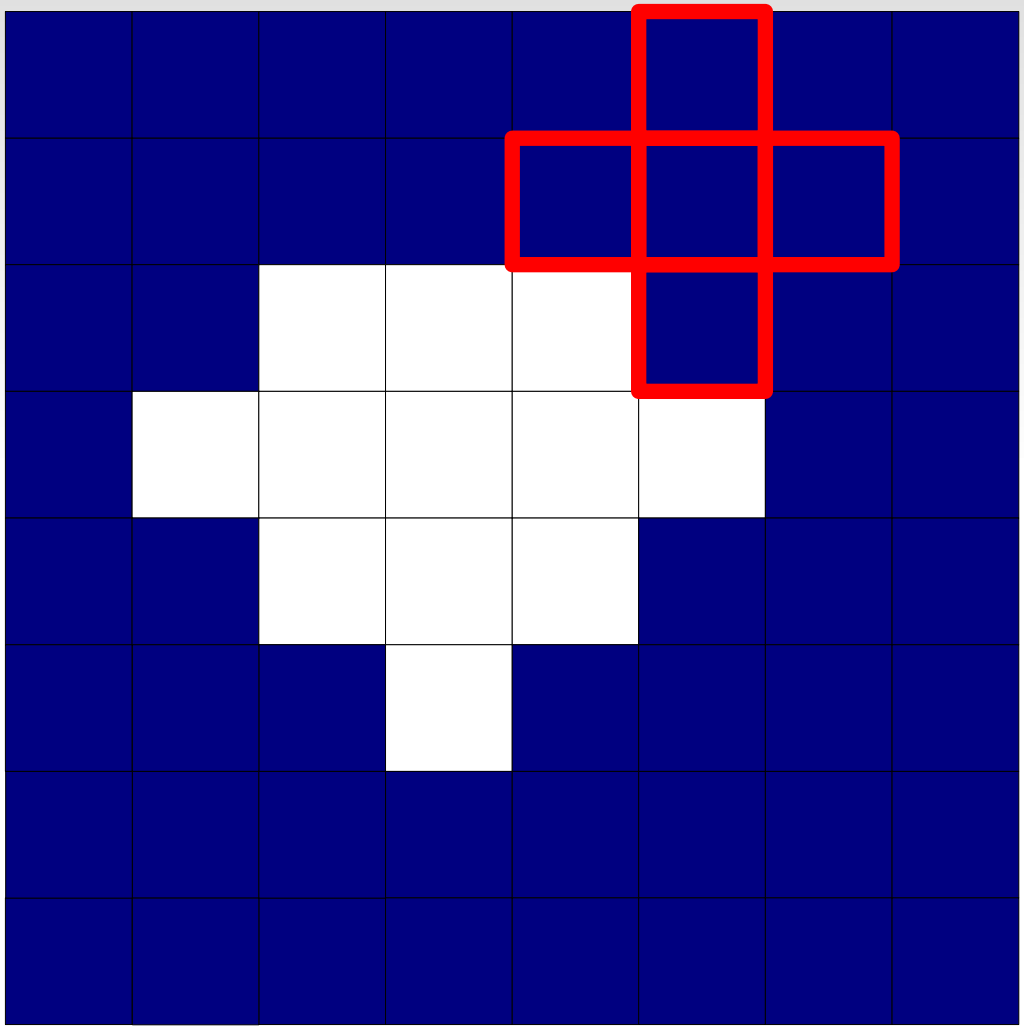
Binary Morphology - erosion



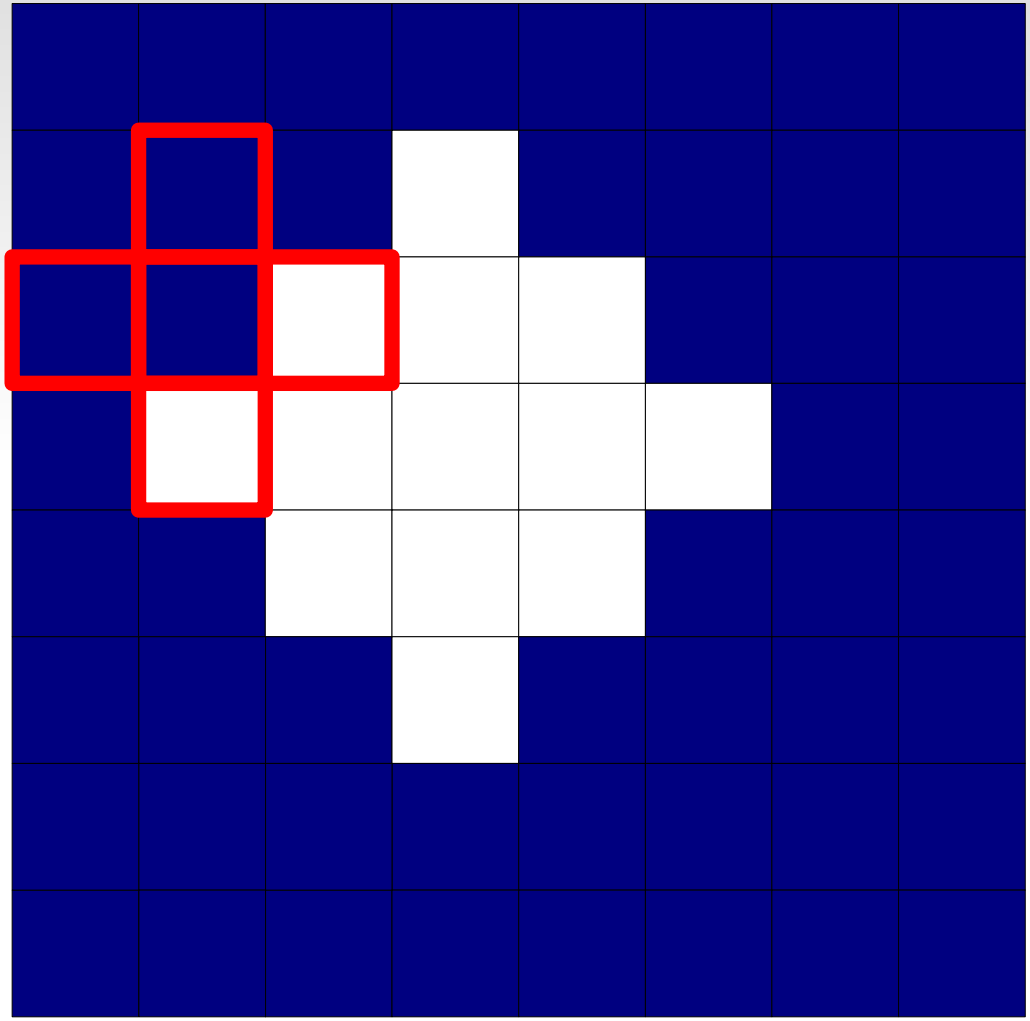


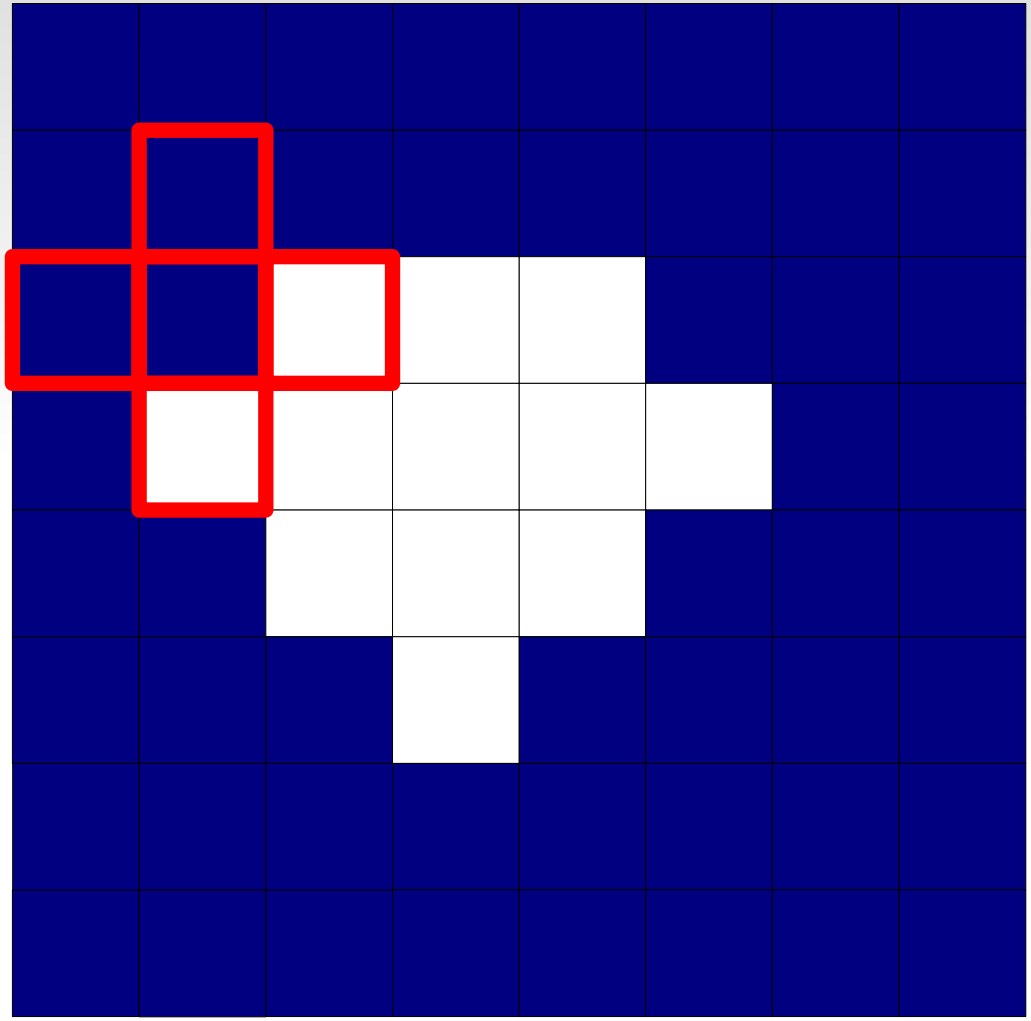
Binary Morphology - erosion



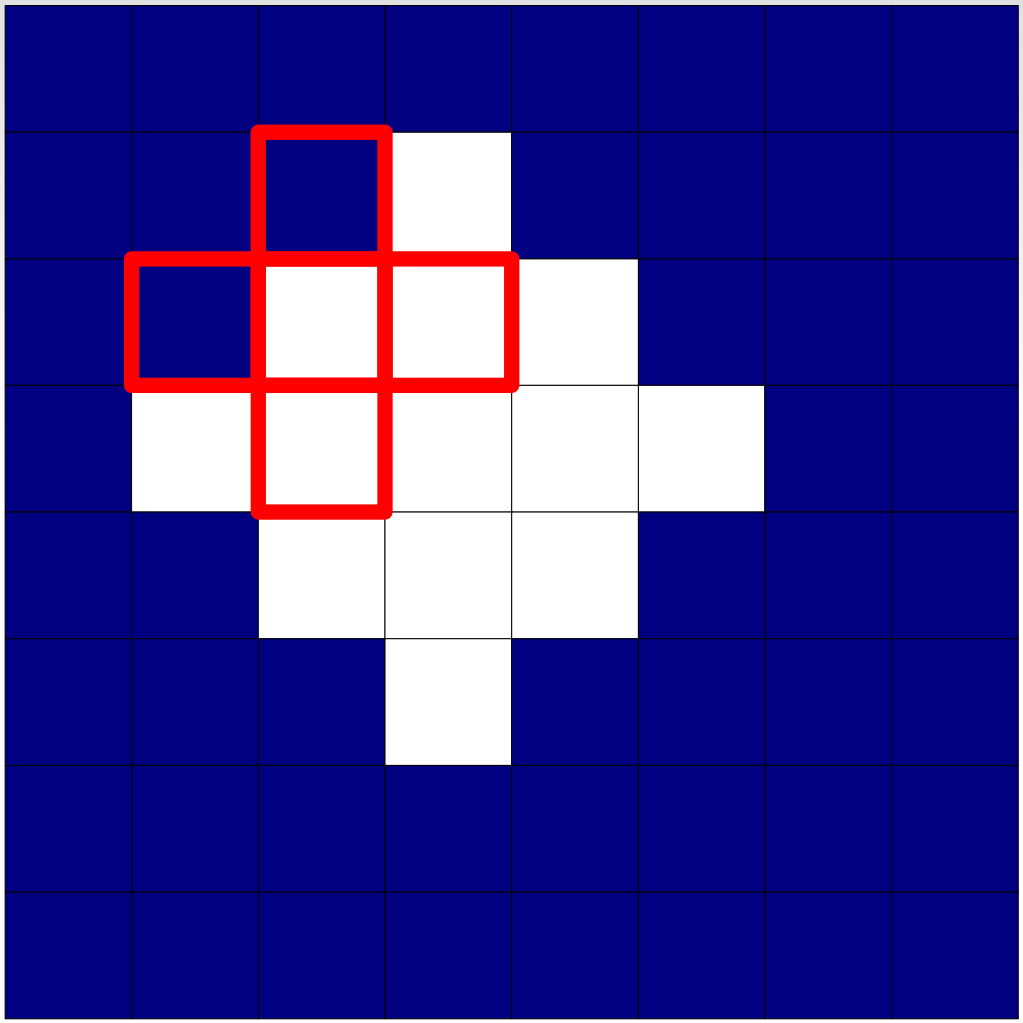


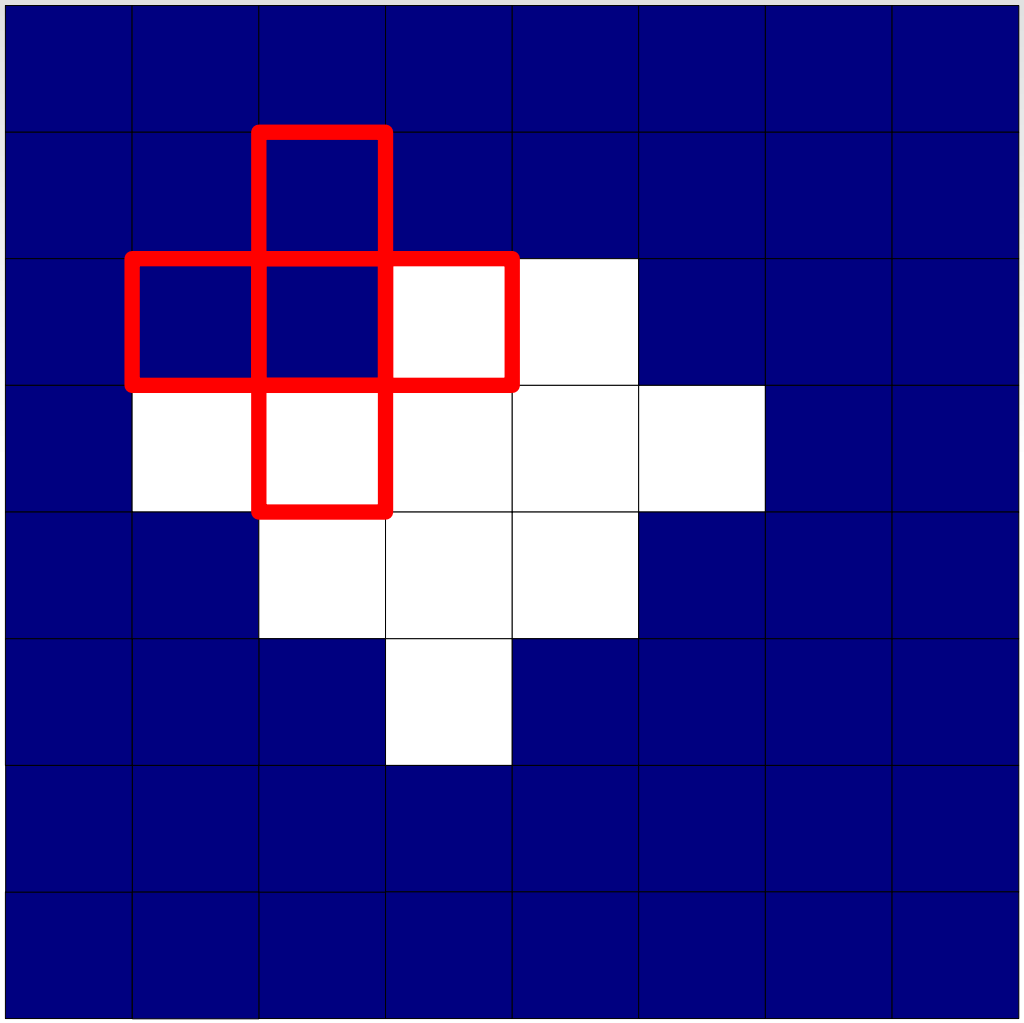
Binary Morphology - erosion



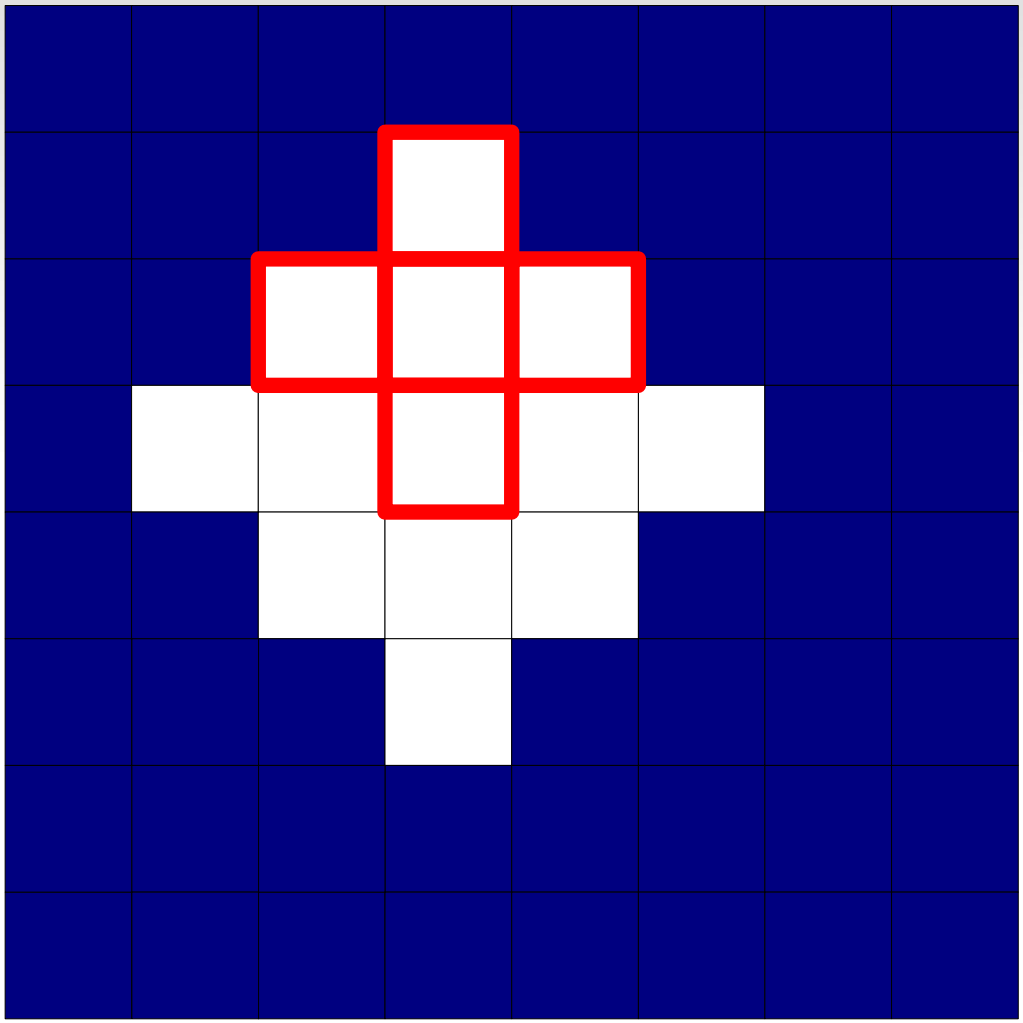


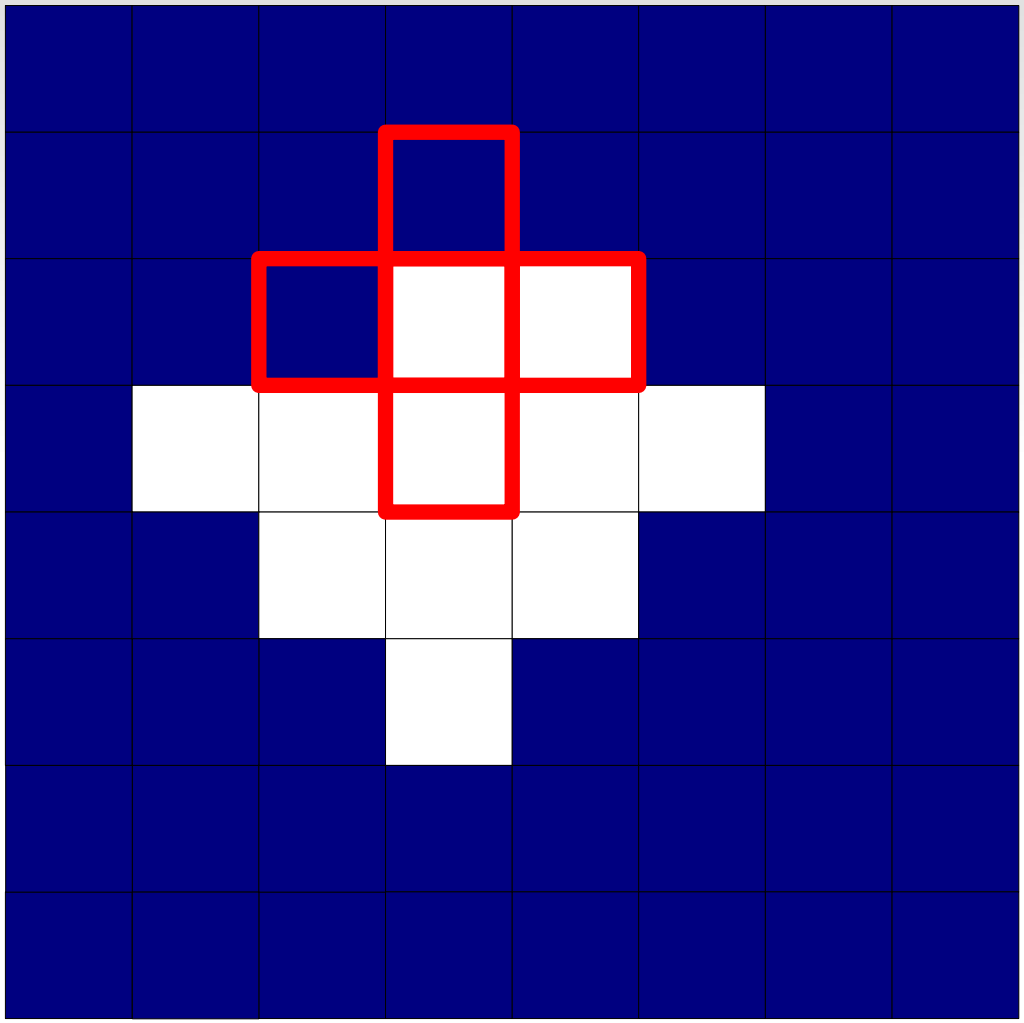
Binary Morphology - erosion



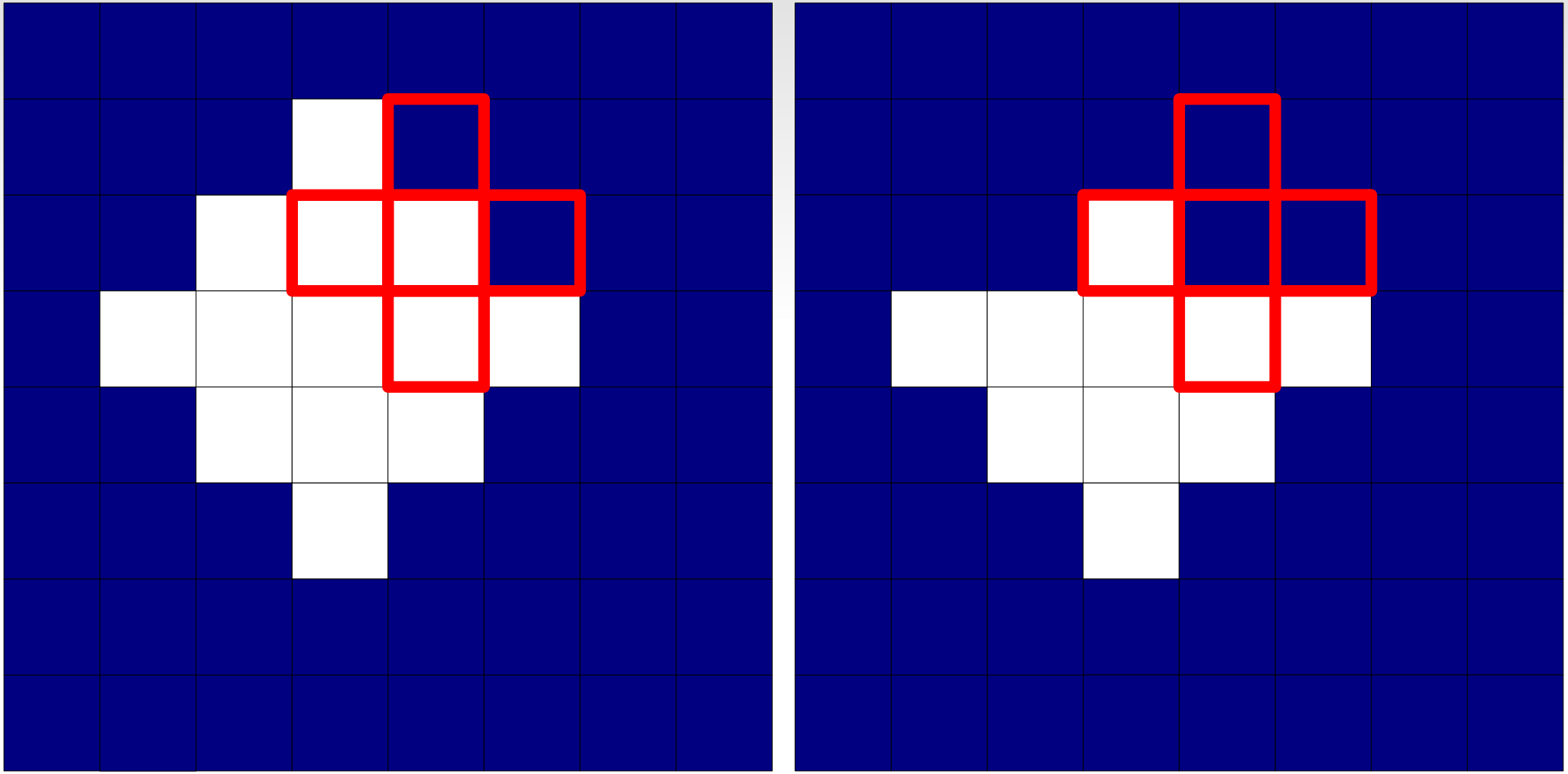


Binary Morphology - erosion

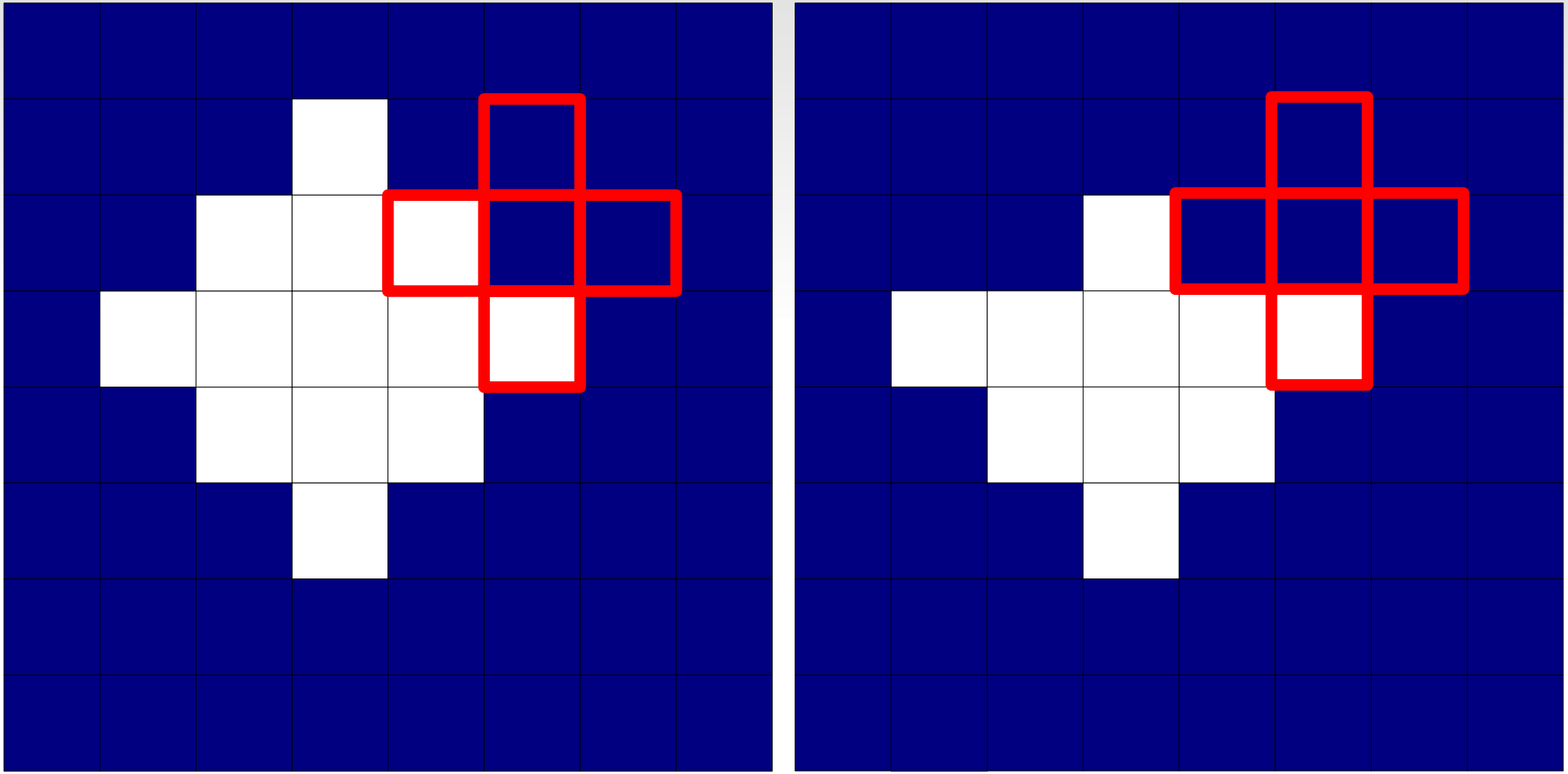




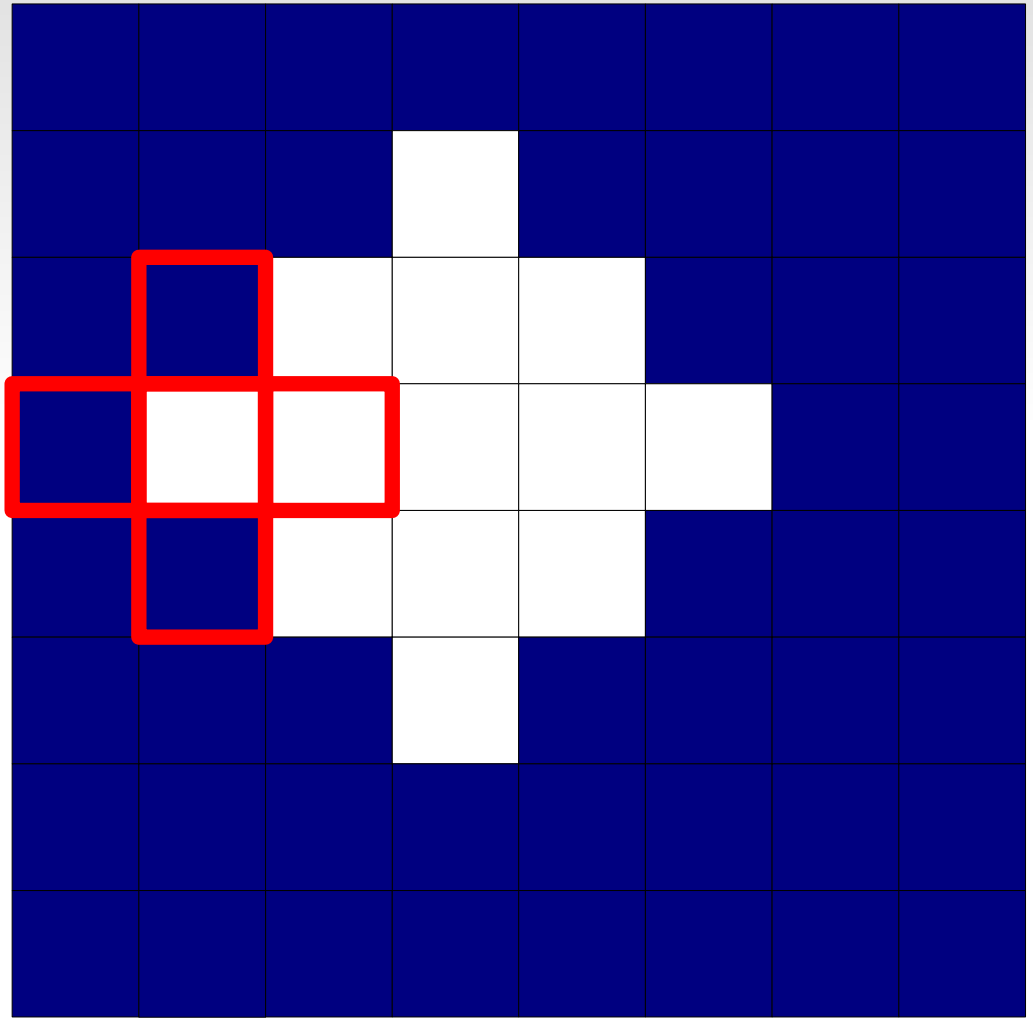
Binary Morphology - erosion

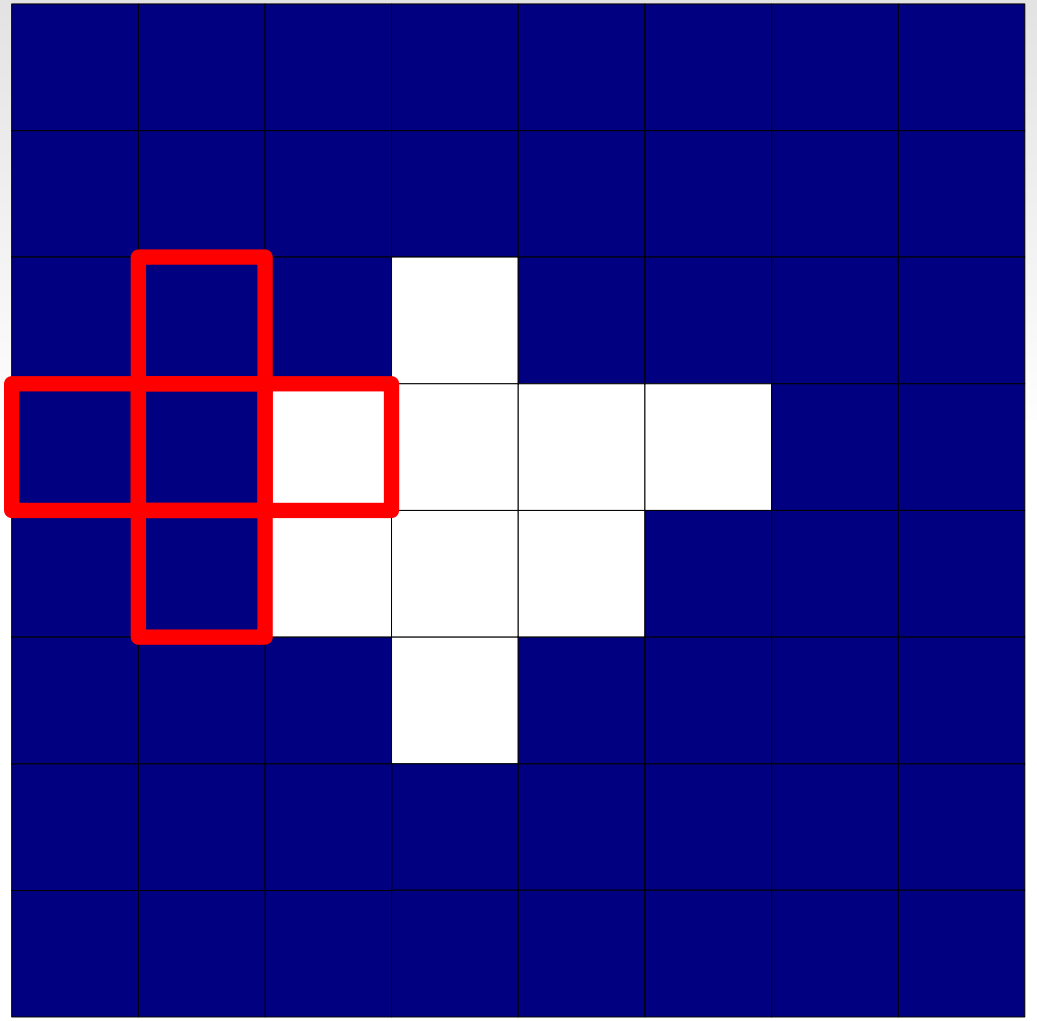


Binary Morphology - erosion

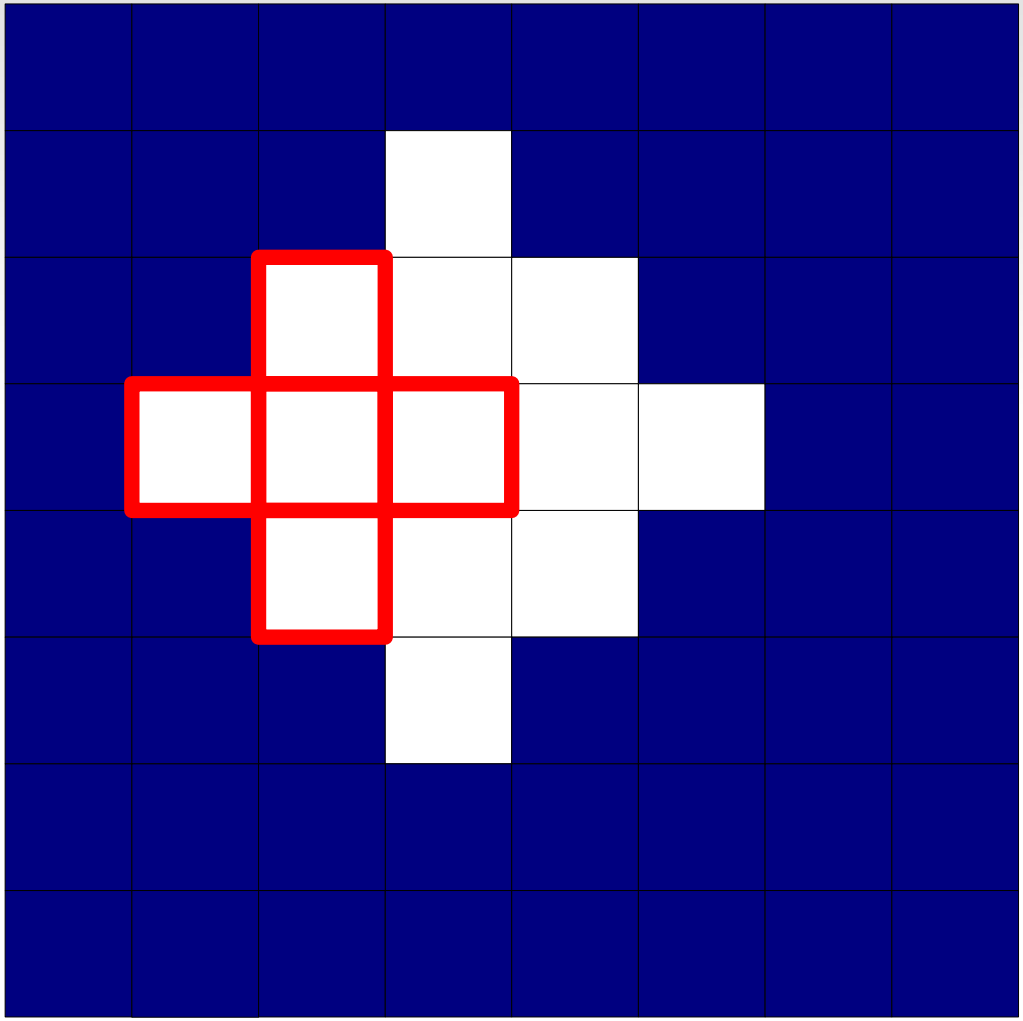


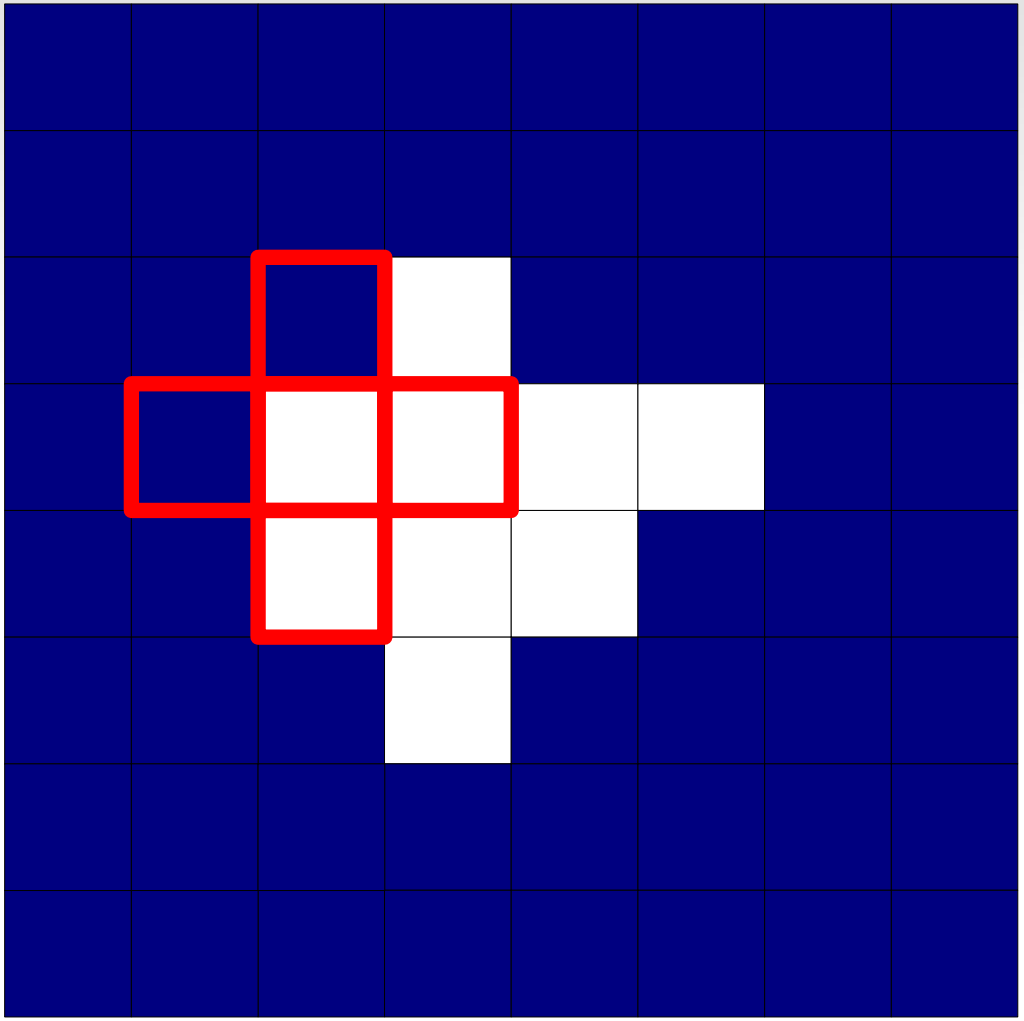
Binary Morphology - erosion



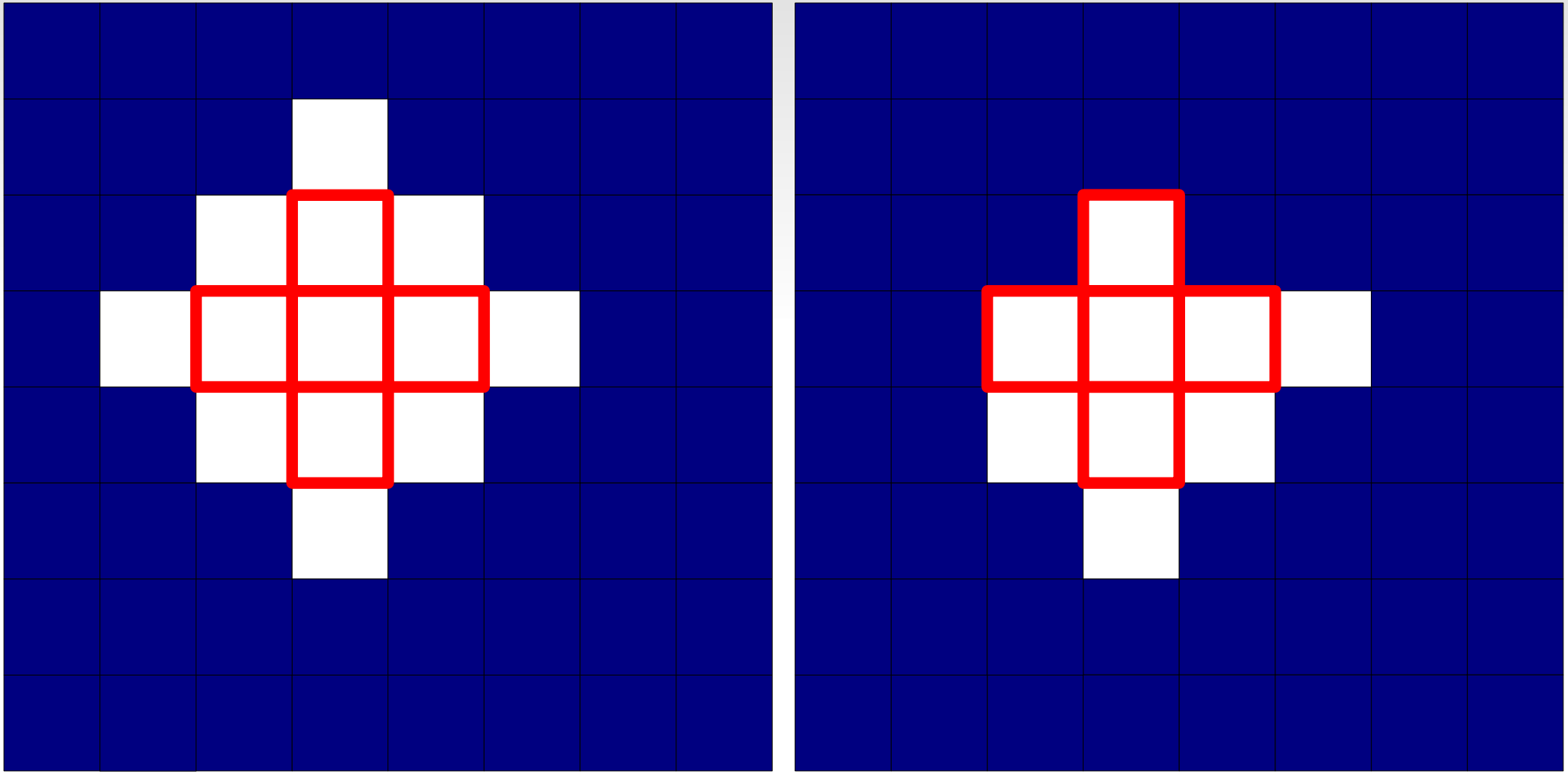


Binary Morphology - erosion

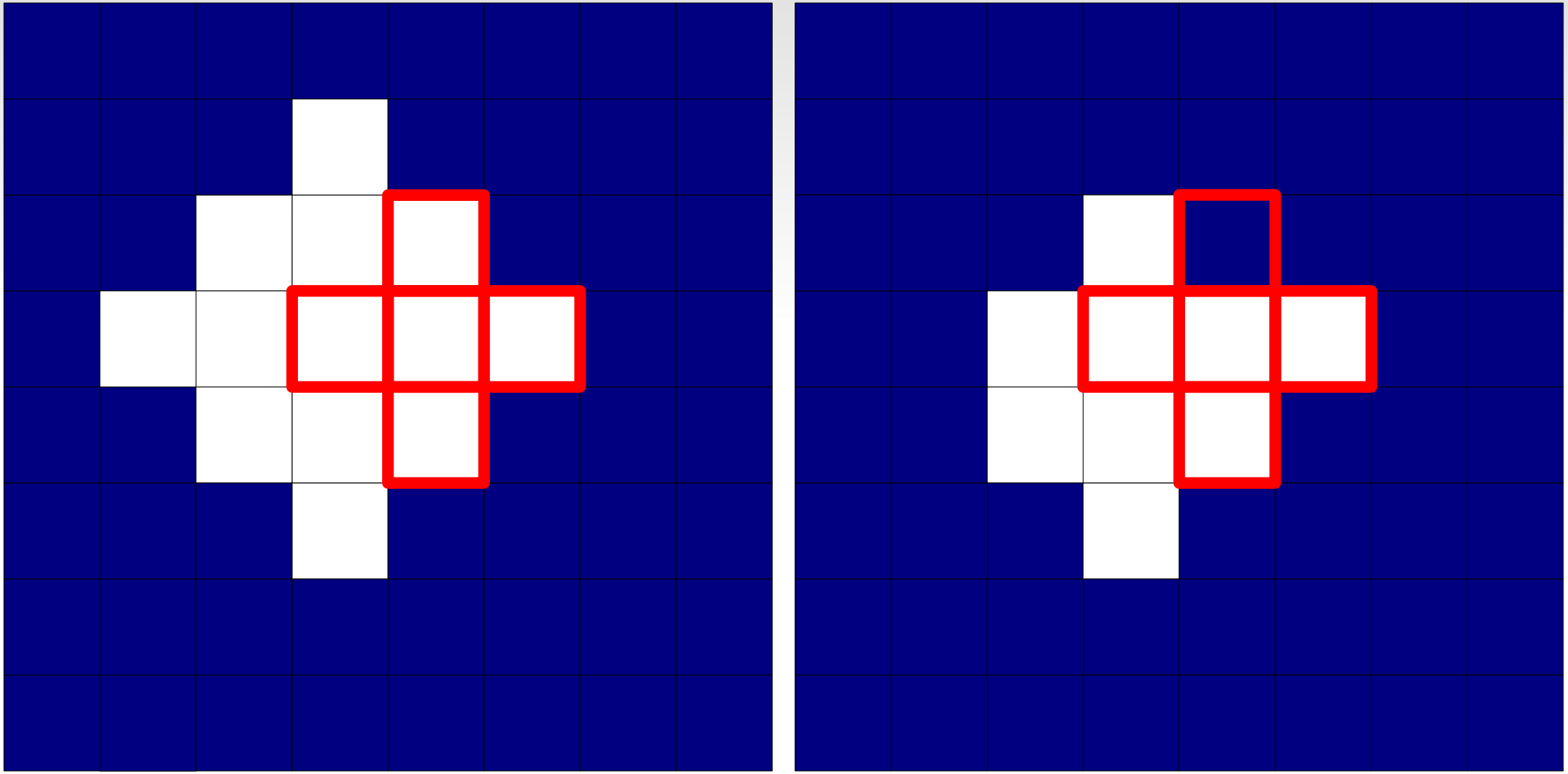




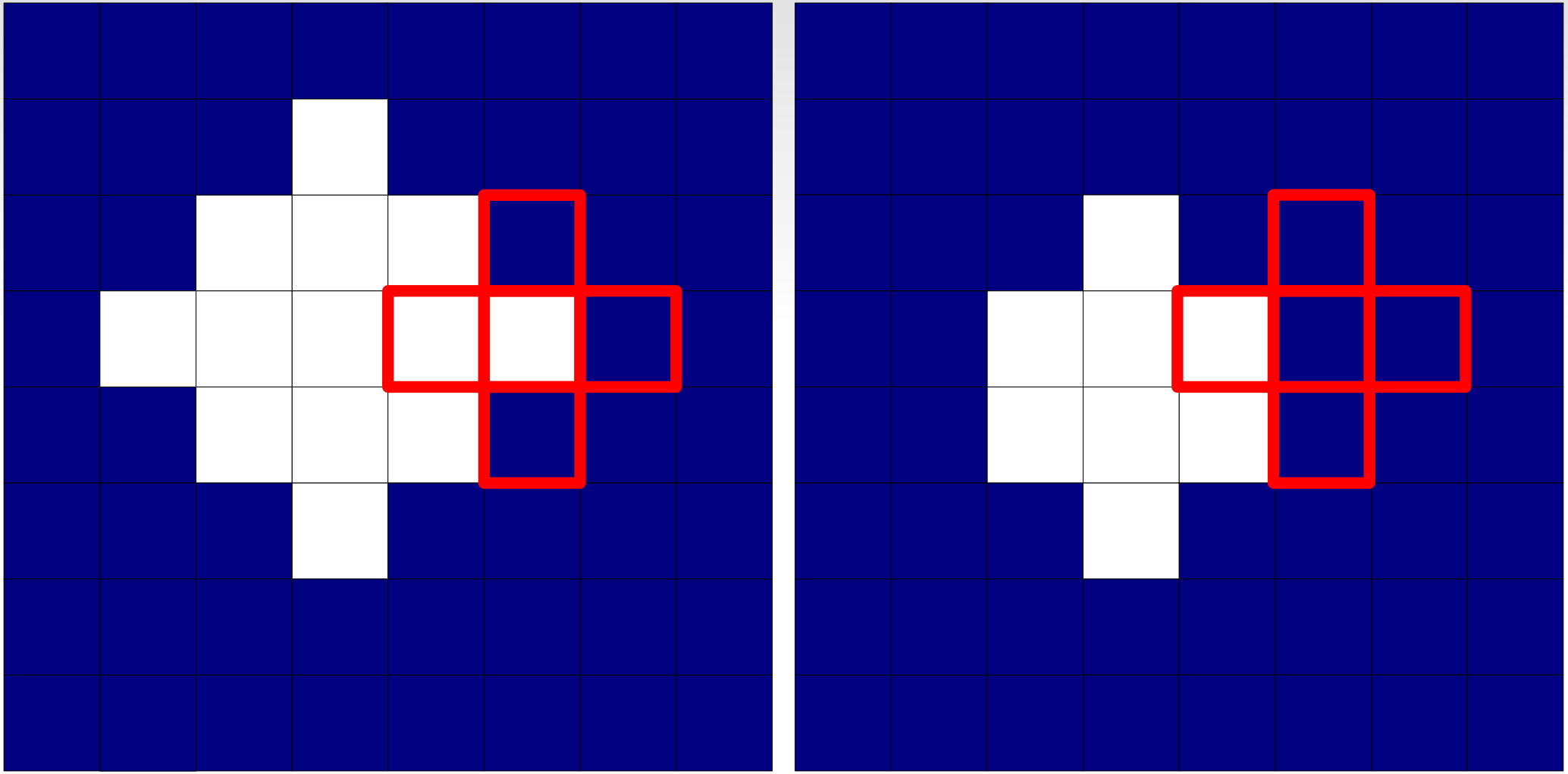
Binary Morphology - erosion



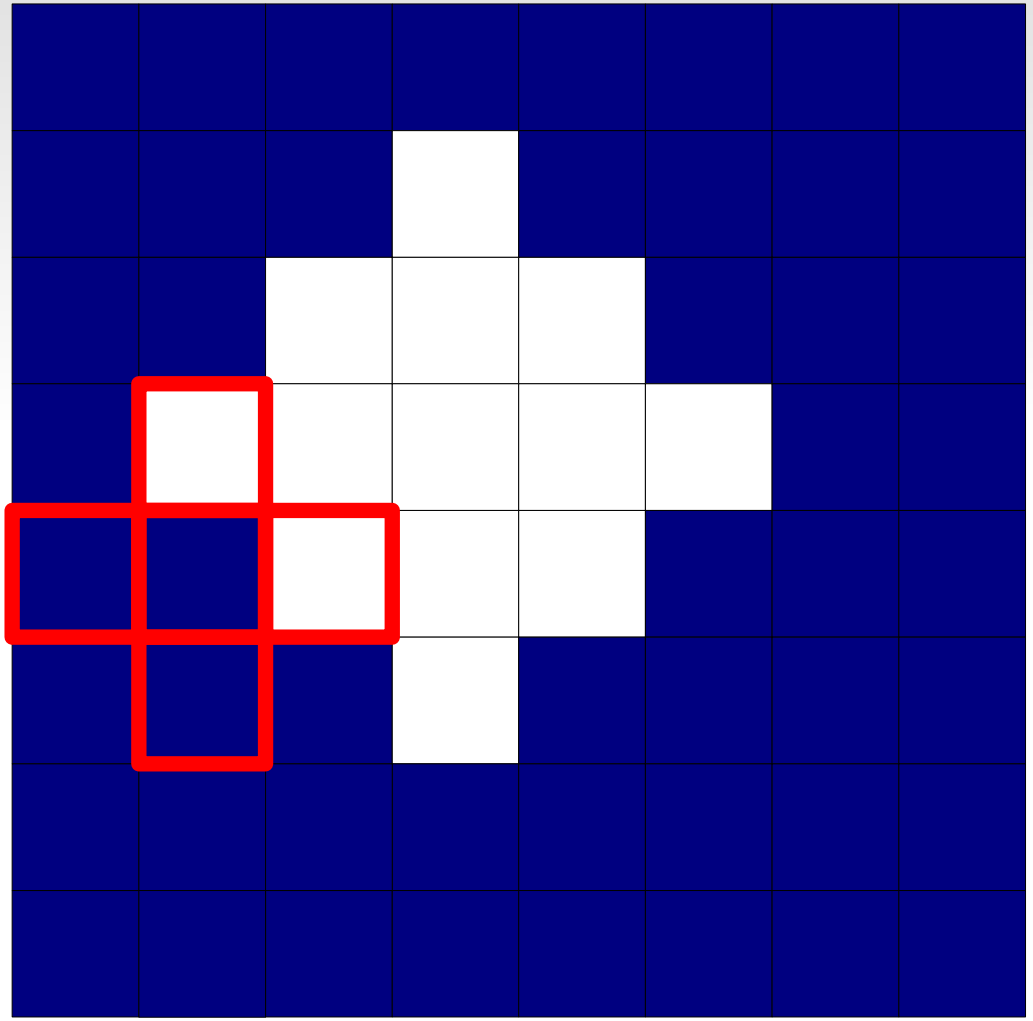
Binary Morphology - erosion

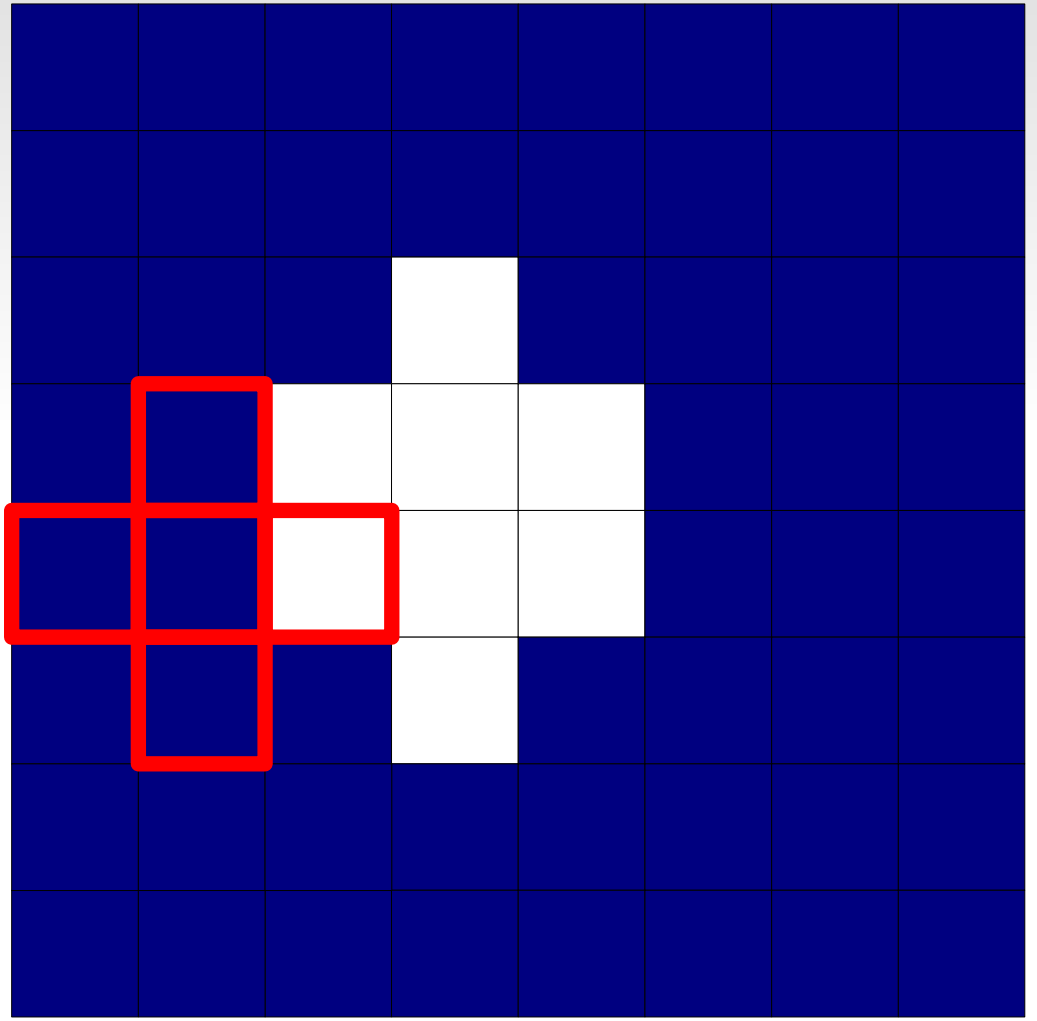


Binary Morphology - erosion

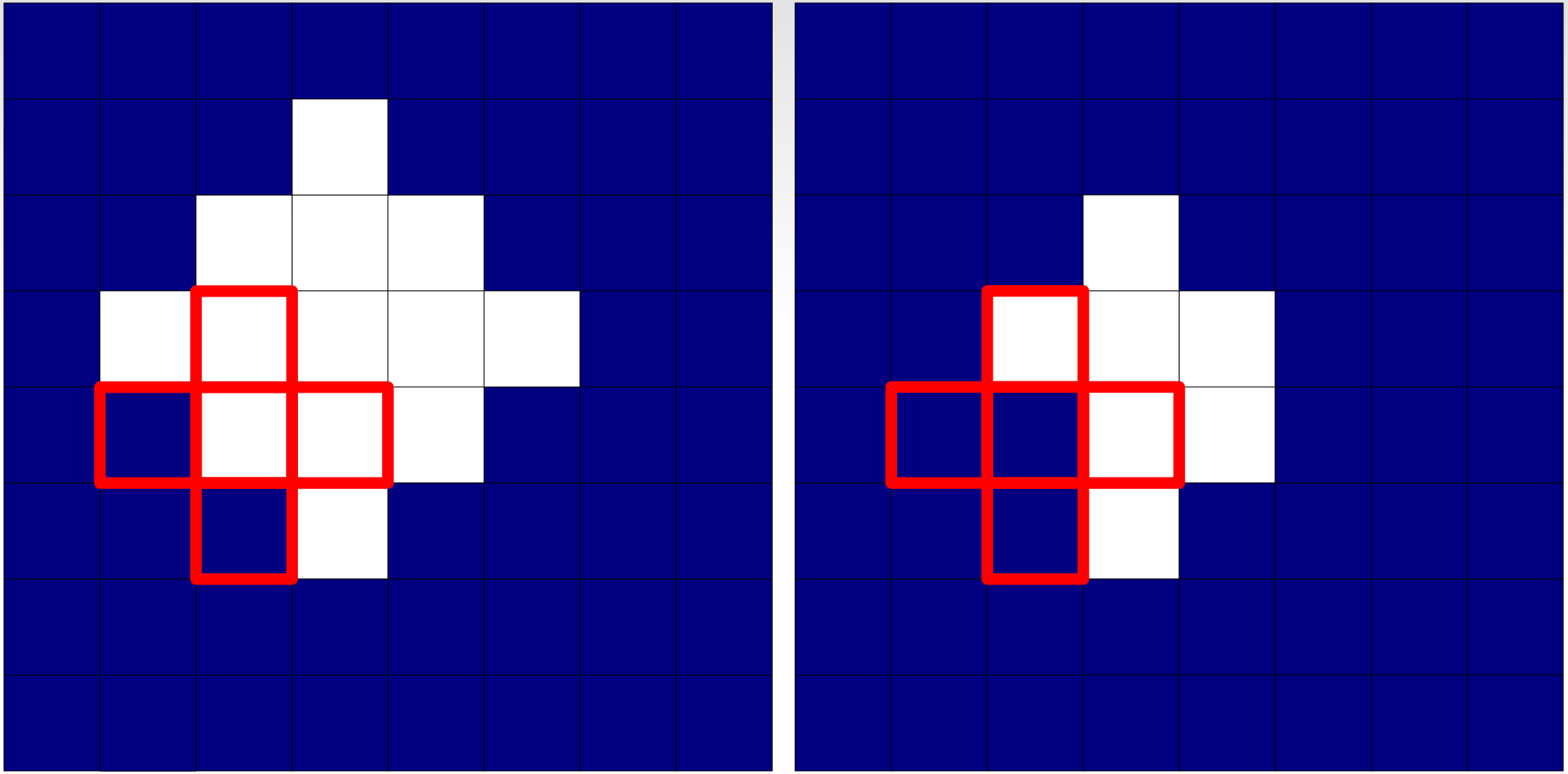


Binary Morphology - erosion

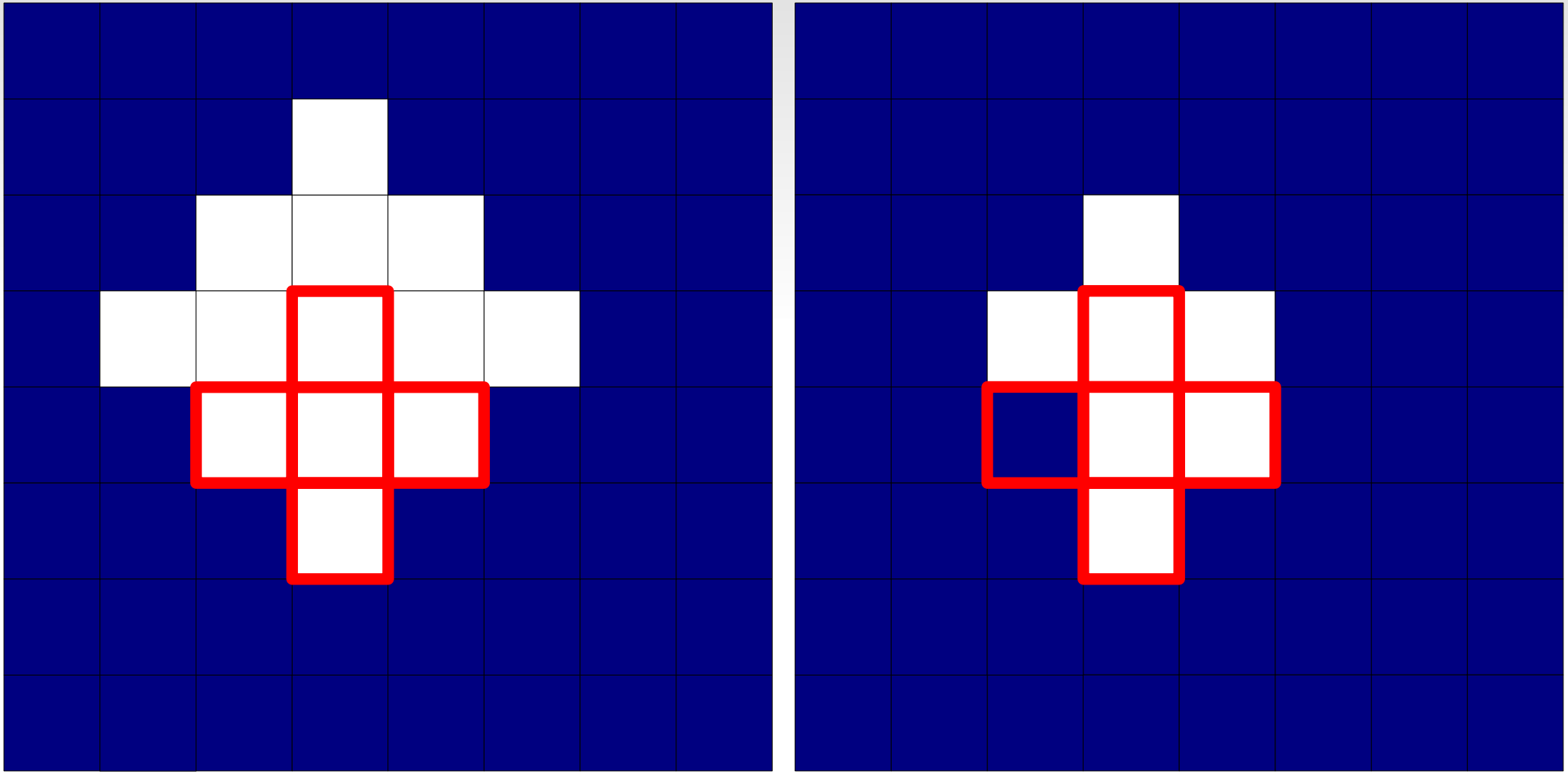




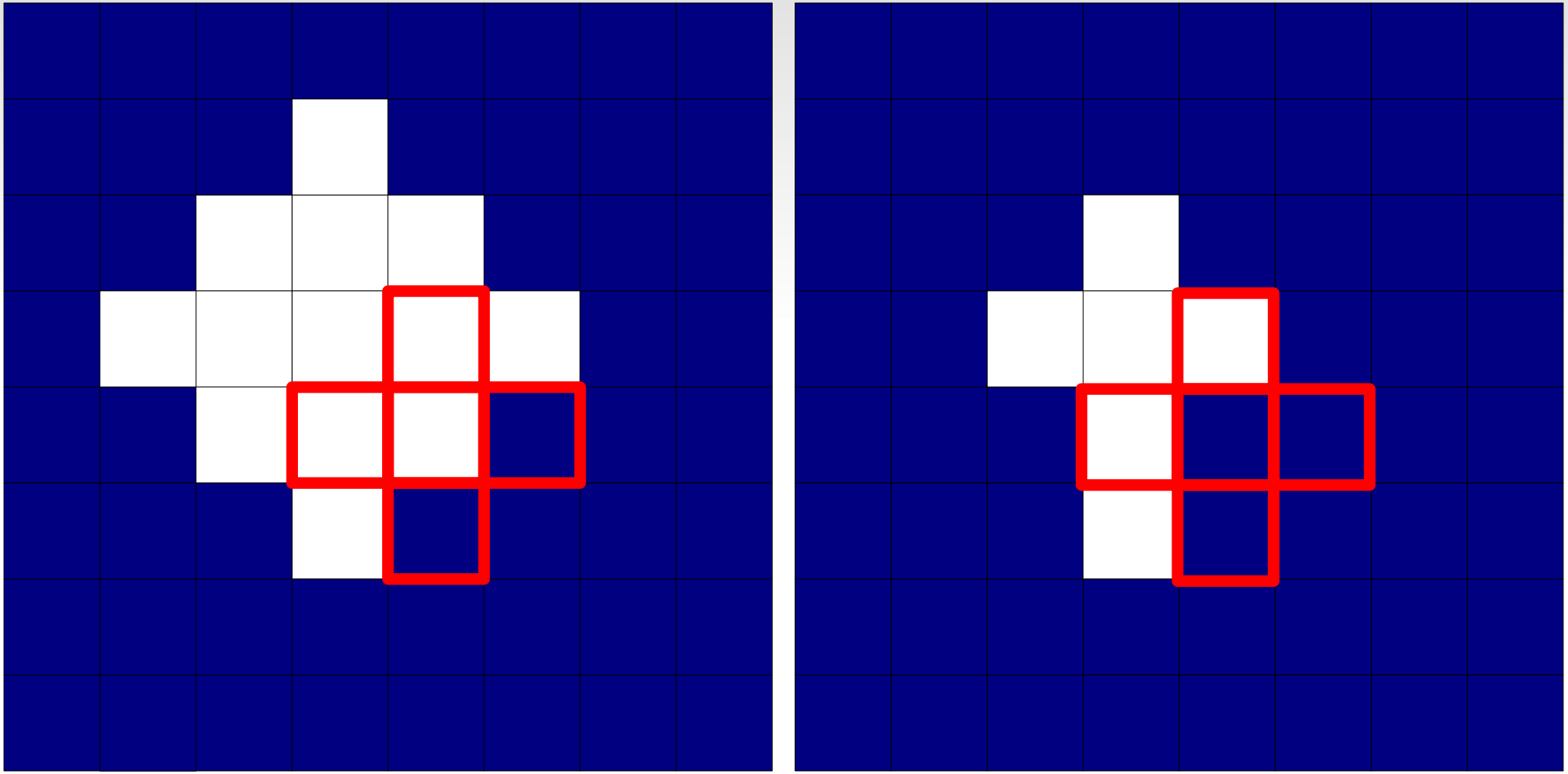
Binary Morphology - erosion



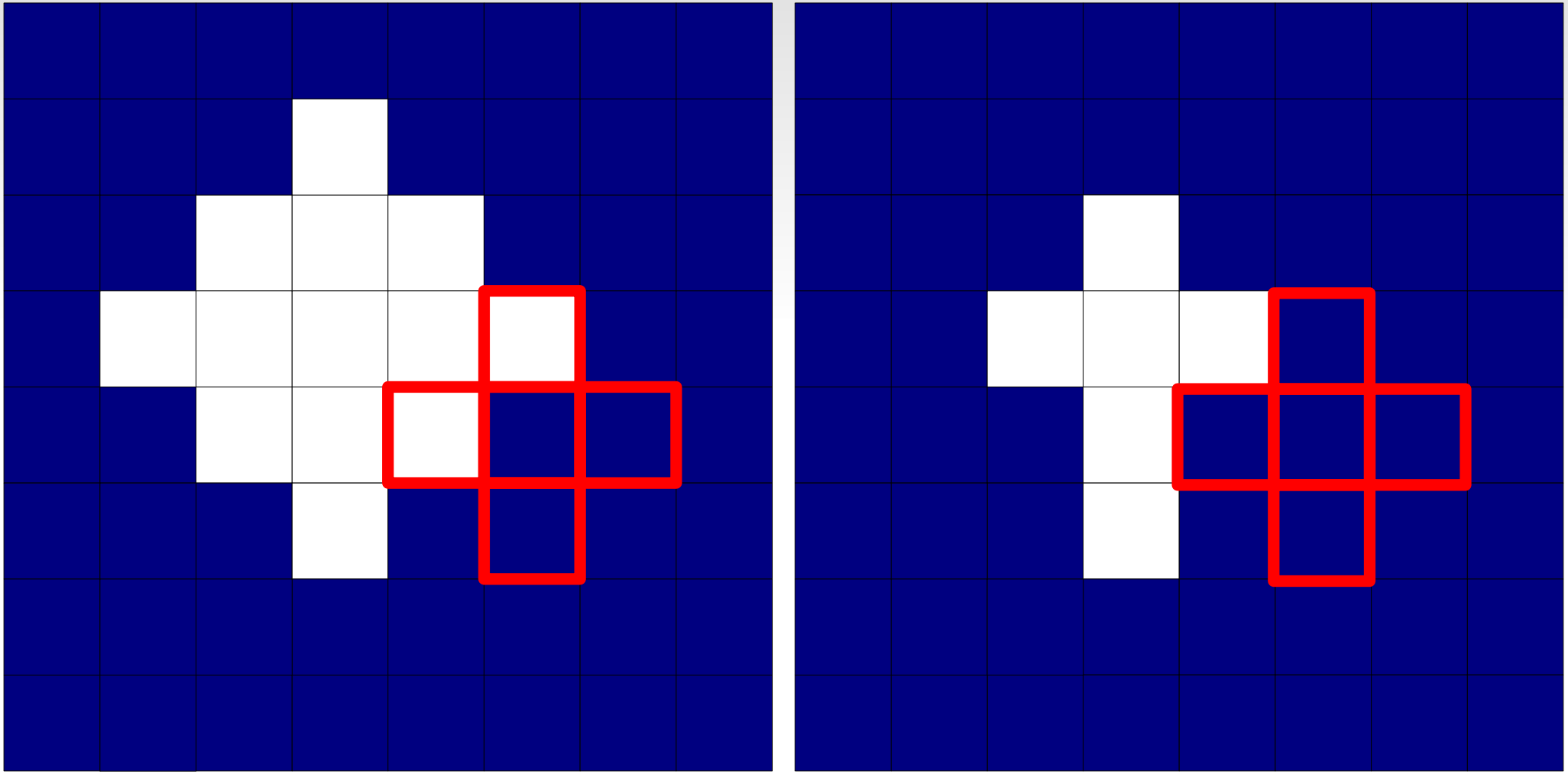
Binary Morphology - erosion



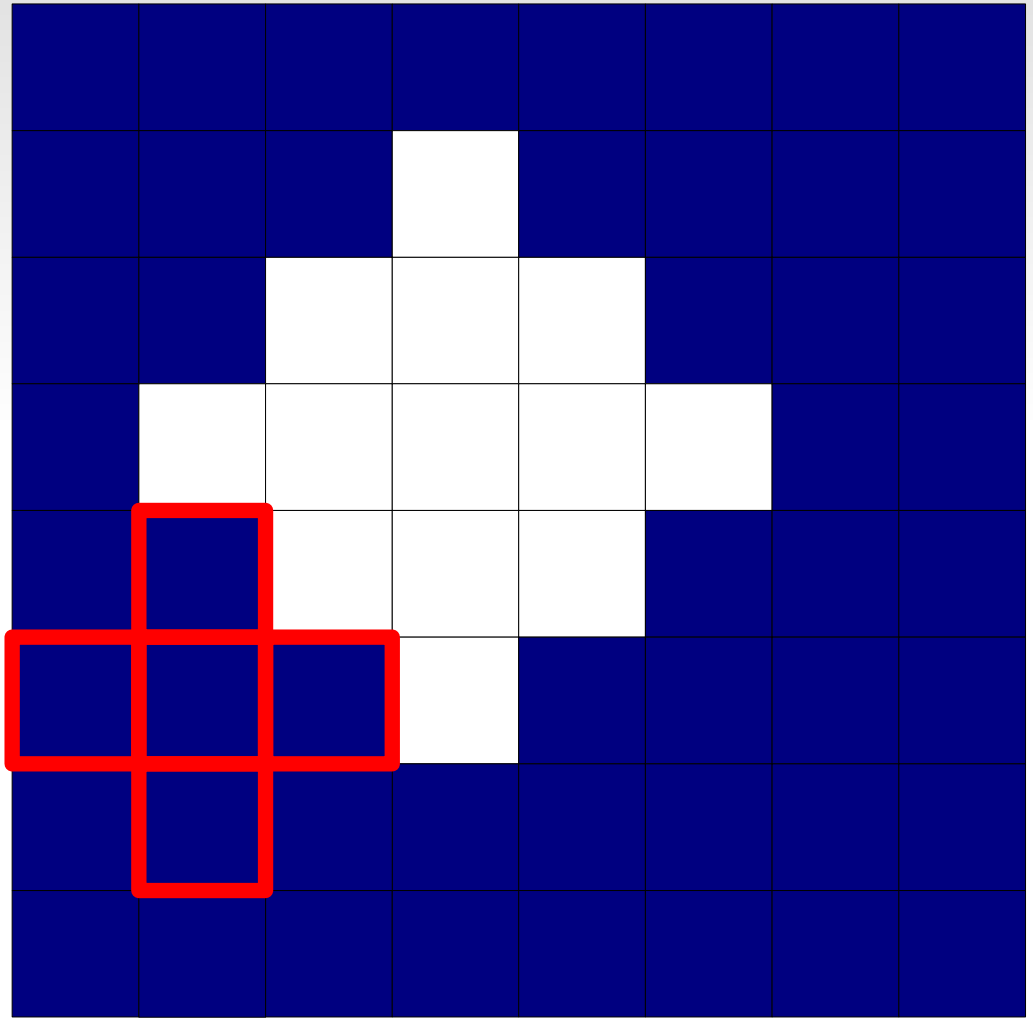
Binary Morphology - erosion

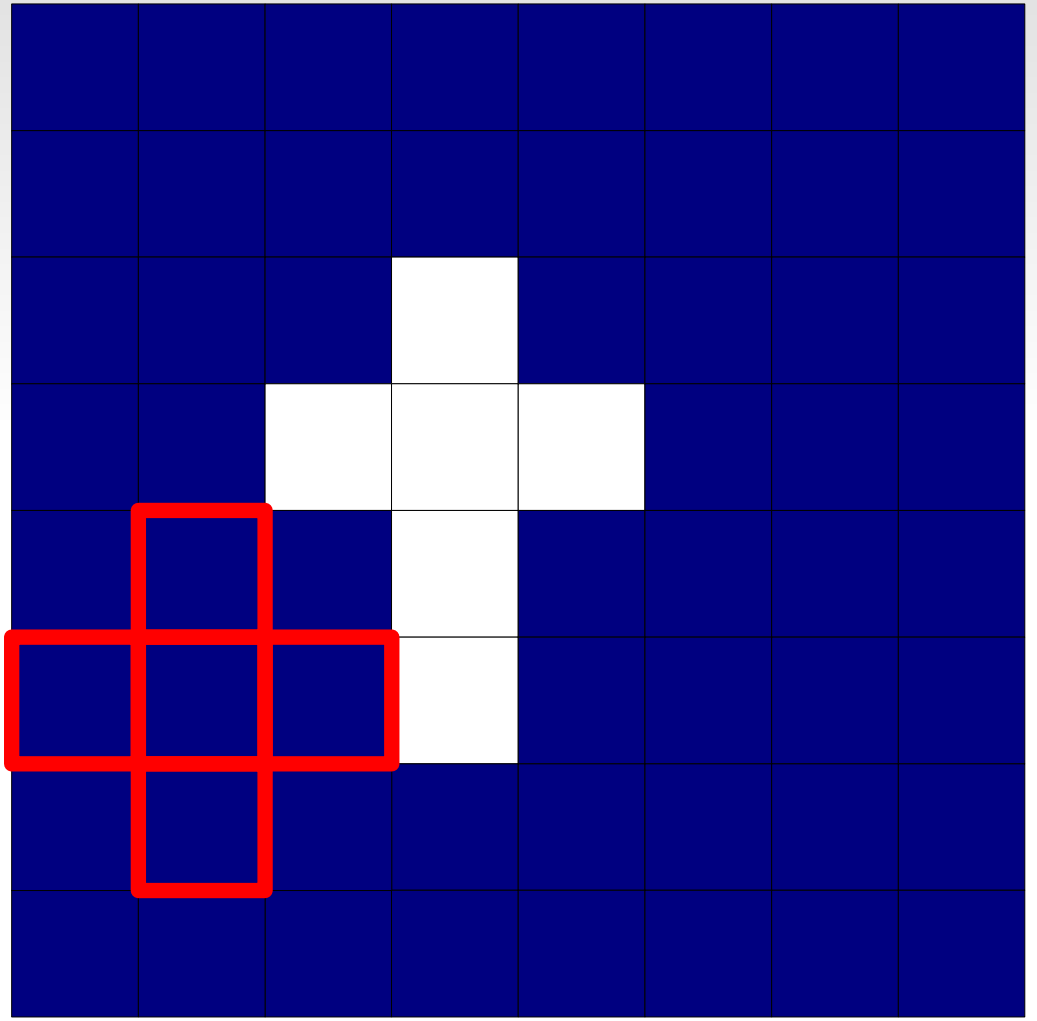


Binary Morphology - erosion

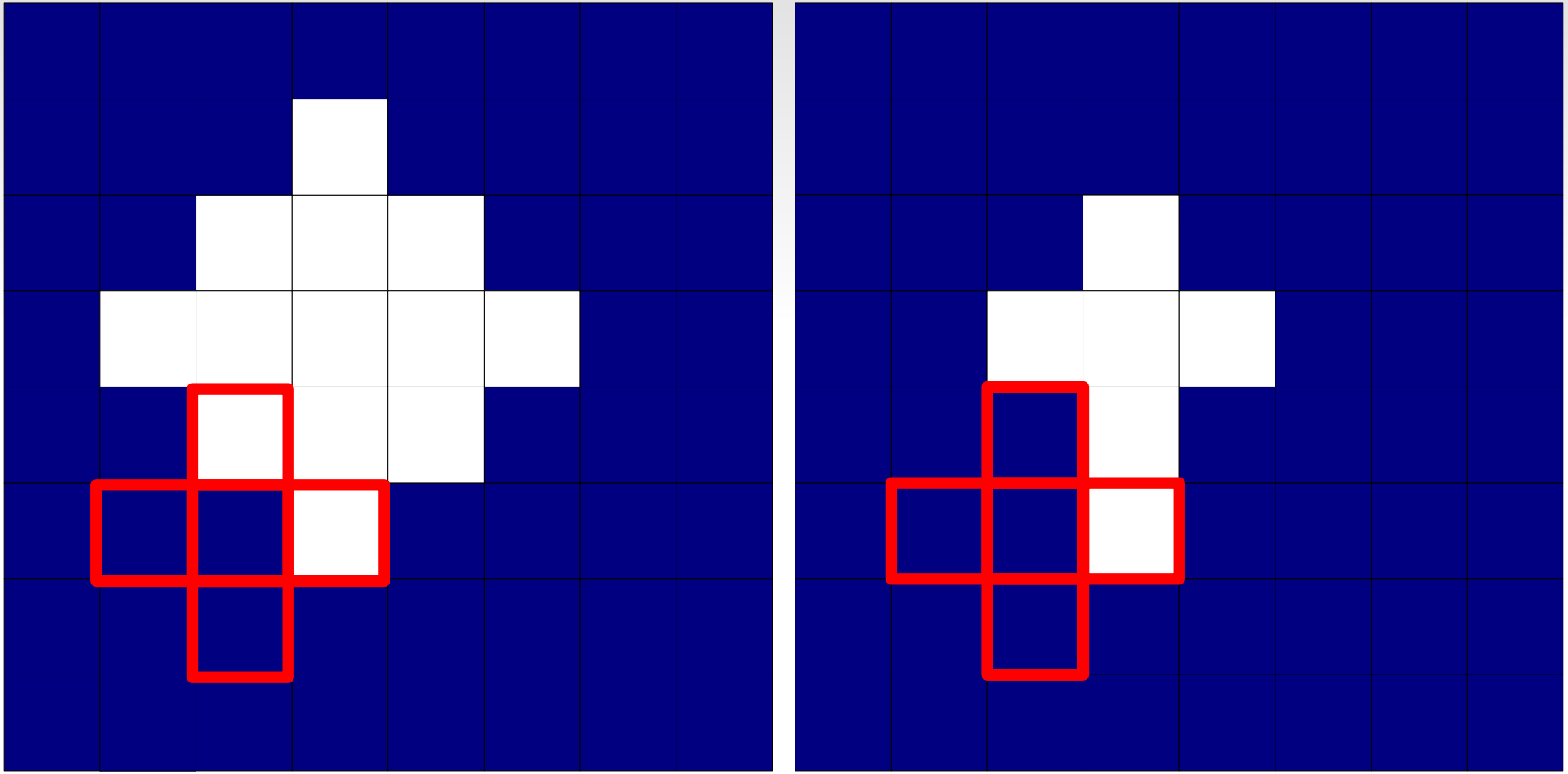


Binary Morphology - erosion

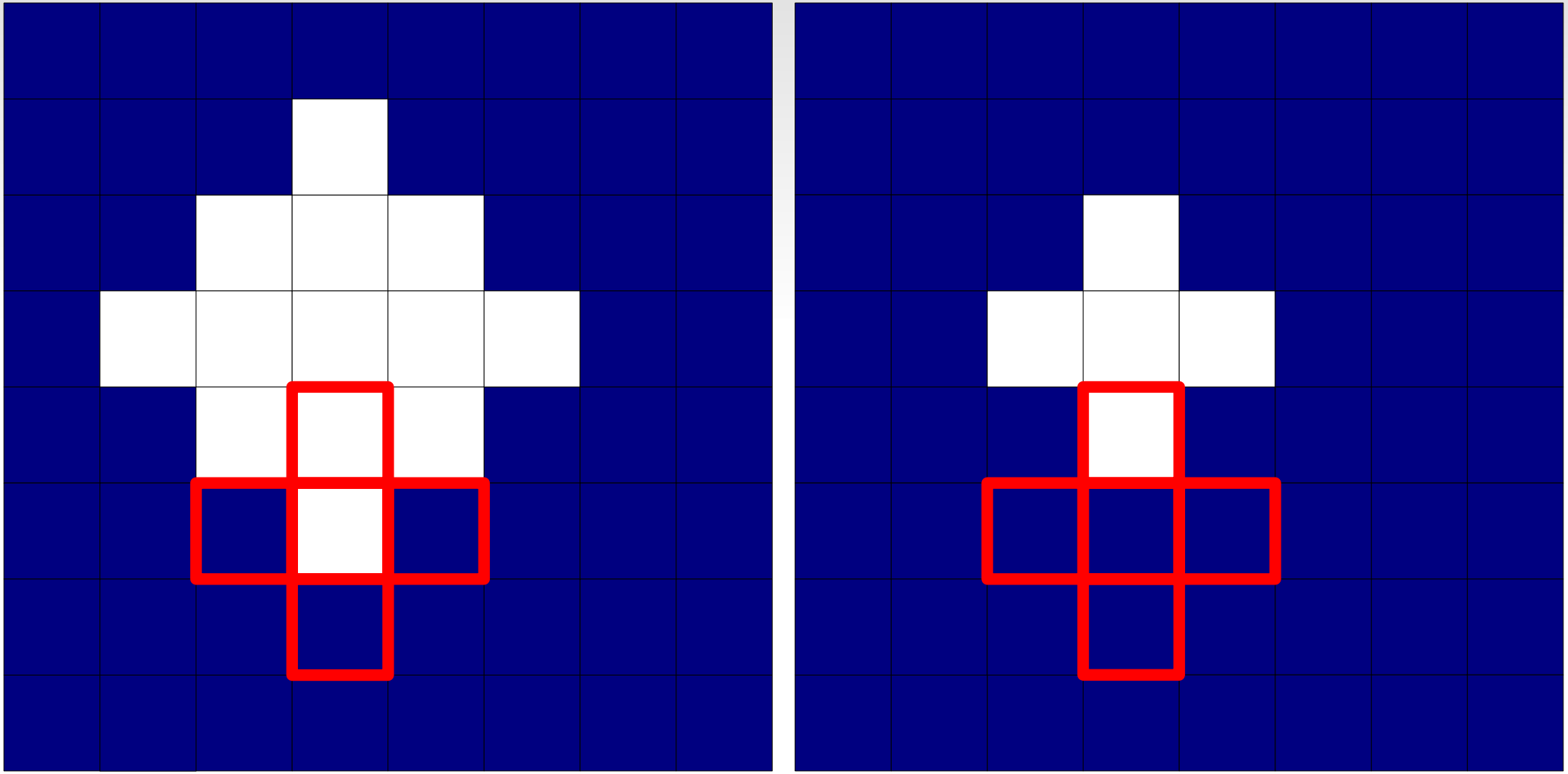




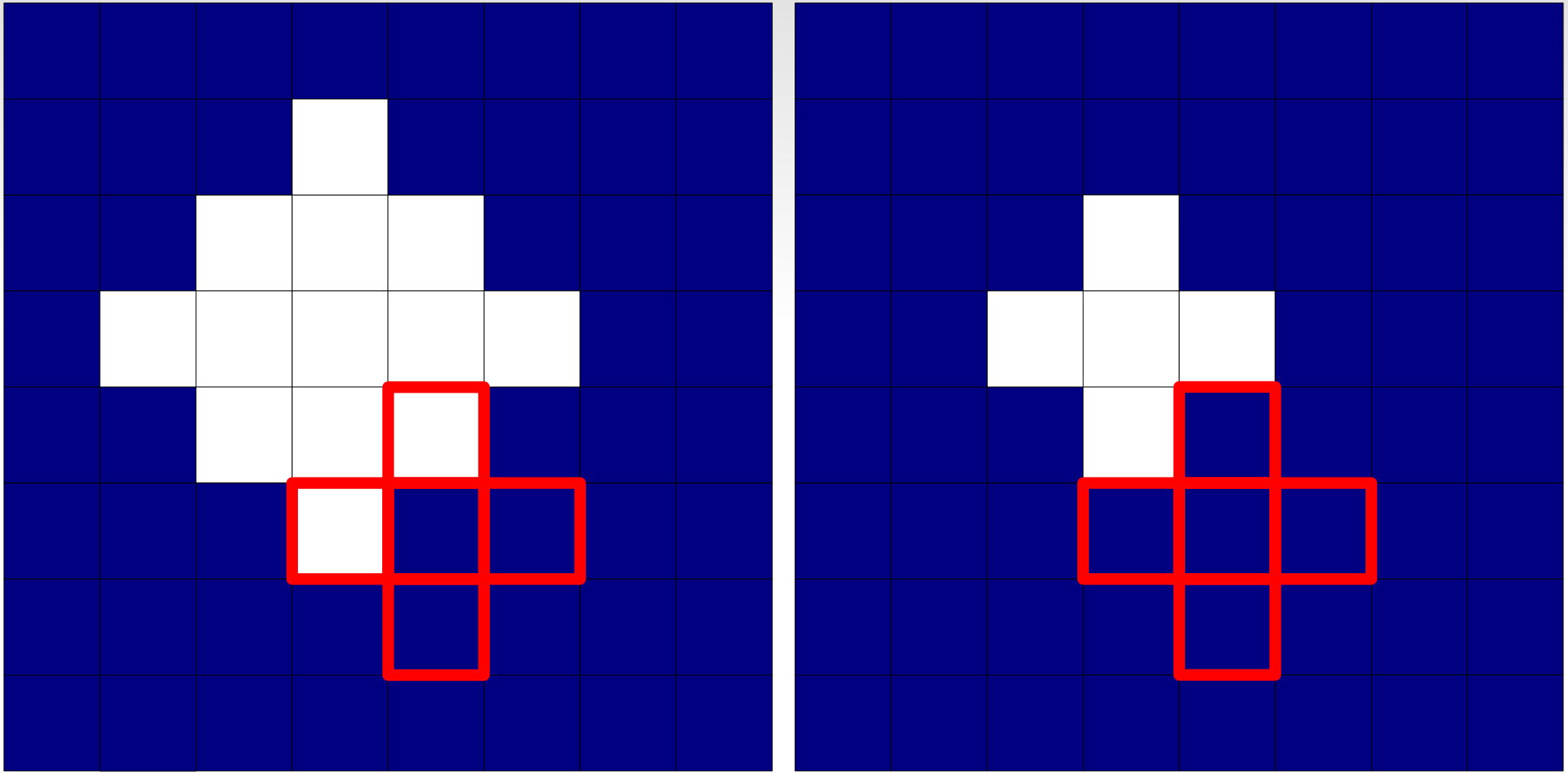
Binary Morphology - erosion



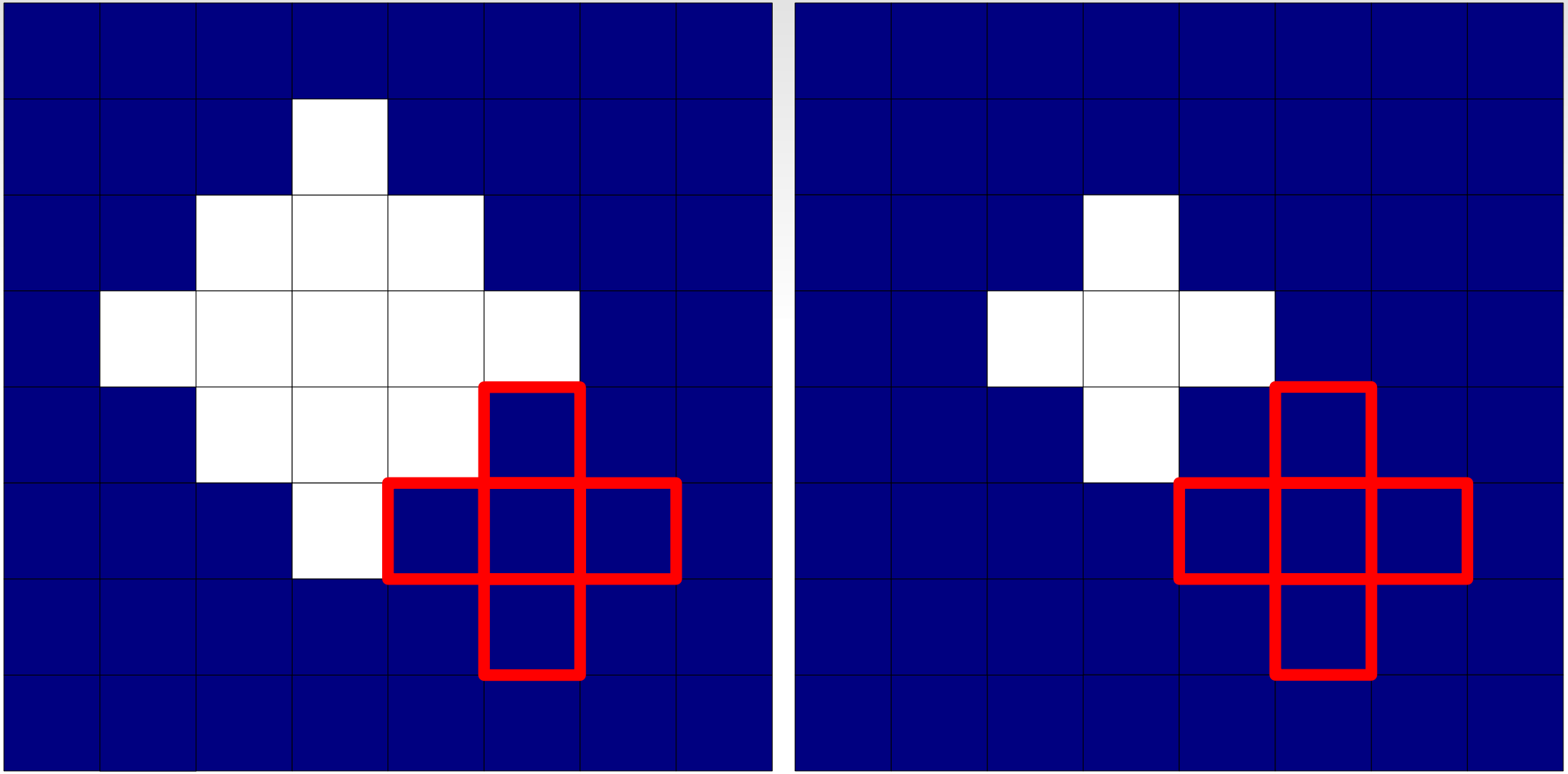
Binary Morphology - erosion



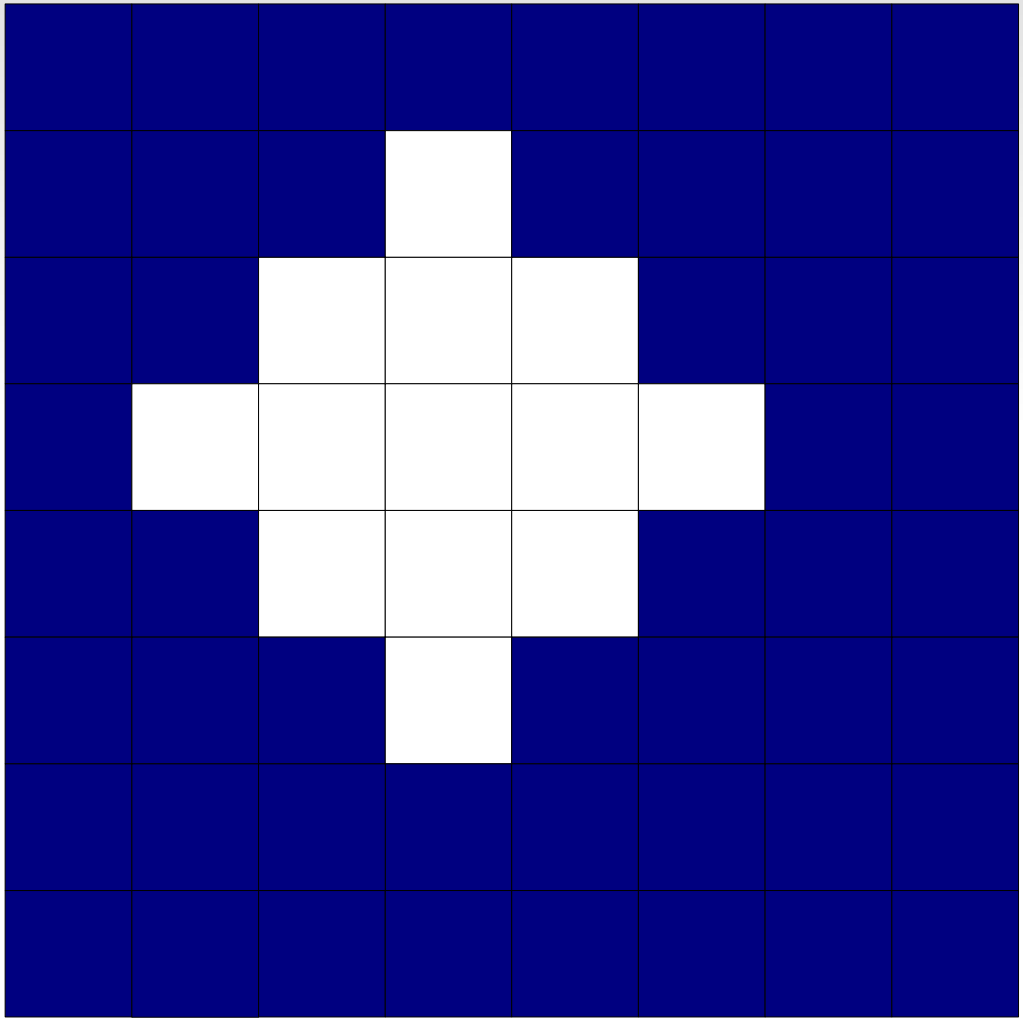
Binary Morphology - erosion

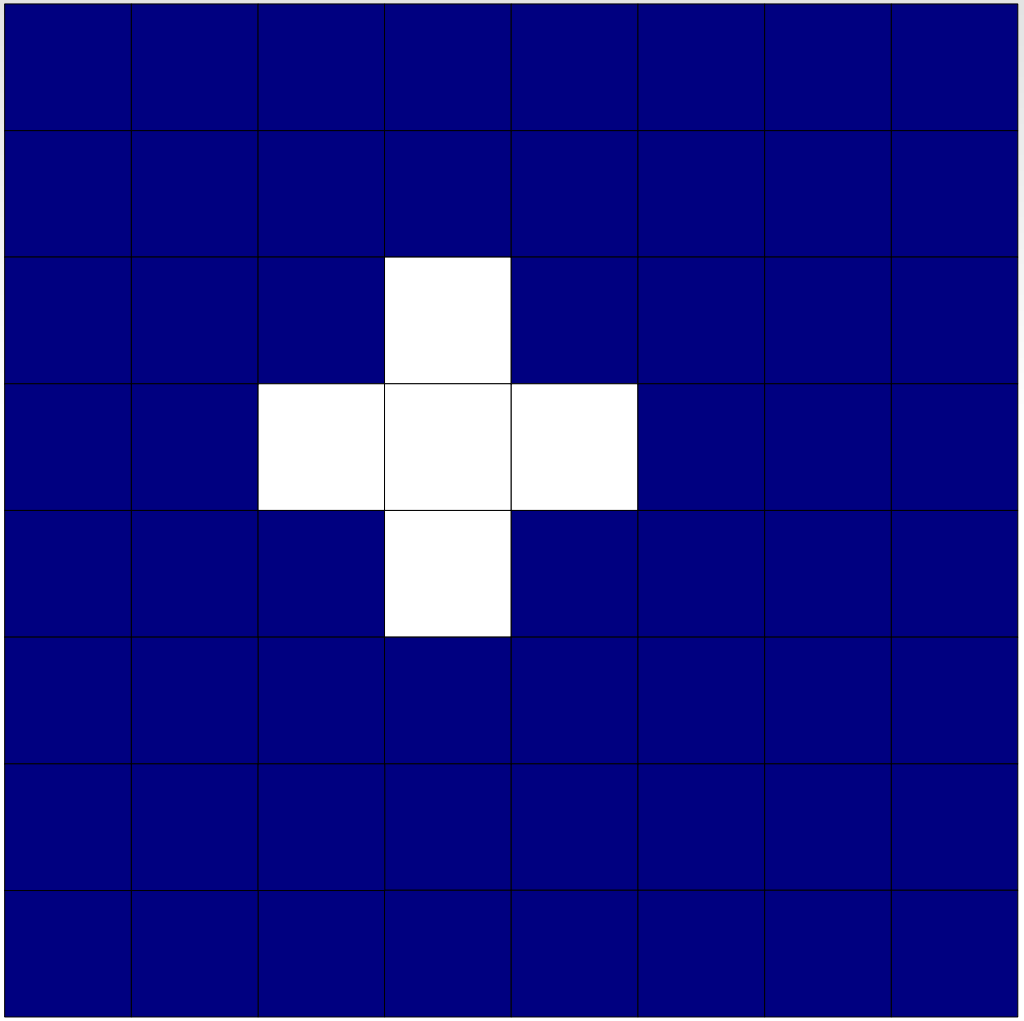


Binary Morphology - erosion

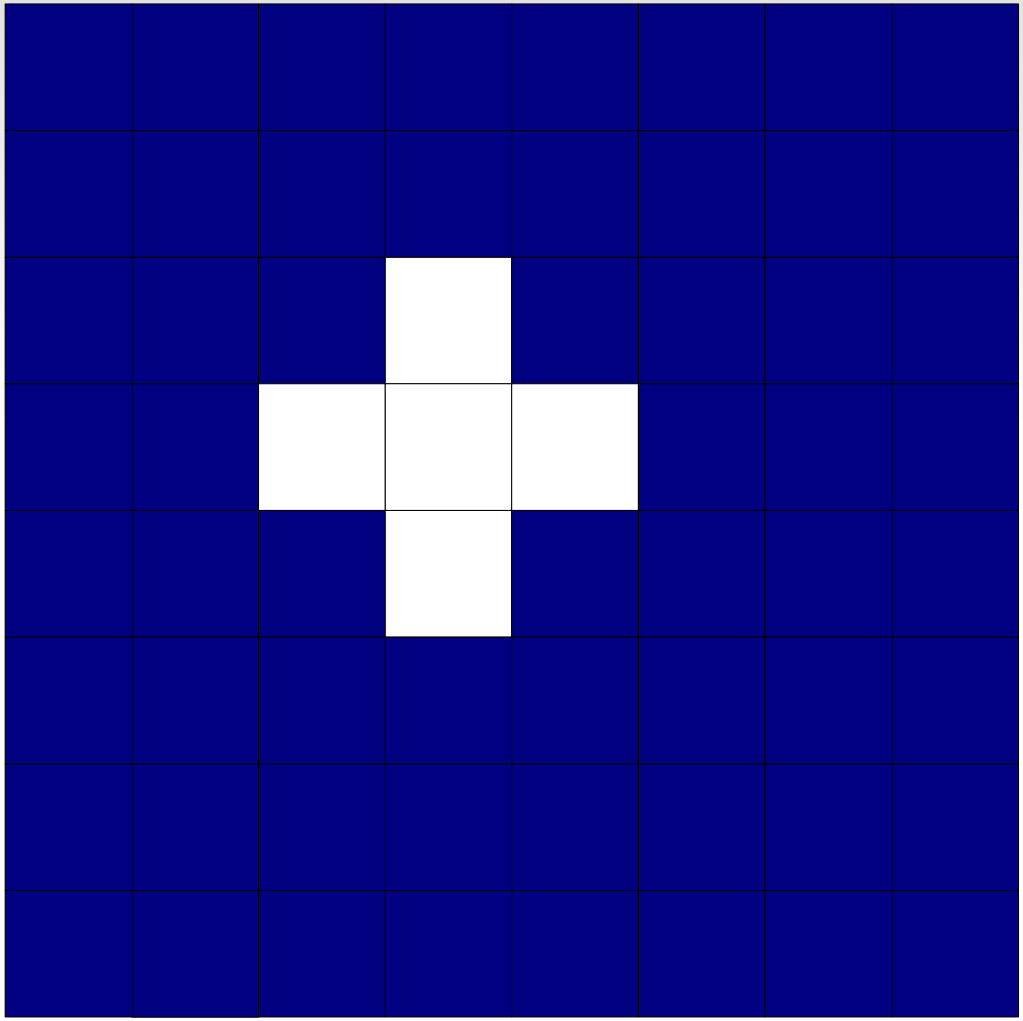


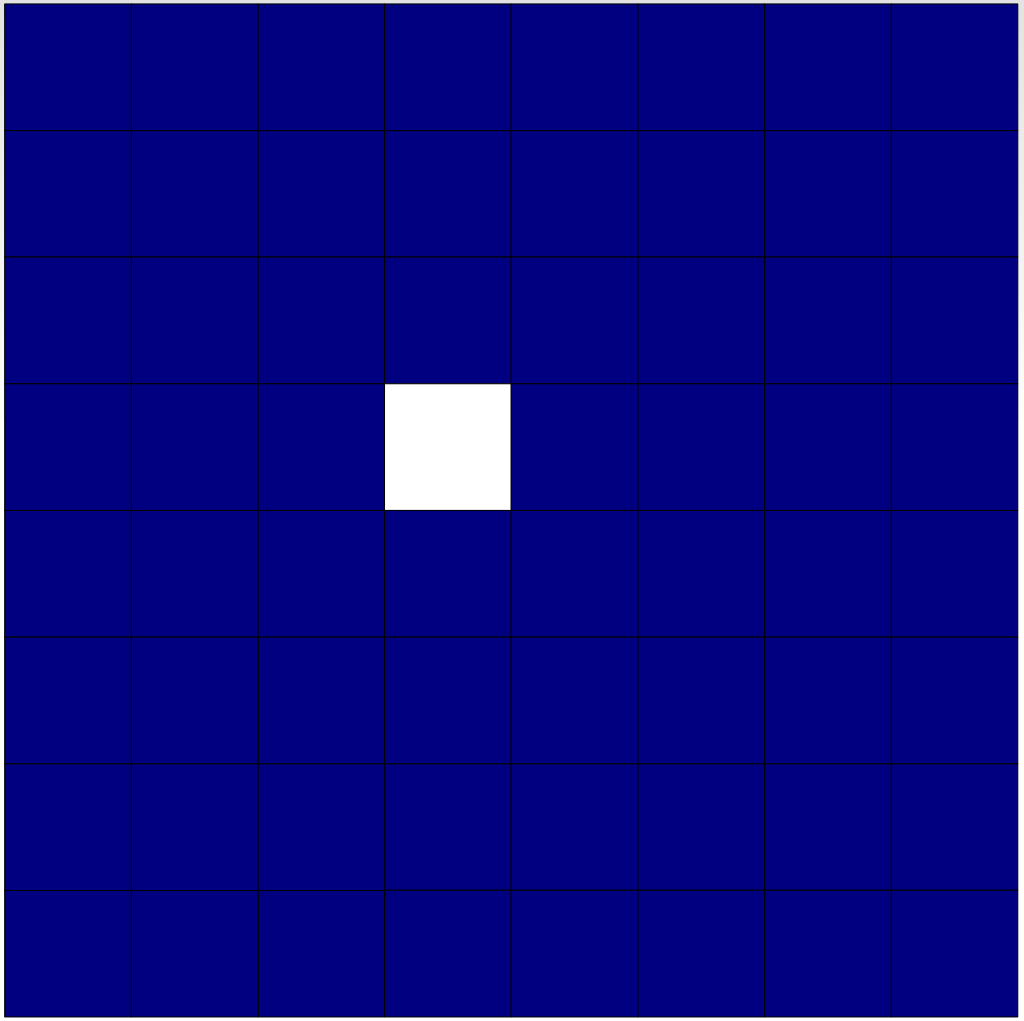
Binary Morphology - erosion



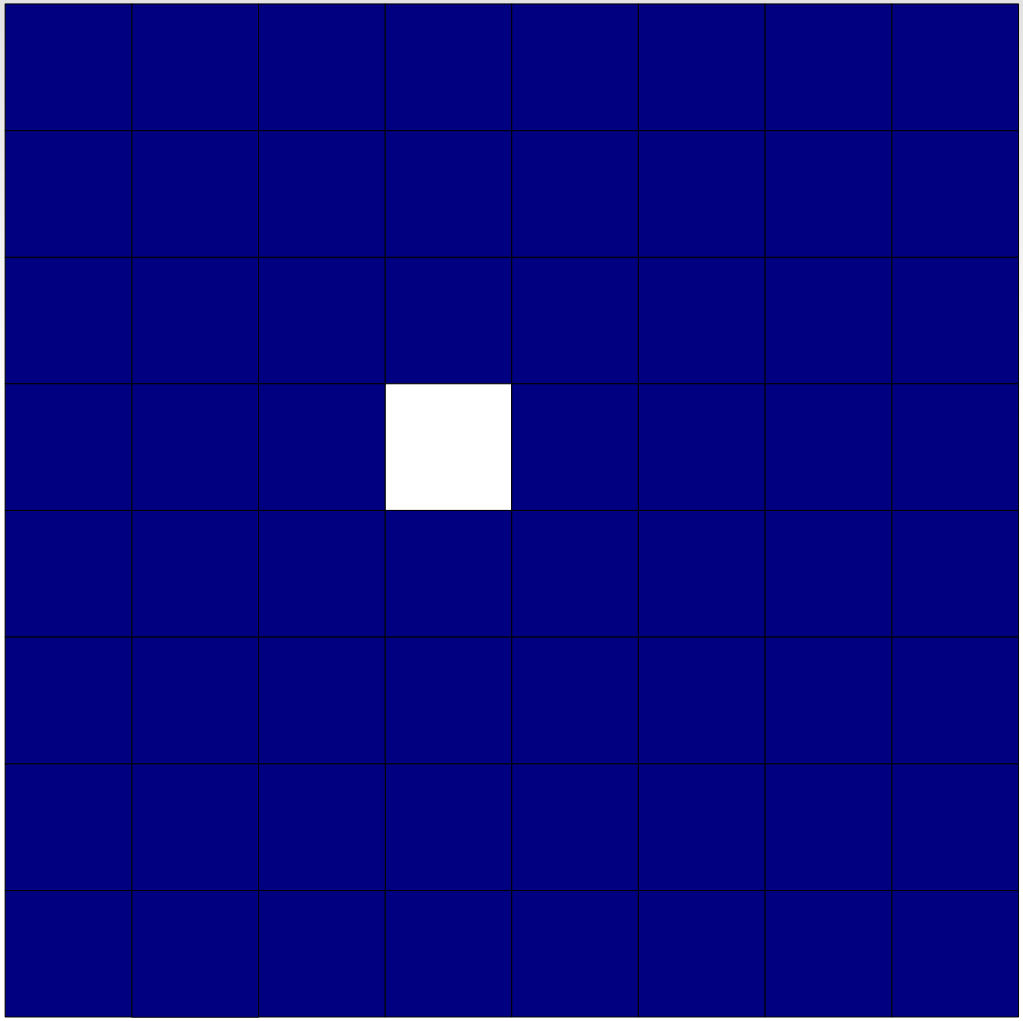


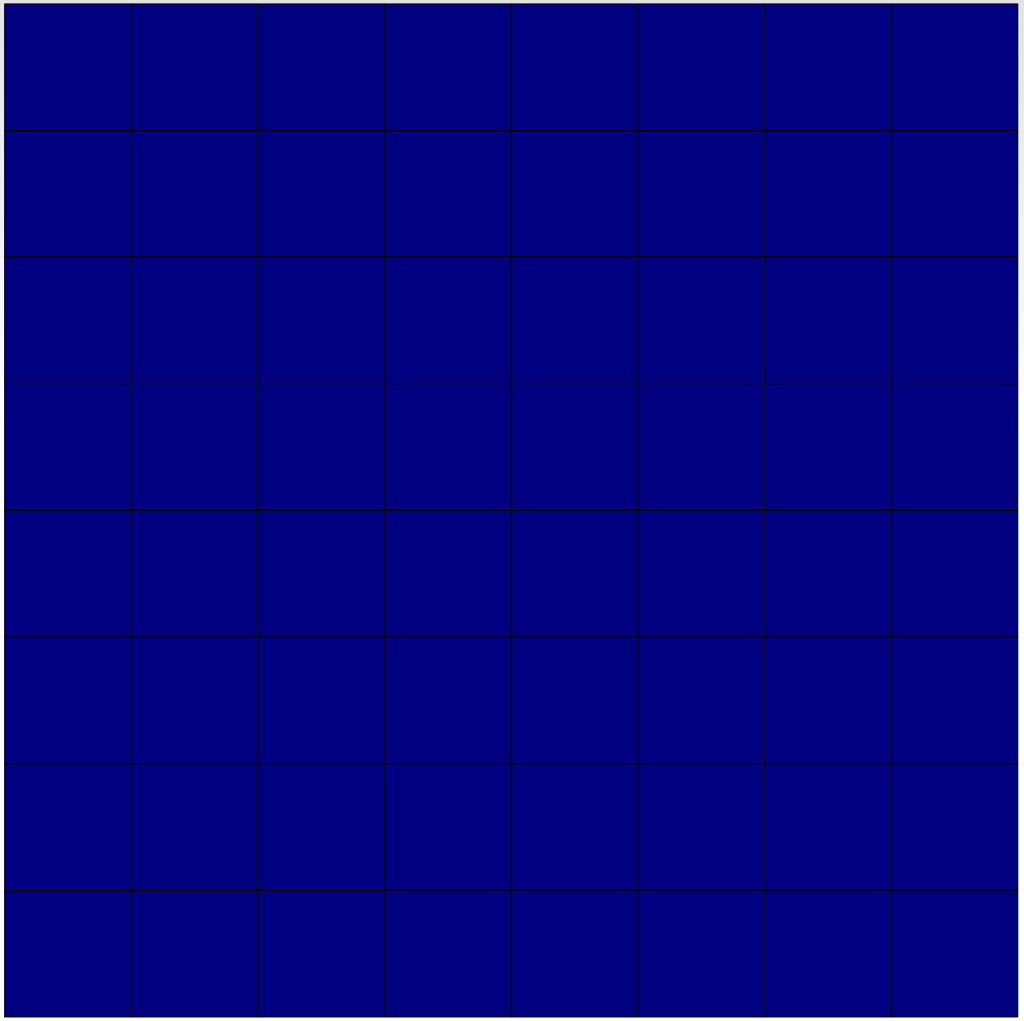
Binary Morphology - erosion





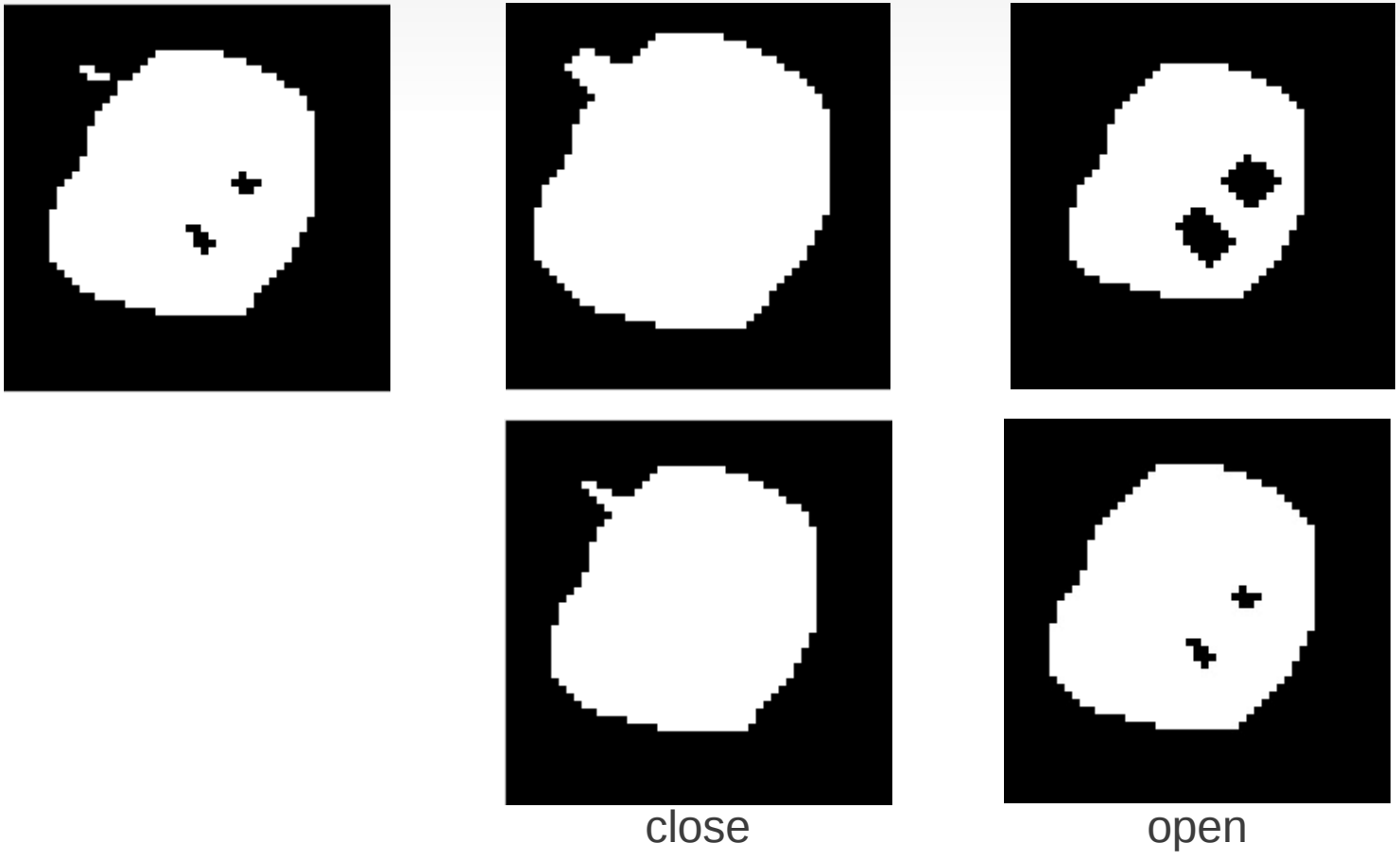
Binary Morphology - erosion





Binary Morphology - open and close

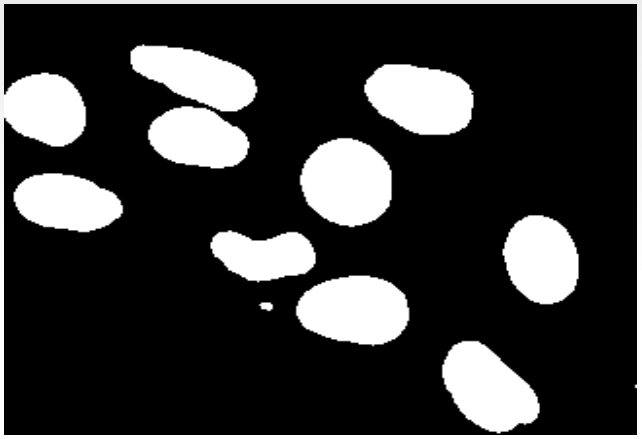
- close(X) = dilate(erode(X)) close holes in objects
- open(X) = erode(dilate(X)) remove small objects



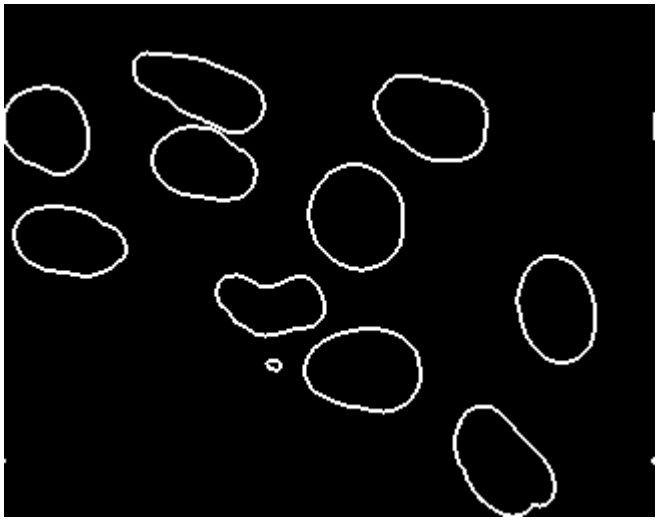
Binary Morphology - applications

edge detection

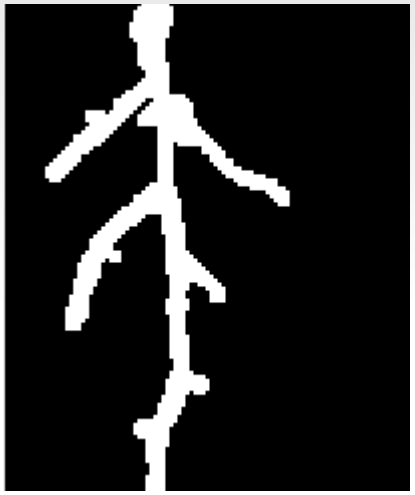
I

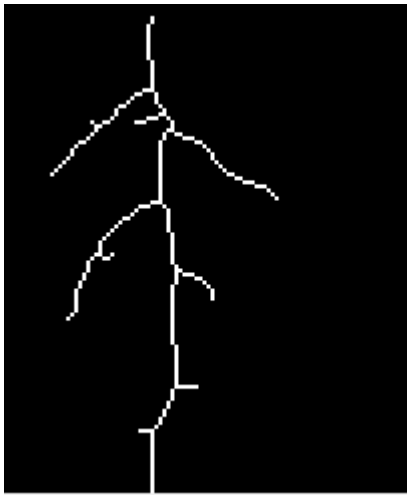


dilate(I) - erode(I)

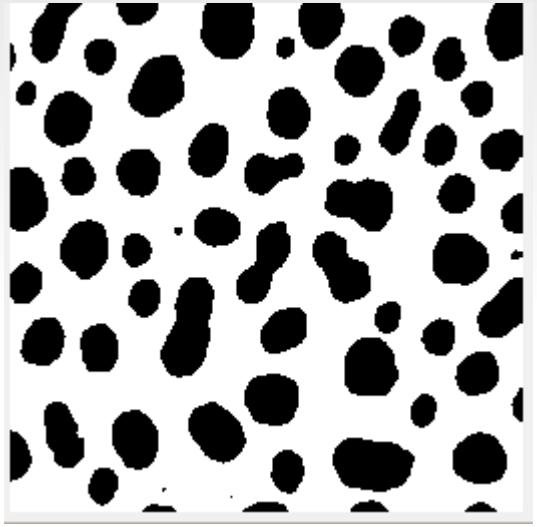


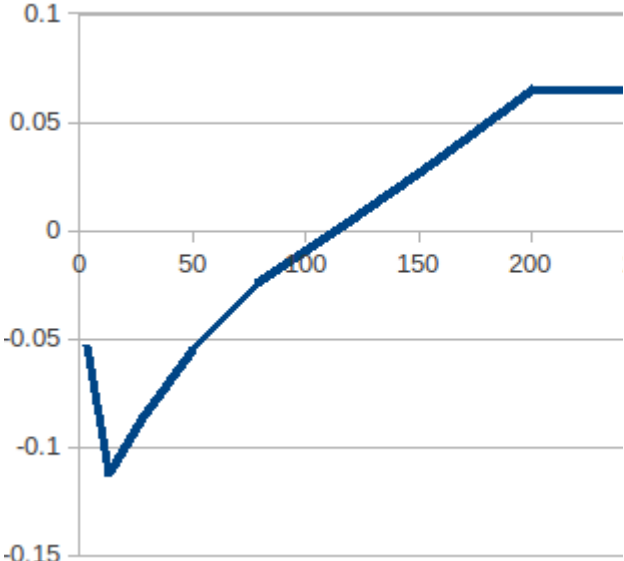
skeletonization





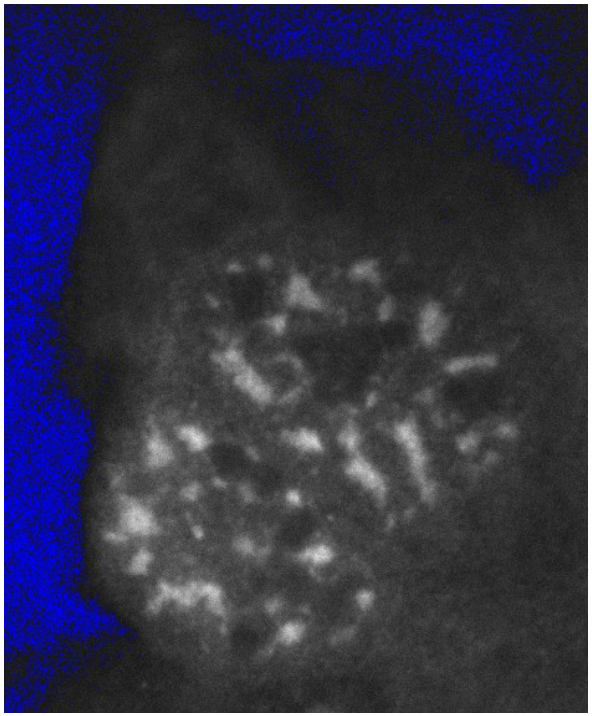
granulometry

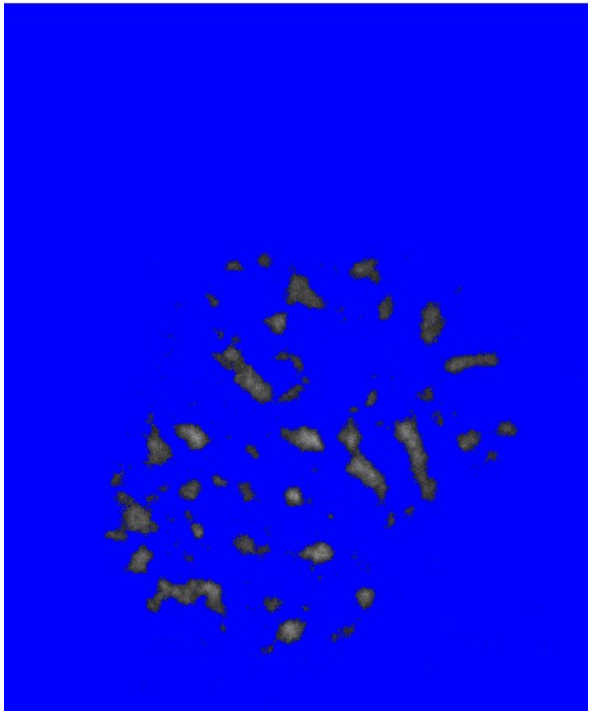




grayscale morphology

- dilate – max over structuring element
- erode – min over structuring element
- Example: grayscale top-hat filter (I-open(I))



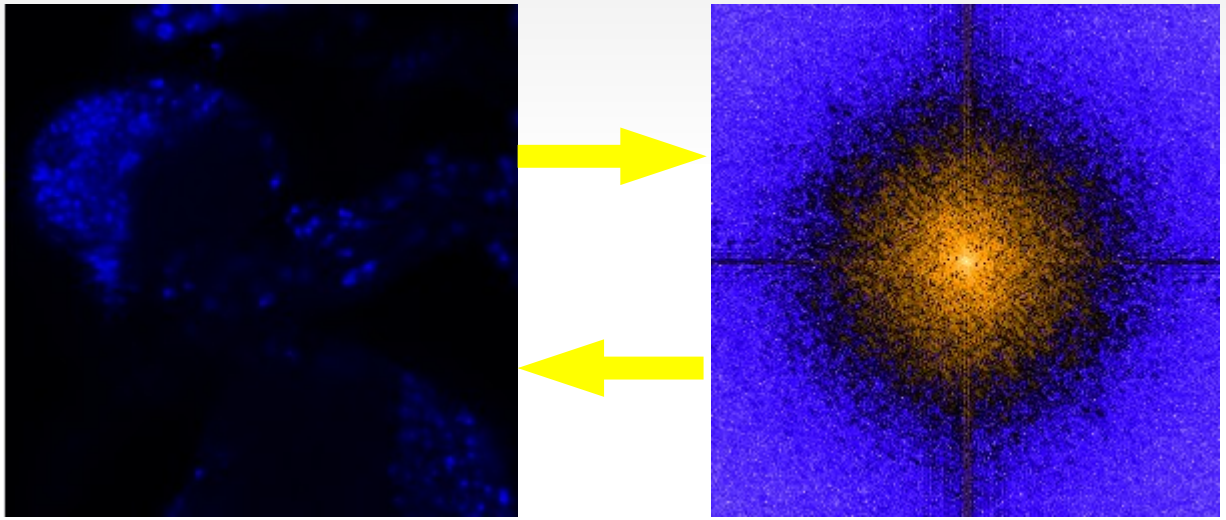


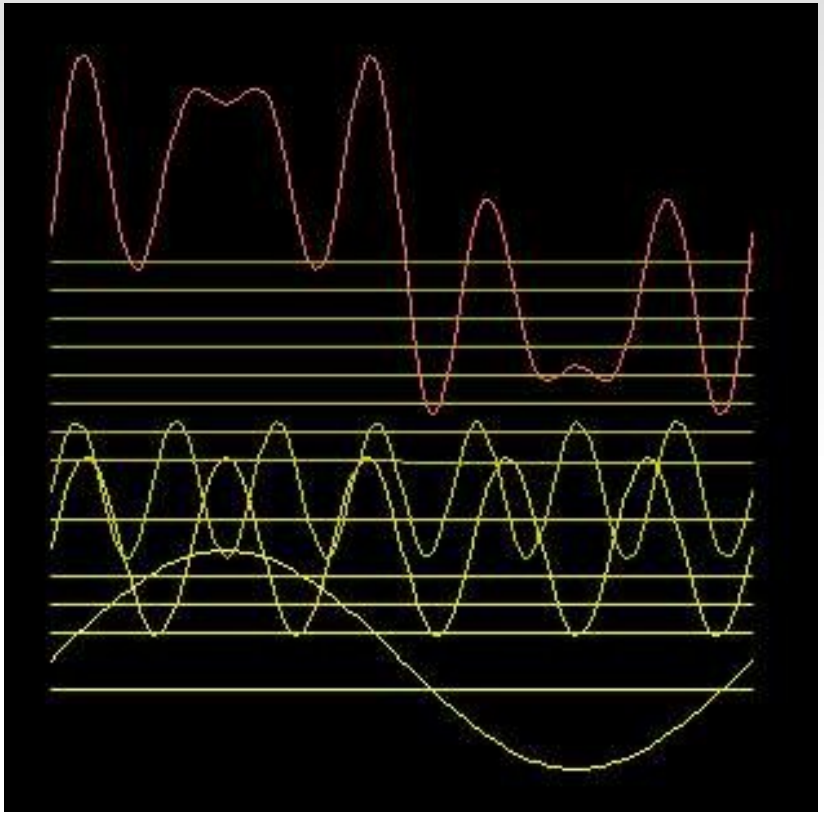
filtering in the frequency domain

- Fourier Transform
- low-pass
- high-pass
- band-pass
- correlation
- convolution

filtering in the frequency domain – fourier transform

$$F(\nu)=\int f(x)\,\mathrm{e}^{-i2\pi\nu x}\,dx$$

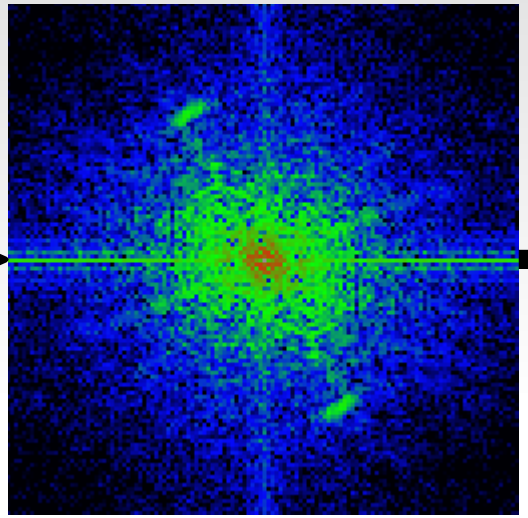




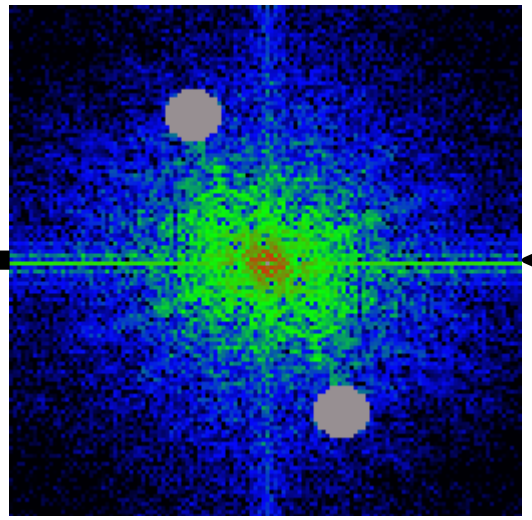
- signal can be represented as sum of sinoids
- FT transforms from spatial to frequency domain

Filtering in the frequency domain

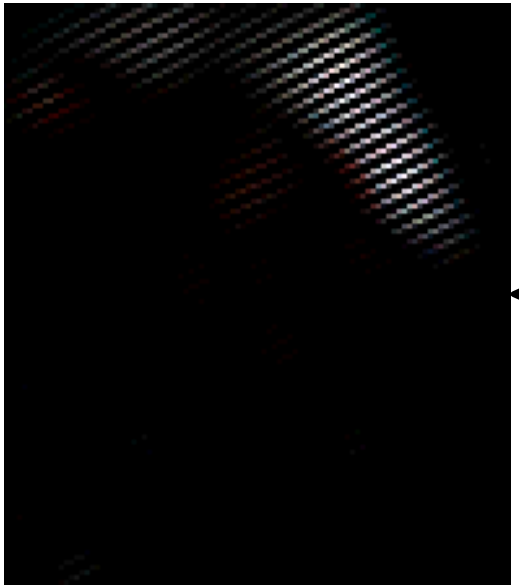
FFT



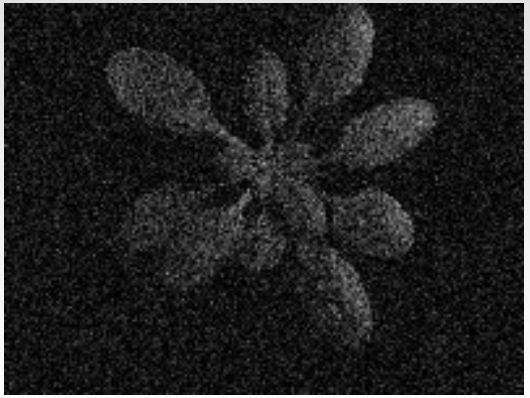
select frequencies

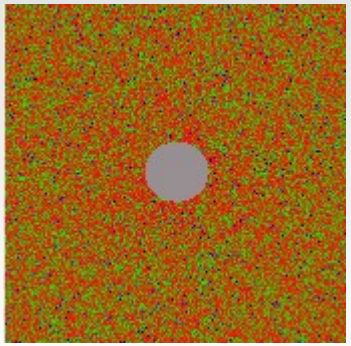


Inverse FFT

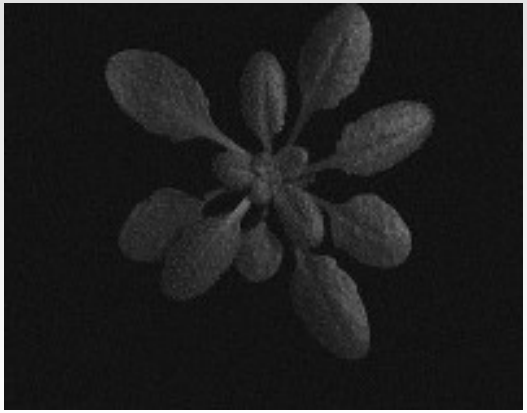


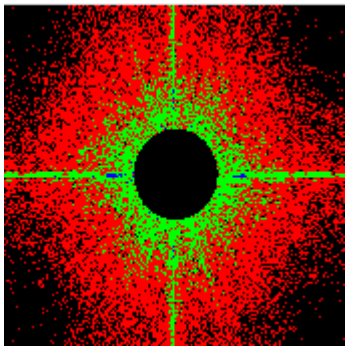
Filtering in the frequency domain



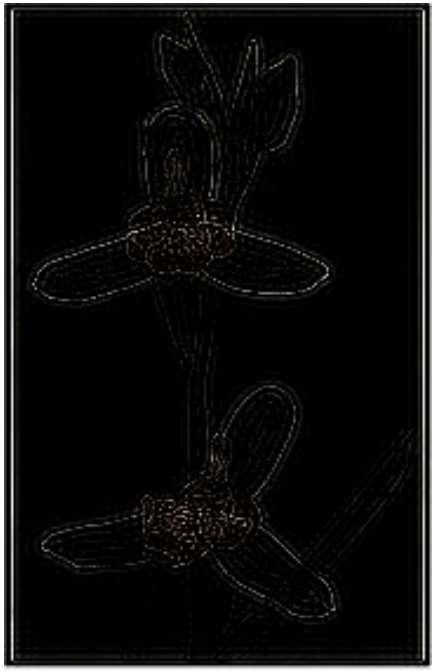


Low pass filter



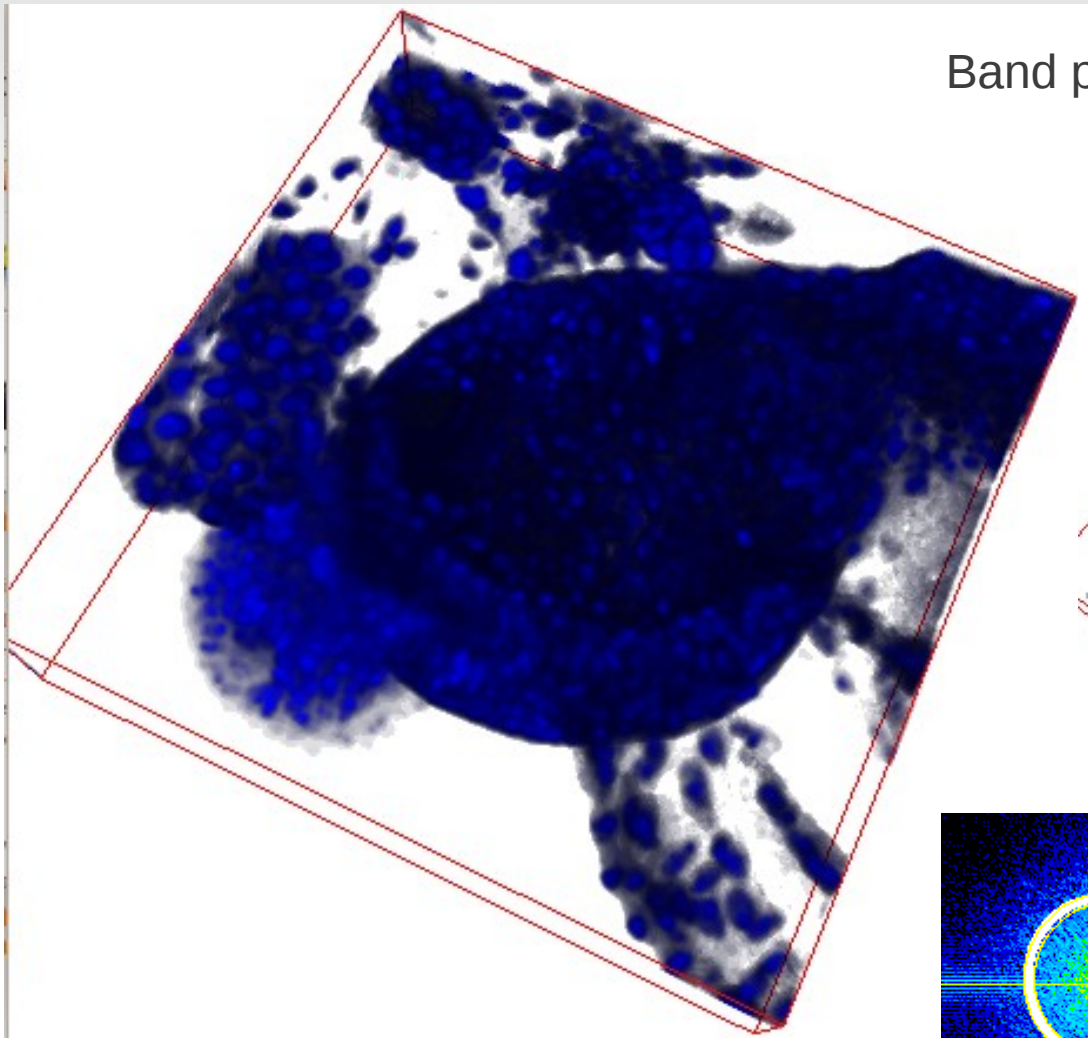


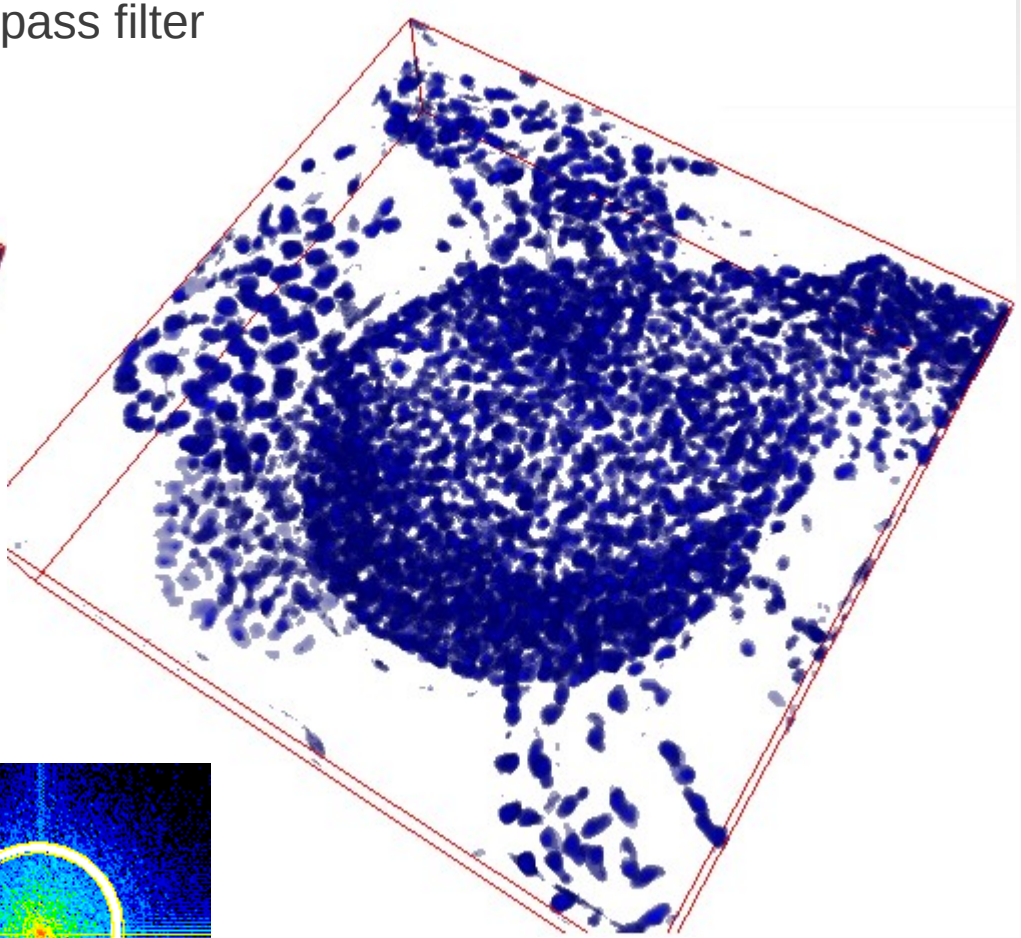
High pass filter



Filtering in the frequency domain

Band pass filter





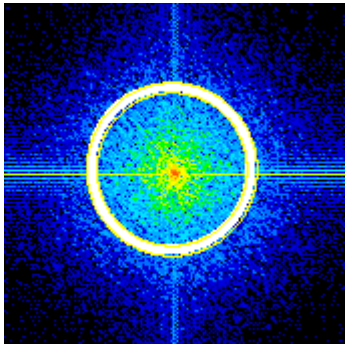
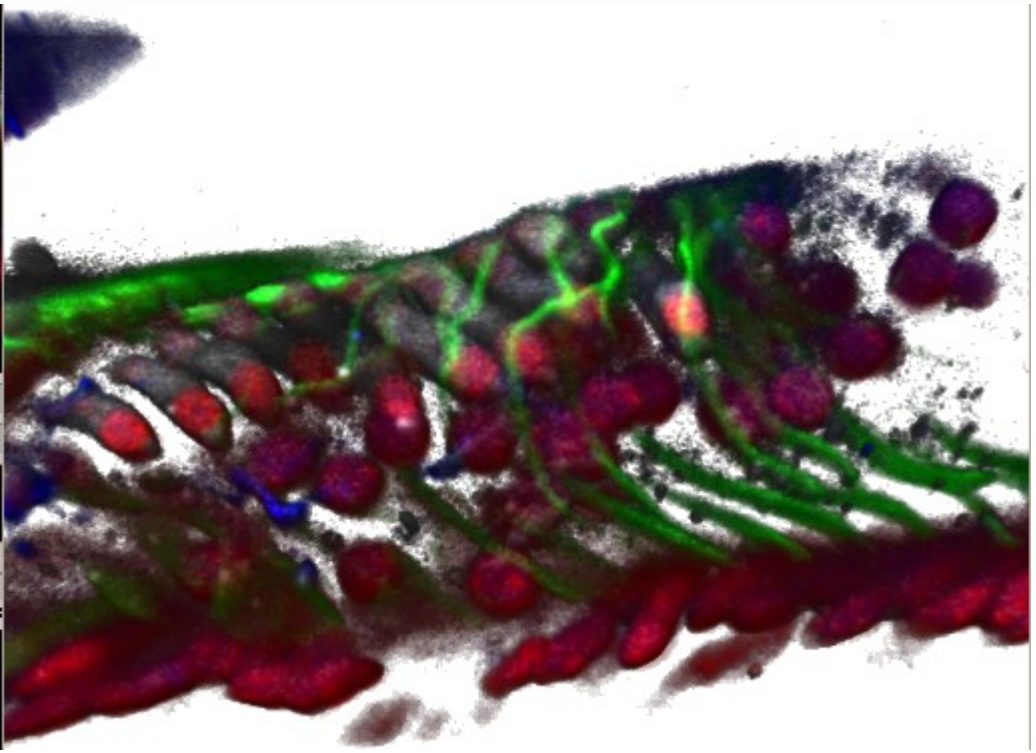


Image Restoration

- Image degraded
  - Noise
    - quantum nature of light (poisson distribution)
    - imperfect electronics (gaussian distribution)
  - Background
    - imperfect illumination
  - Blur
    - out of focus light

Image Restoration – Noise reduction

- Mean Filter, Gaussian filter, Median filter
- Nonlinear diffusion filtering (anisotropic diffusion, Perona–Malik)
  - Smooth noise while keeping edges



• pde based approach
• inhomogeneous process that reduces the diffusivity at those locations which have a larger likelihood to be edges

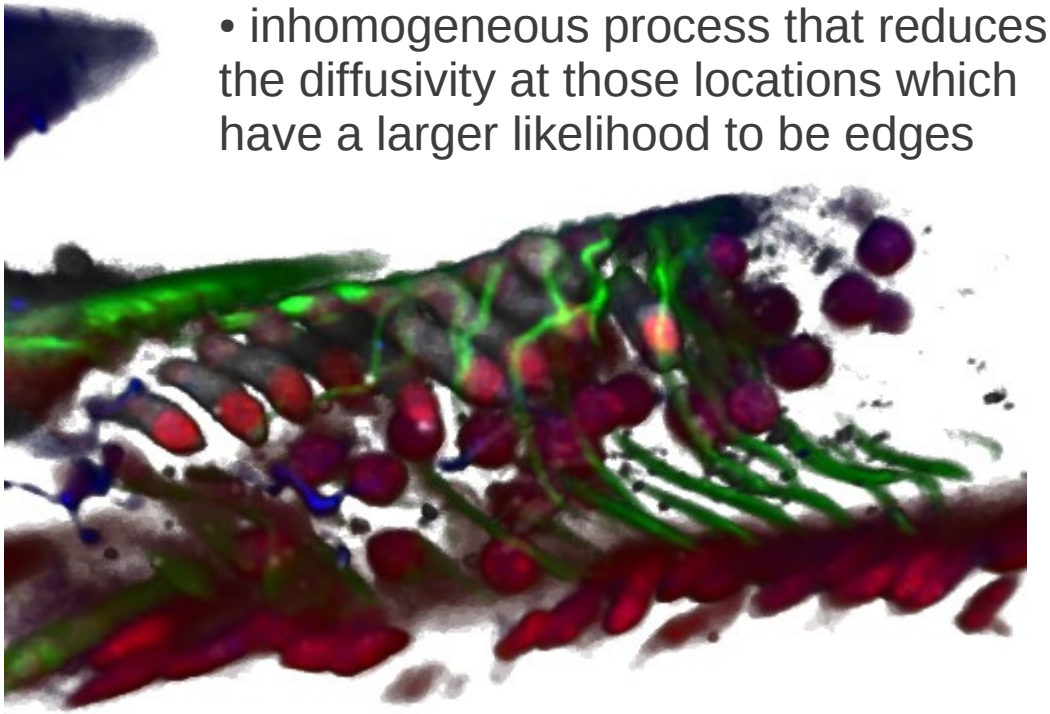
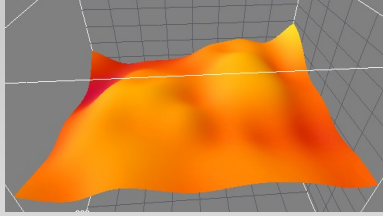
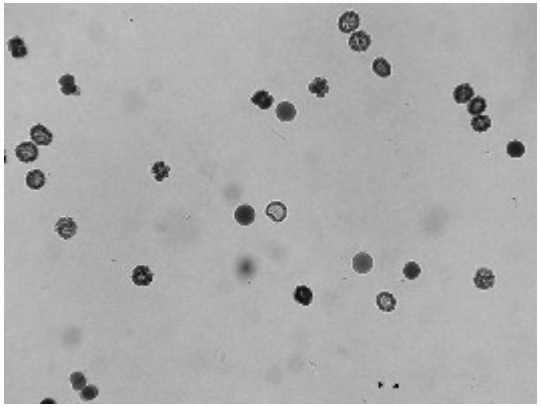
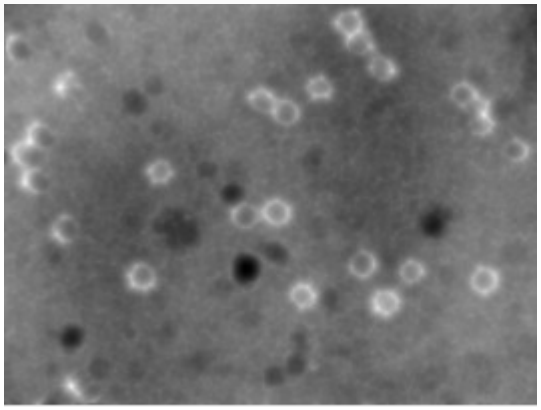


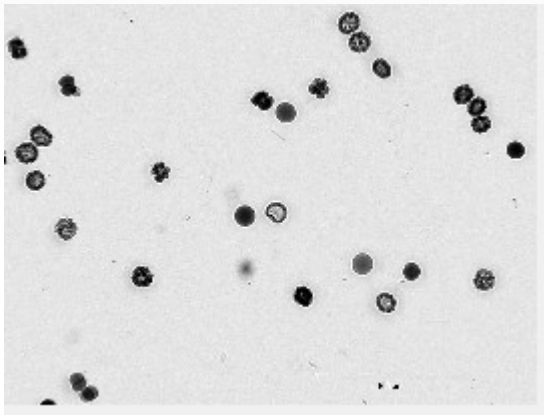
Image Restoration - Background subtraction

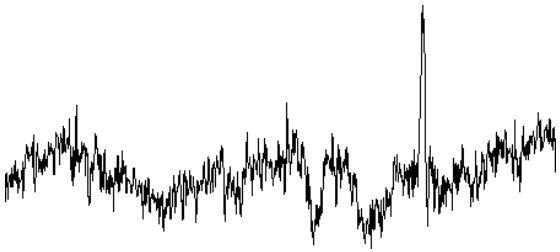


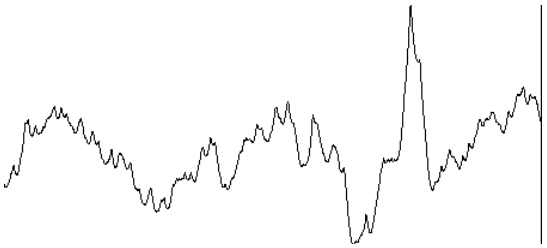
- correct inhomogenous illumination
  - correct with image of background $\frac{I}{B} \cdot mean(B)$
  - if not available: estimate background image











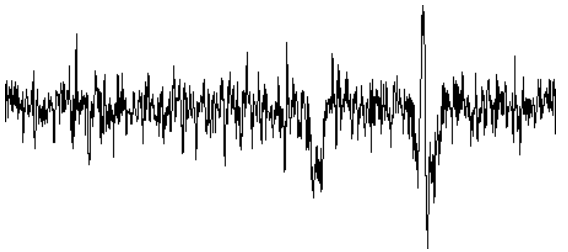
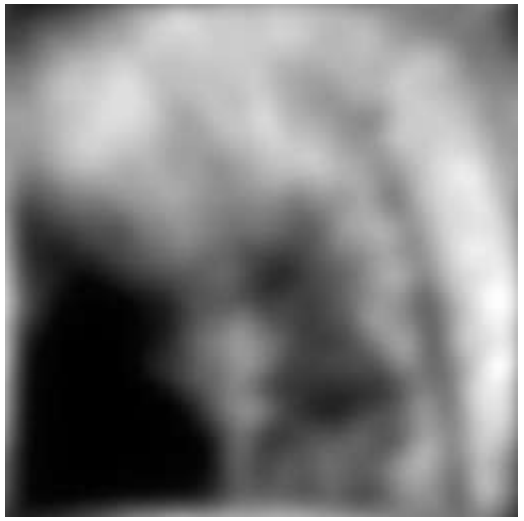
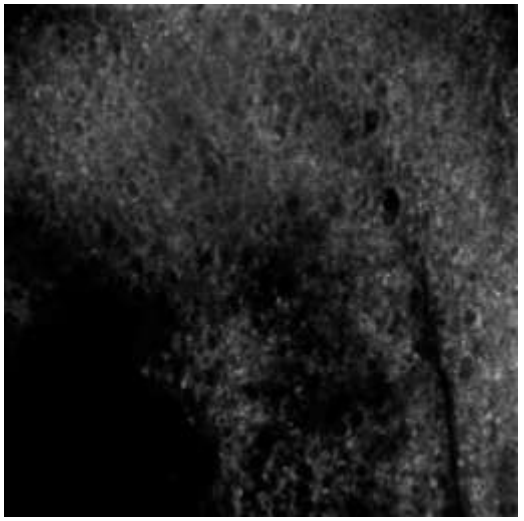


Image Restoration - Deconvolution

- blur
  - diffraction
  - out-of-focus light
- acquired image = object function convolved with psf



=



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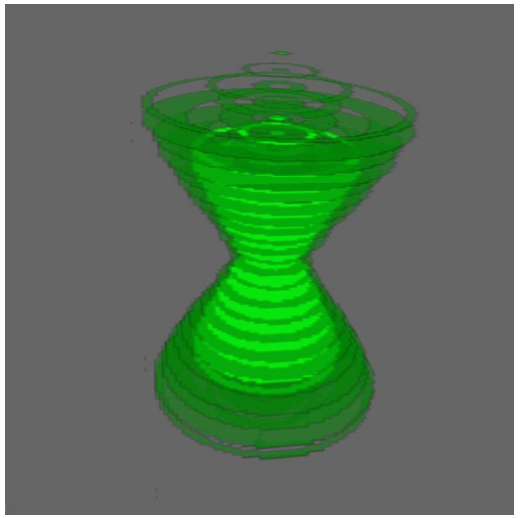
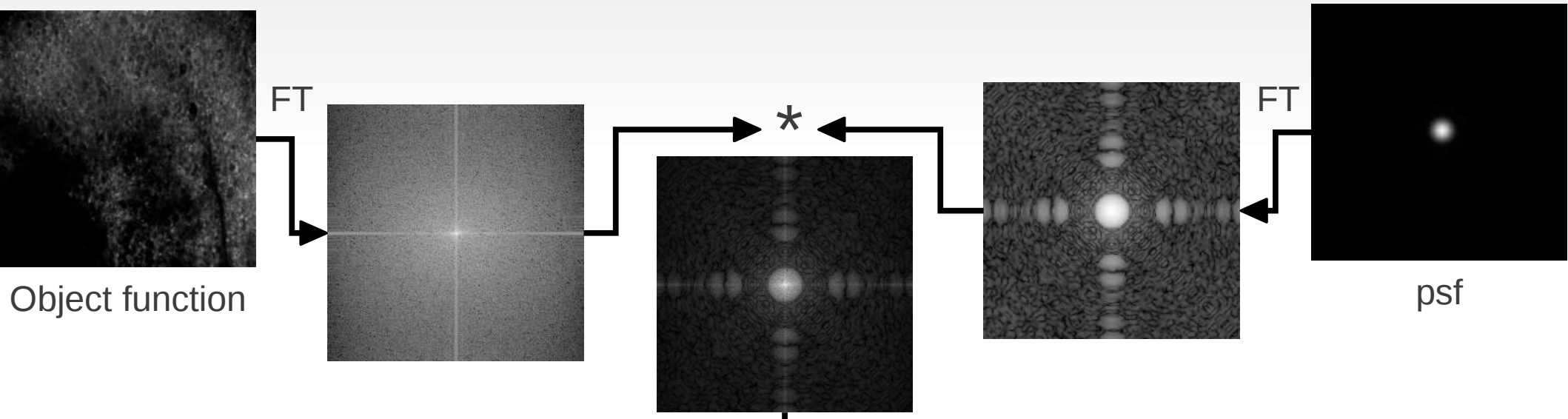


Deconvolution - Convolution theorem

$$i(x) = \int f(x') * g(x - x')\,dx \quad <=> \quad I = F * G$$




```
i(x) : aquired image
f(x) : object function
g(x) : psf

I fourier transform of i
F fourier transform of f
G fourier transform of g
```

Object function convolved with psf

Deconvolution

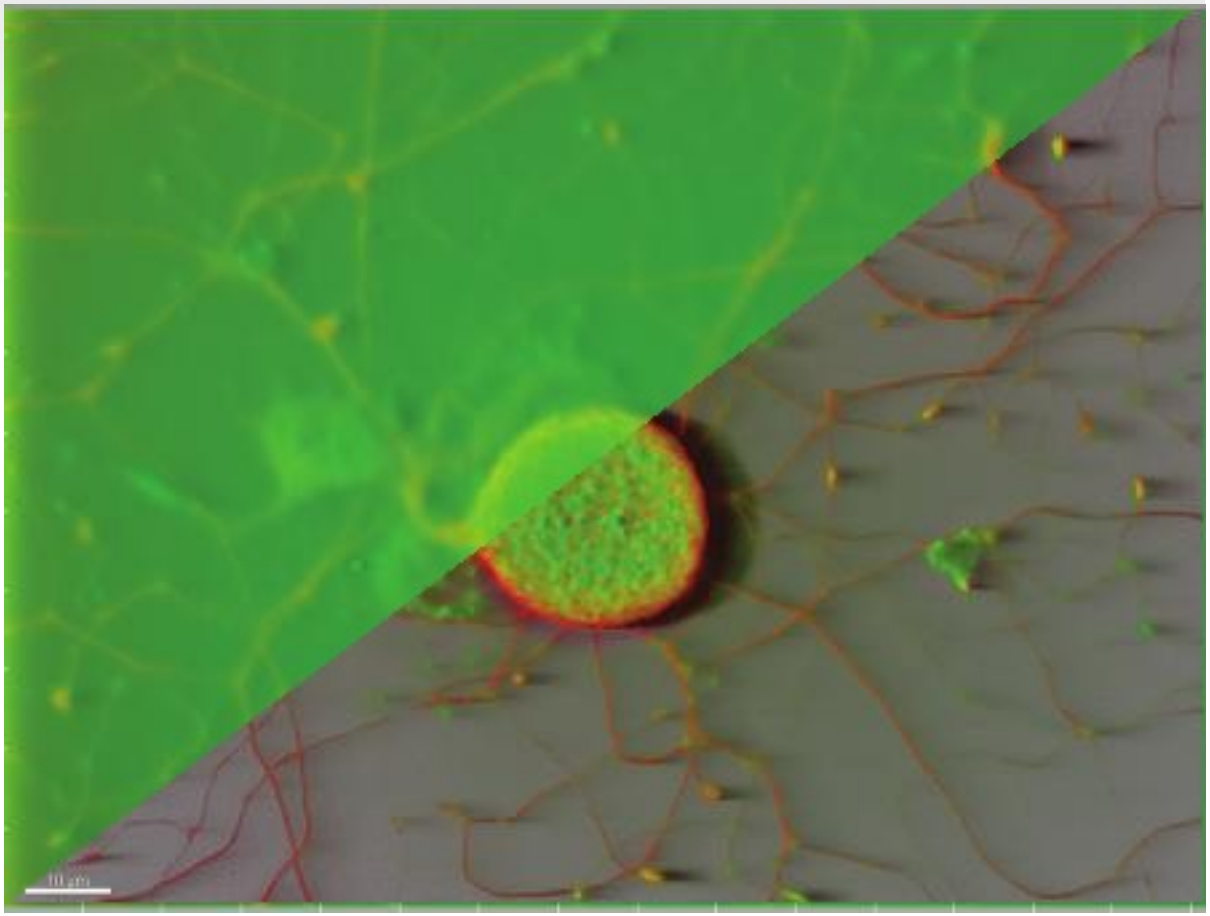
$$i(x)=\int f(x')*g(x-x')dx' \quad <=> \quad I=F*G$$

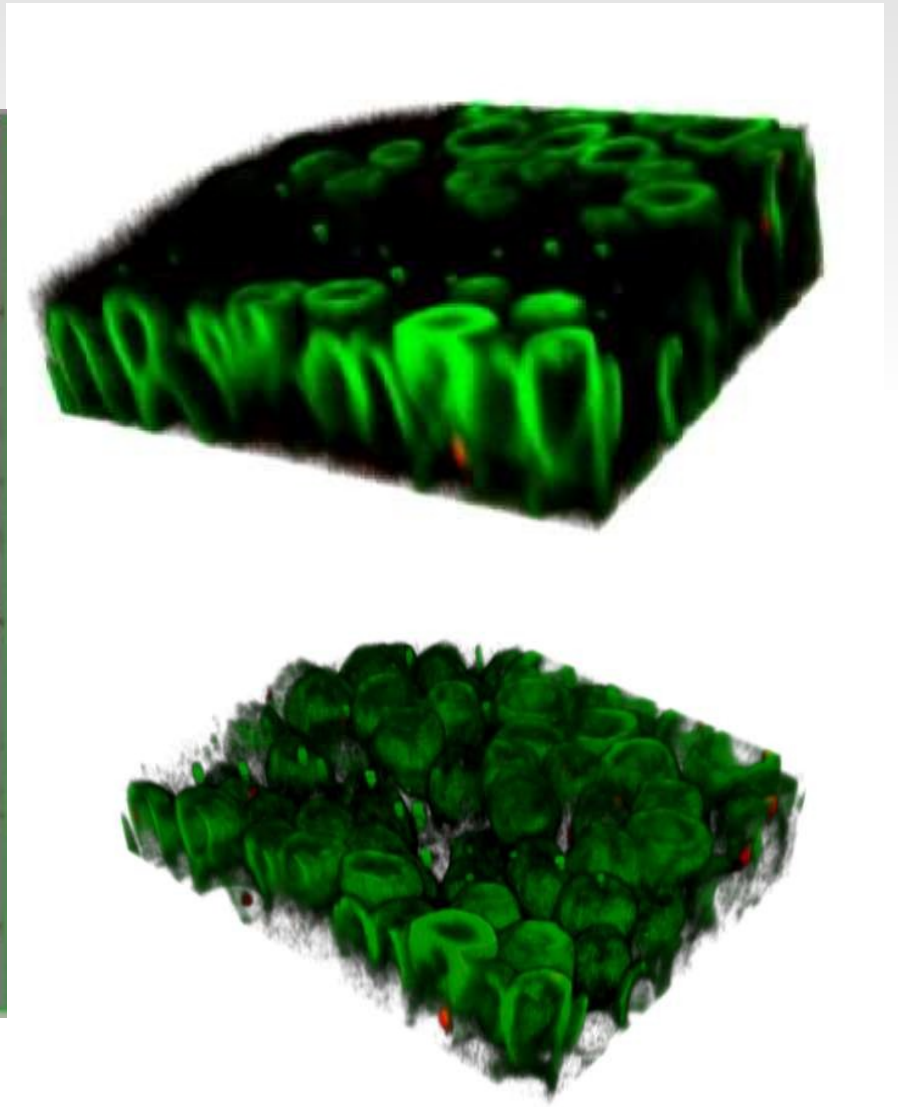
- Deconvolution:
  find object function f for given image i and psf g
- Unfortunatly it is not practicable to compute $F=\frac{I}{G}$
  - G has zeros outside certain regions
    - Setting F zero for these would create artefacts
  - In practice there is noise $I=F*G+N$
    - N/G would amplify noise
- **It's not possible to reconstruct the real object function**

Deconvolution algorithms

- Solution
  - Find an algorithm that computes a function f' so that
    - f' estimates f as good as possible
    - works in the presence of noise
- Different deconvolution algorithms exist
- In general best for fluorescent microscopy:
  - (Classical) Maximum Liklihood Estimation - MLE

Deconvolution - examples



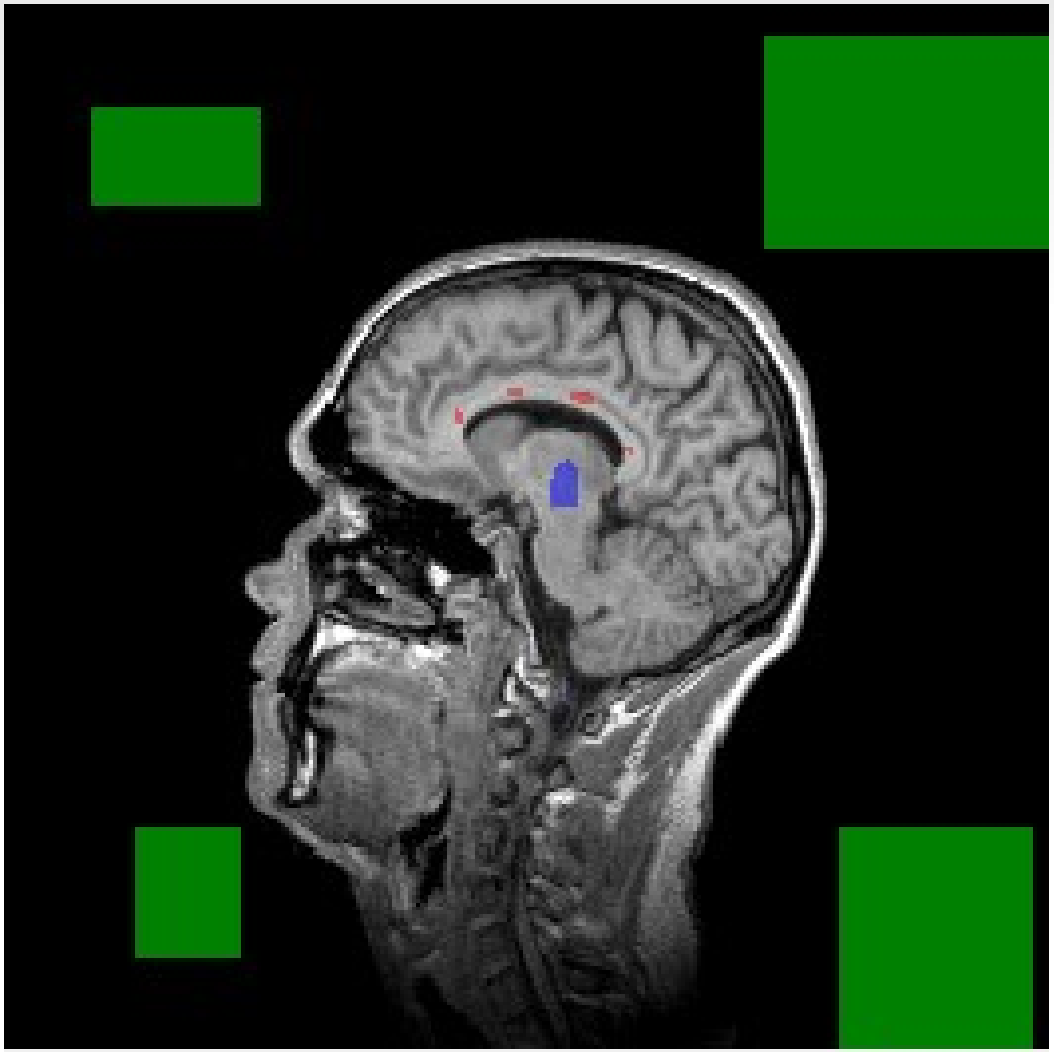


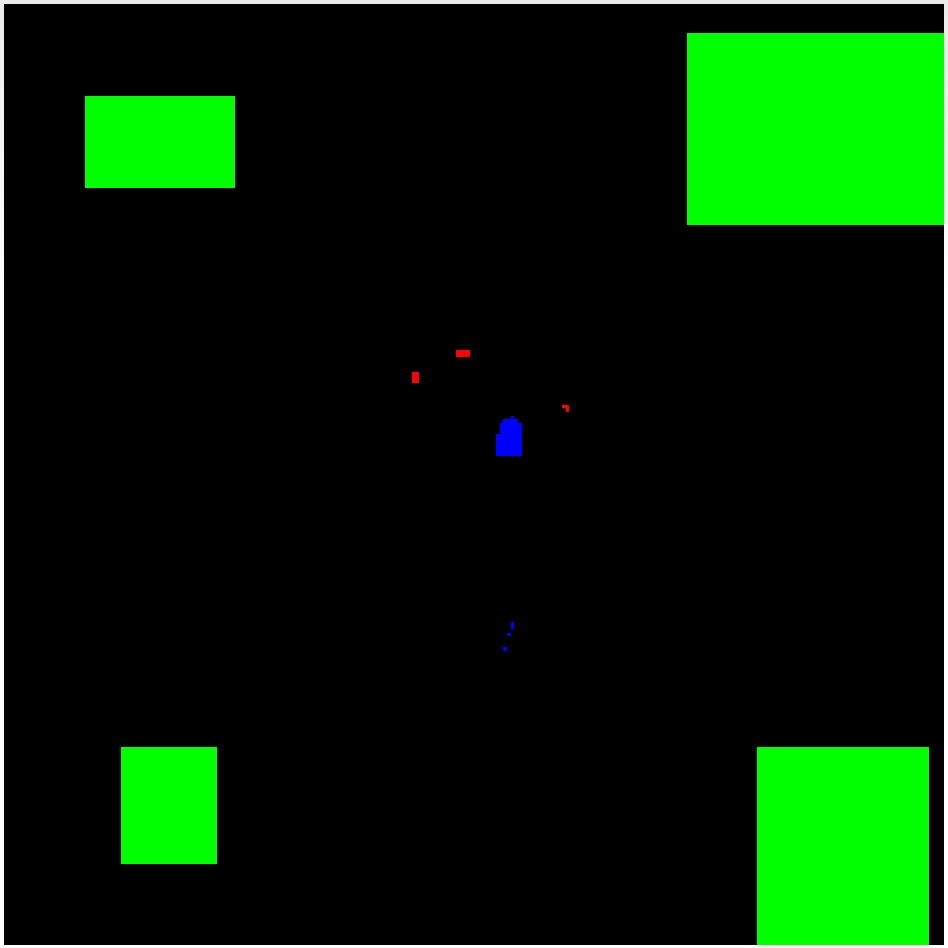
Segmentation

- separate objects from background and objects from each other
  - region growing
  - clustering
  - watershed transform

Segmentation - region growing

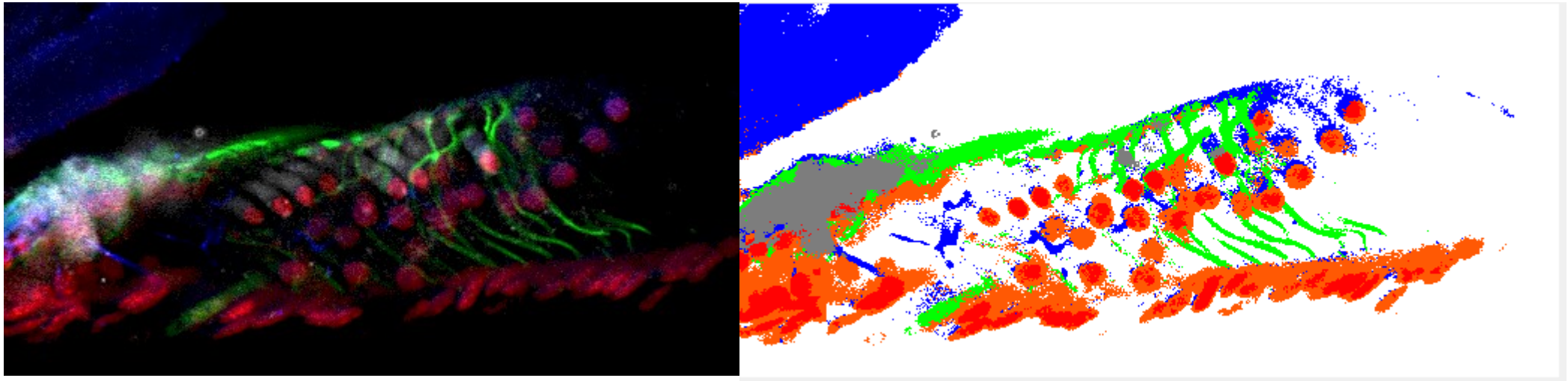
- start from seed-points
- simultaneously grow regions
- stop according to a homogenity criterium





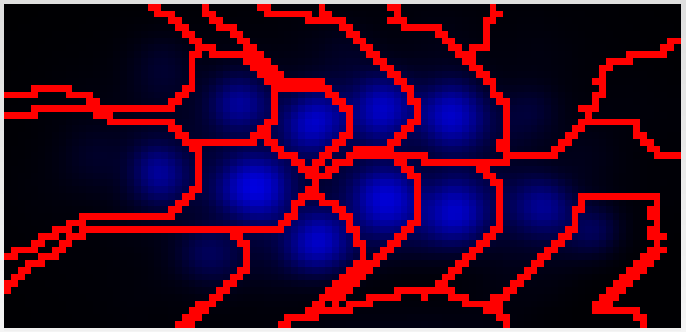
Segmentation - clustering

- k-means clustering
  - interpret channel values as coordinate vectors in space
  - partition space around mean values into k-clusters
  - iterative, optimization algorithm

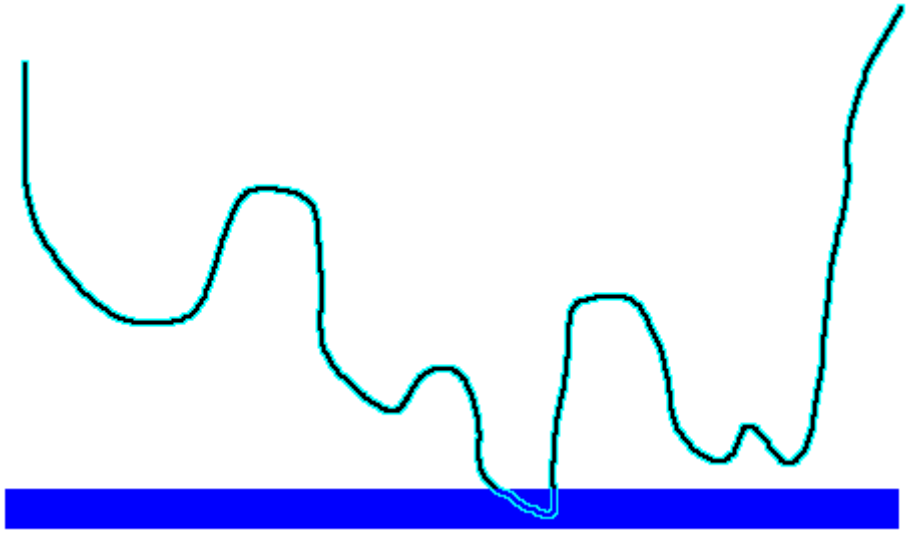


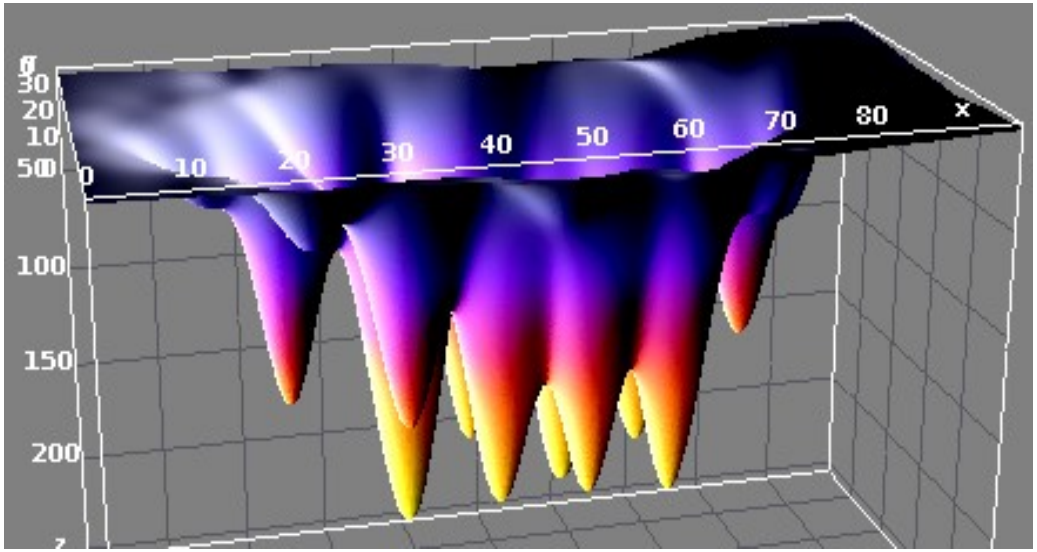
6 clusters

Segmentation - Watershed

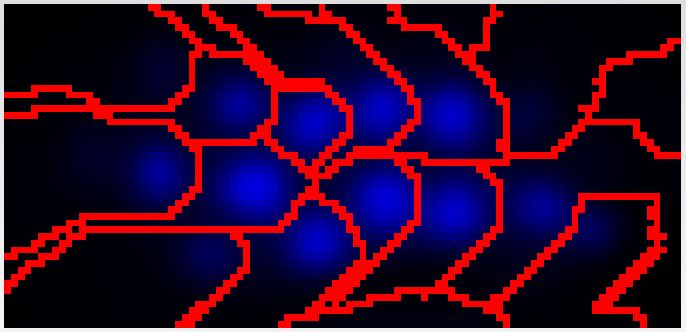


- interpret intensity as valleys
- fill slowly with rising water
- whenever two basins join create a separation





Segmentation - Watershed



- interpret intensity as valleys
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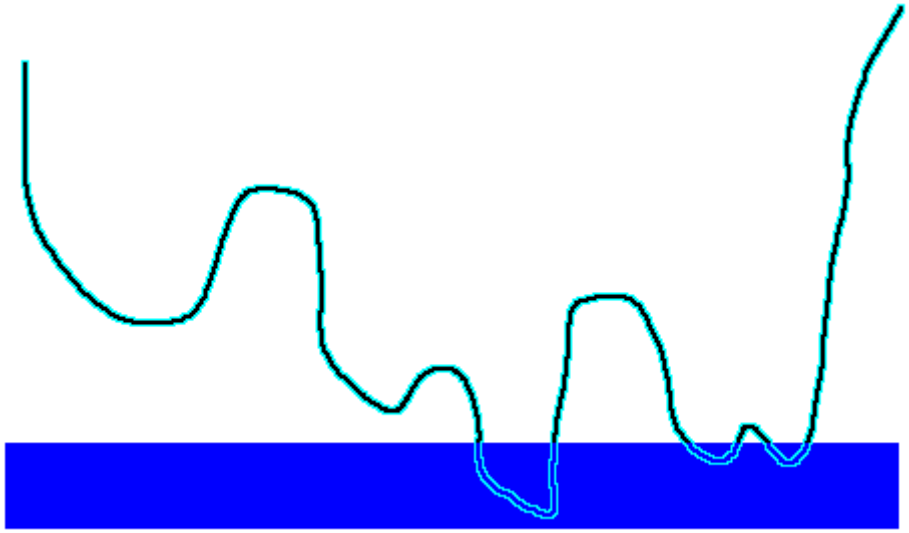
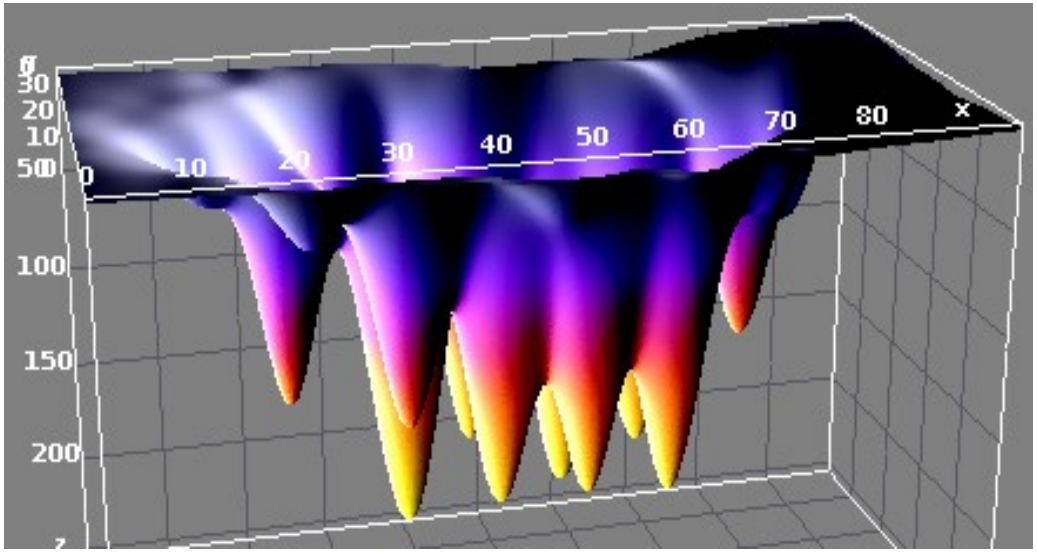
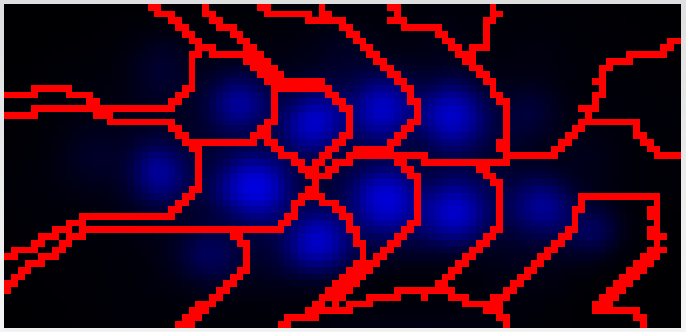
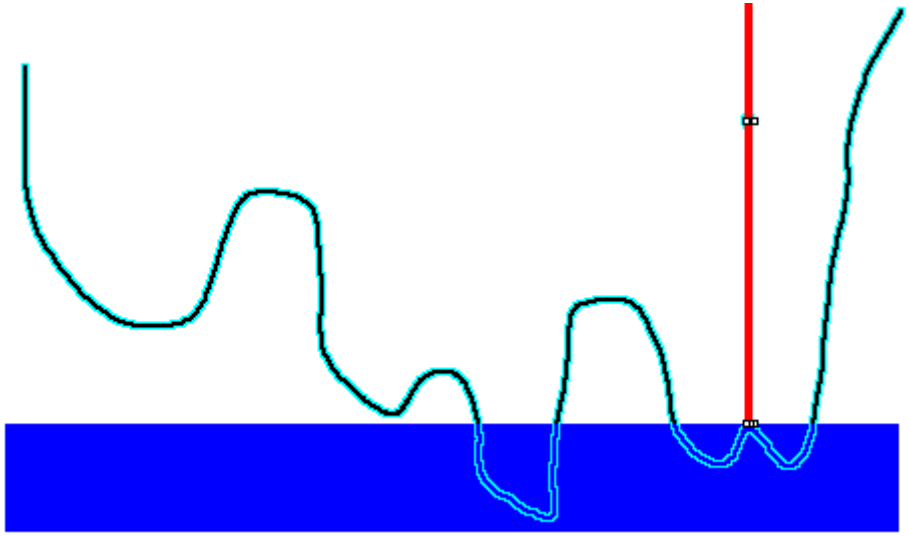


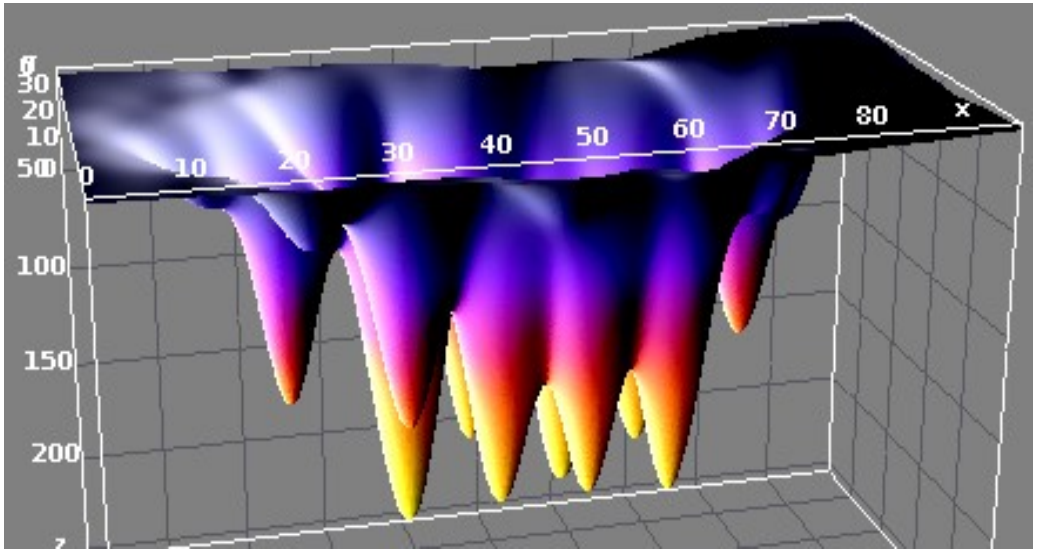


Segmentation - Watershed

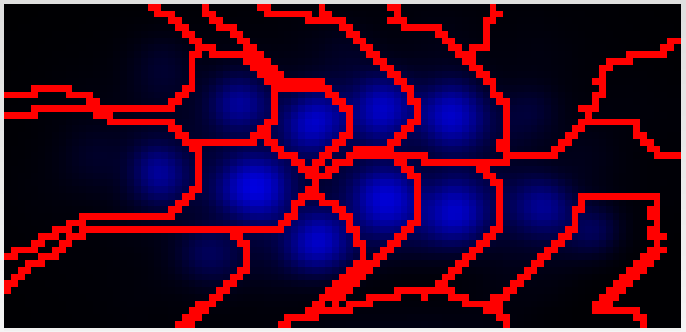


- interpret intensity as valleys
- fill slowly with rising water
- whenever two basins join create a separation





Segmentation - Watershed



- interpret intensity as valleys
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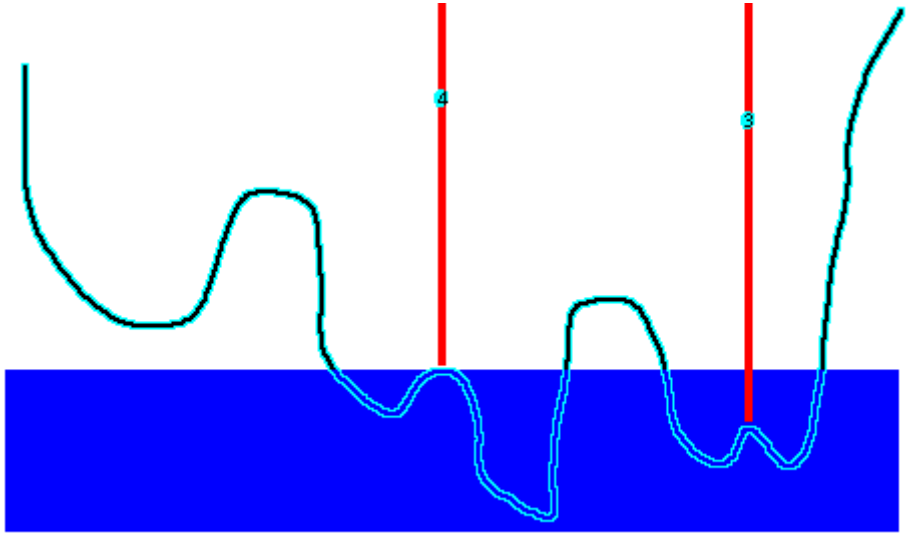
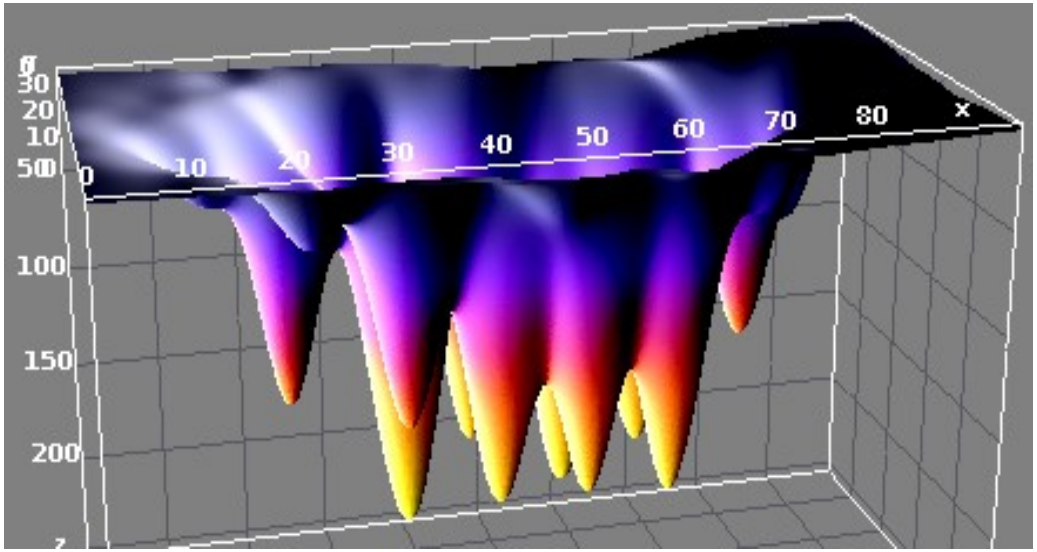
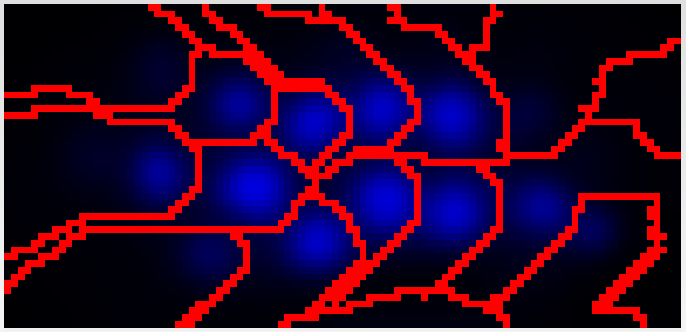




Segmentation - Watershed



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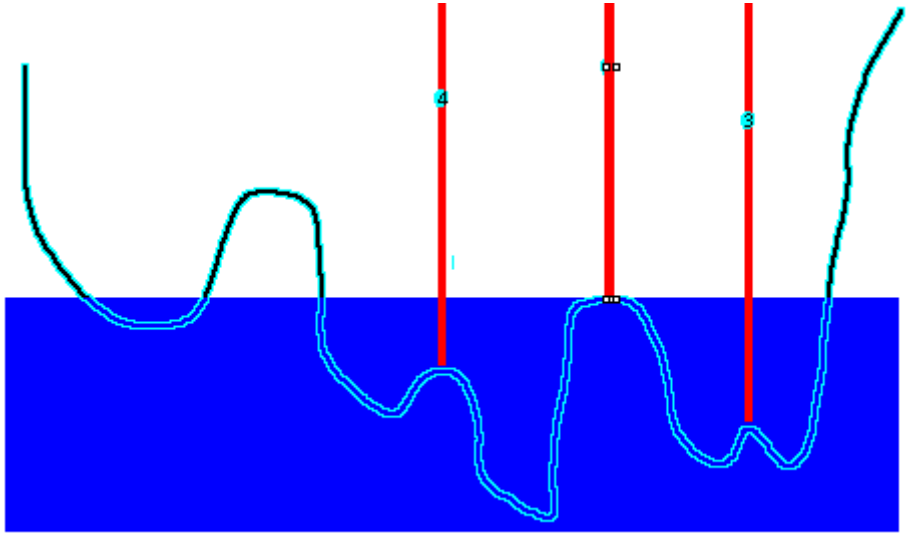
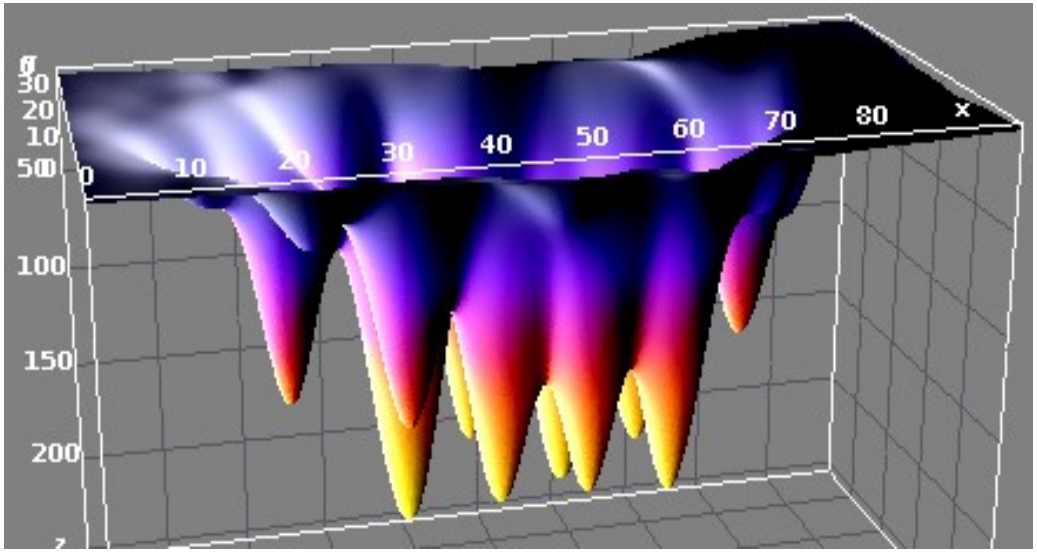
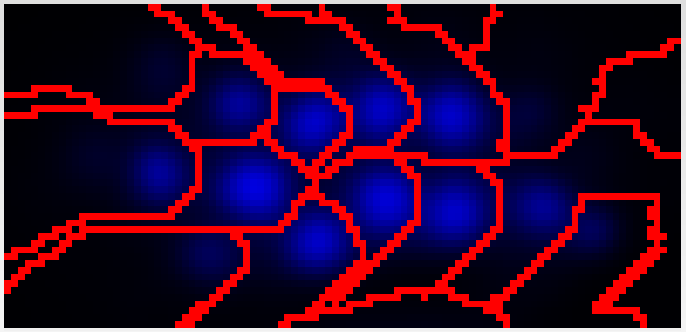




Segmentation - Watershed



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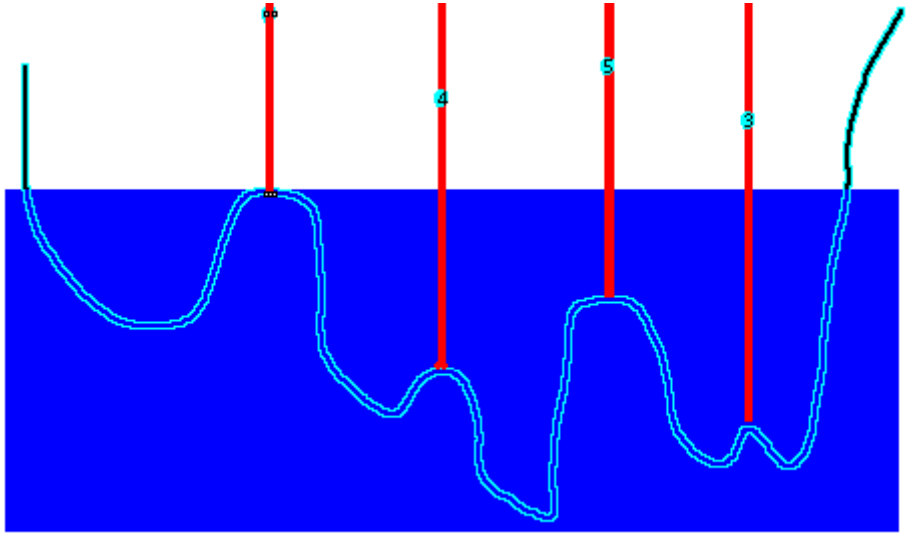
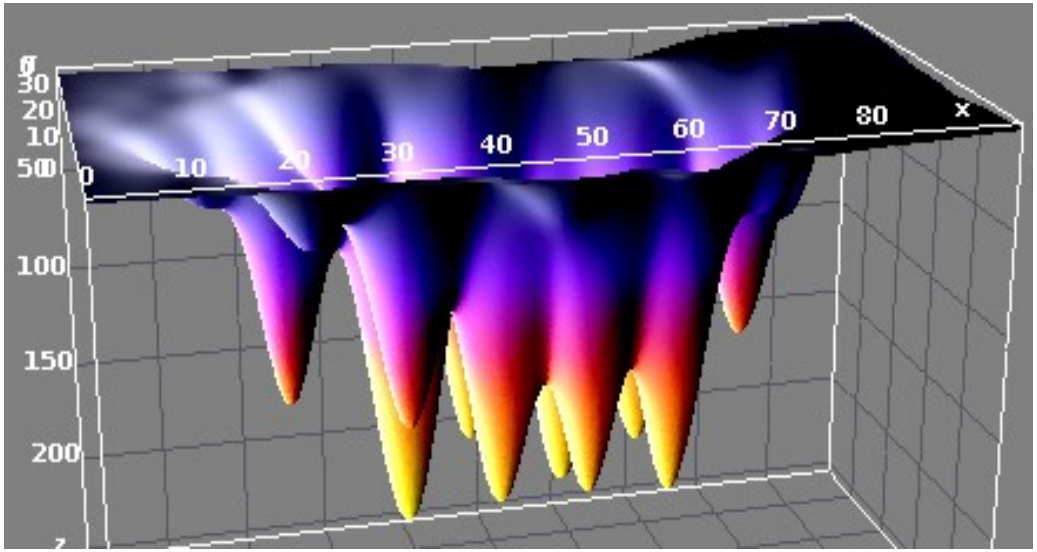
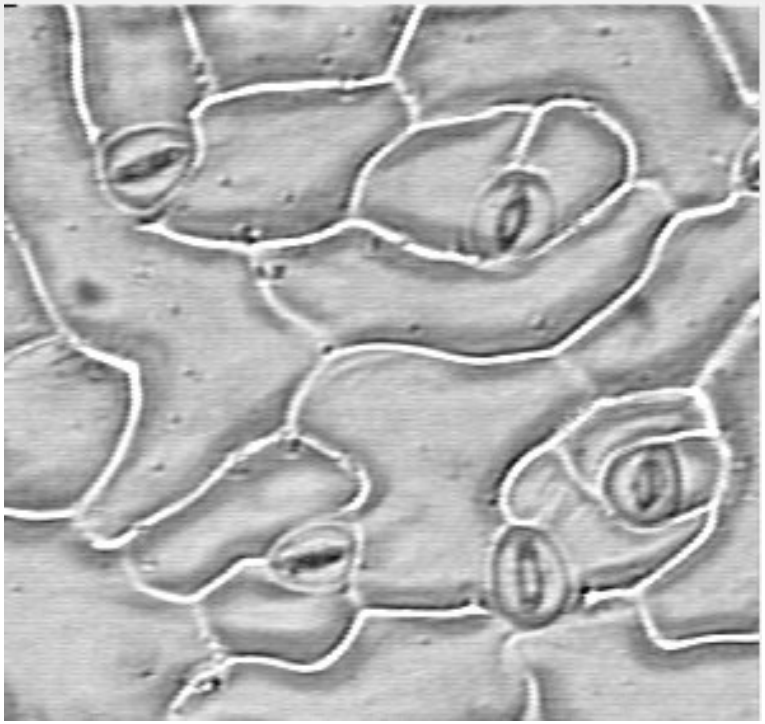
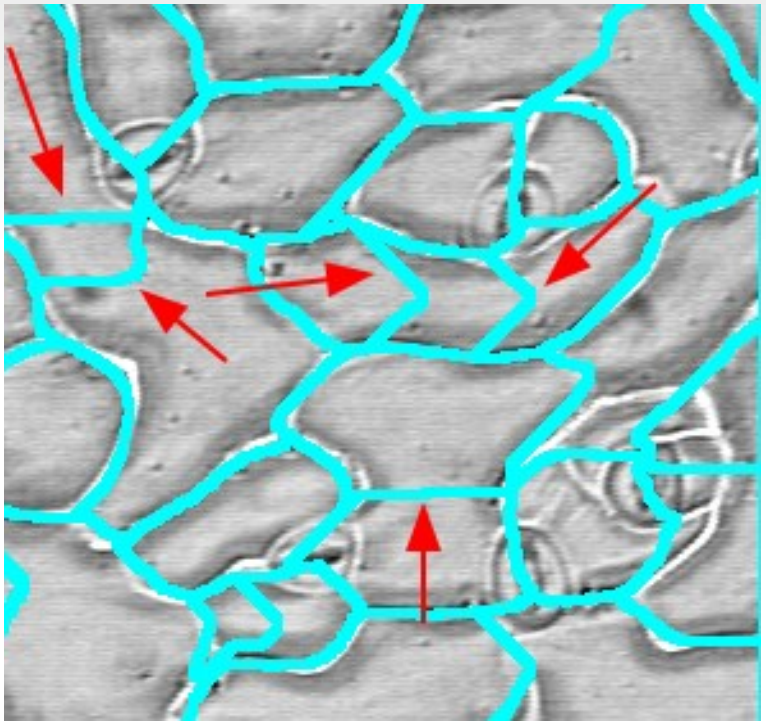




Segmentation - Watershed

- problem: over-segmentation





possible solution: seeded watershed

- number of final basins = number of seeds

Geomectrical Transformation

- problem:
  - image is spatially distorted or
    - mismatch between channels due to chromatic aberration
    - barrel distortion or pincushion distortion
    - speciman moved during acquisition
  - lacks spatial correspondence
    - histological slices
    - combining images from different sources
    - stitching of images of a mosaic
- solution:
  - image registration or alignment

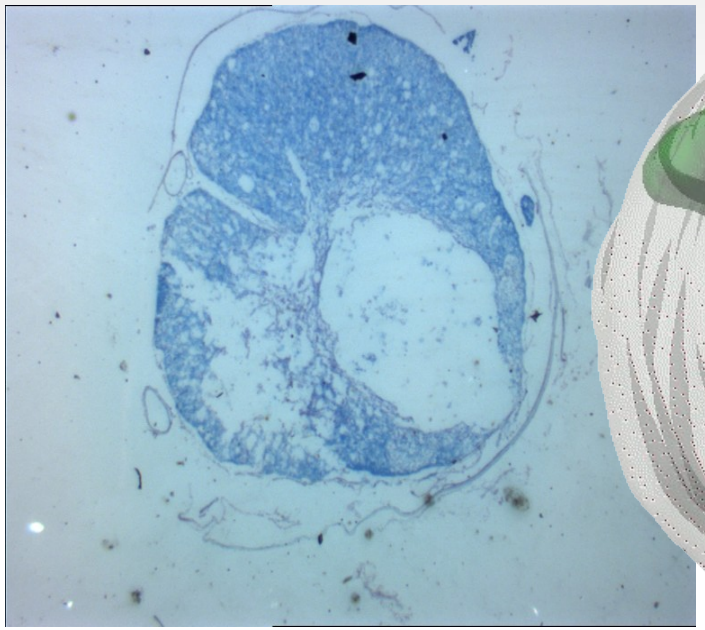
Image Registration

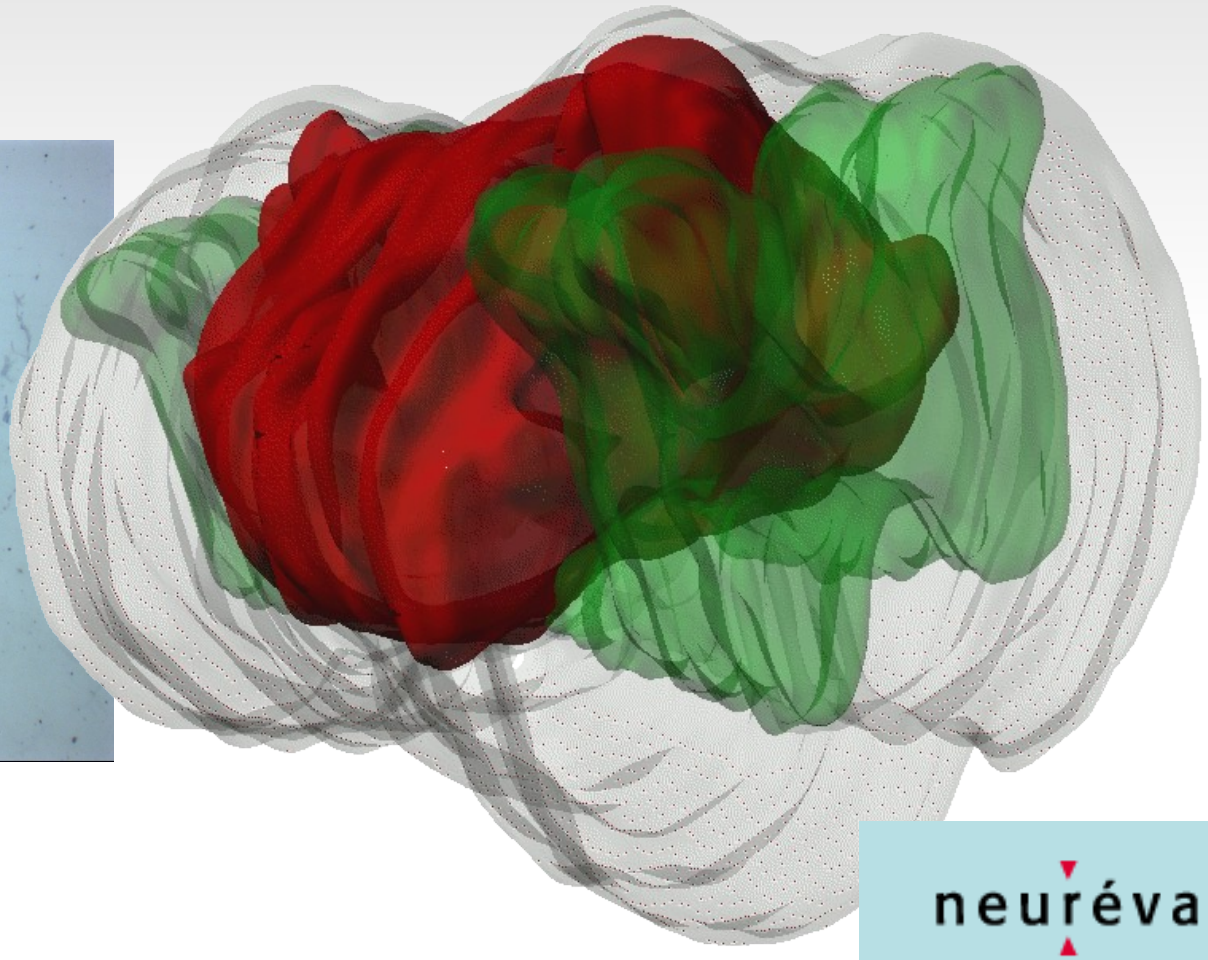
- Image registration
  - coordinate transformation
    - landmark based
      - manually selected
      - automtically extracted
    - intensity based
      - calculate match between images
    - possible transformations
      - rigid, affine, curved
  - resampling
    - interpolation
      - nearest neighbor, linear, cubic spline

Example Registration

Nathalie Cochennec-Laureau
Ifremer
Centre Océanologique du Pacifique
Laboratoire Biotechnologie
et Qualité de la Perle (LBQP)
Tahiti

Example Registration

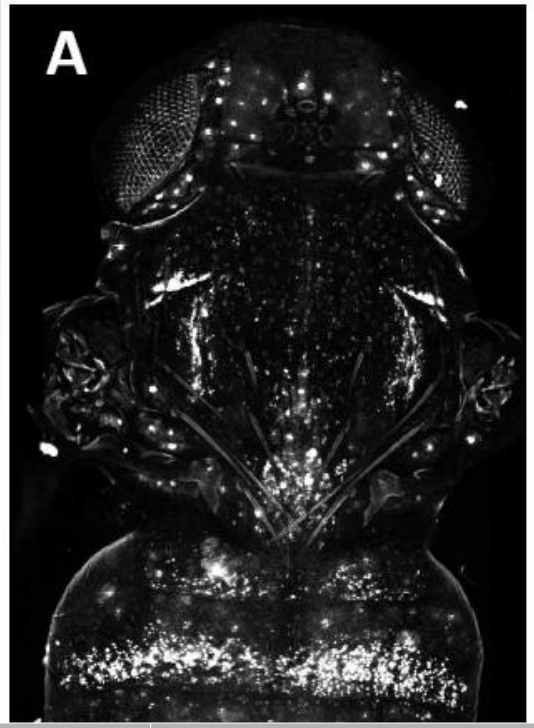


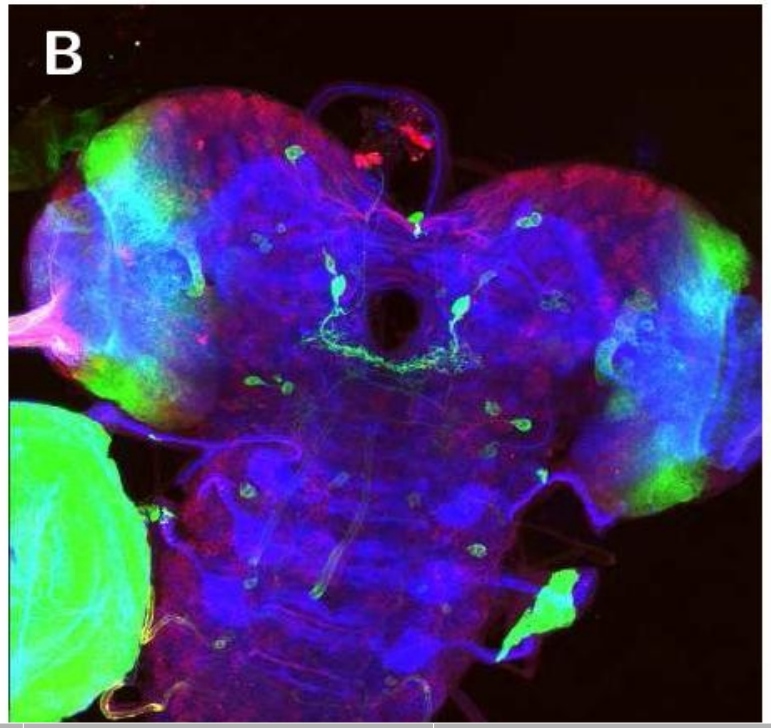


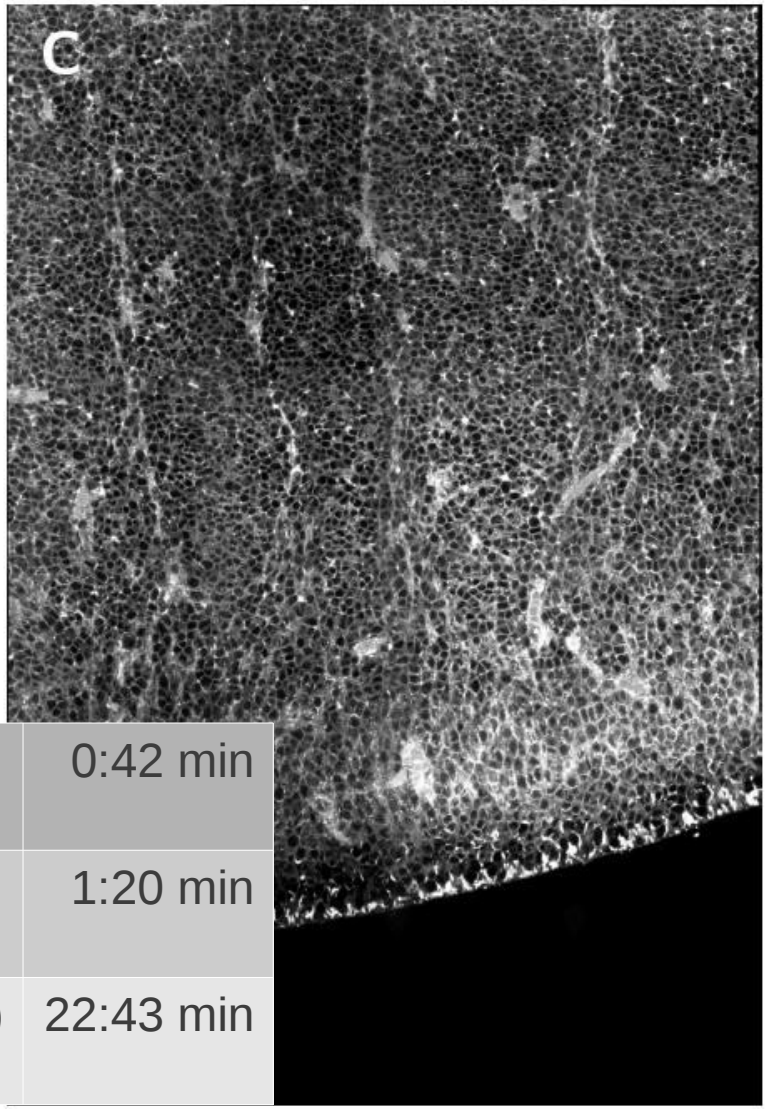
spinal cord
grey matter
traumatic lesion

neuréva

Example Stitching







3	1024×1024×42	1097×2345×43	108 MB (8 Bit)	0:42 min
6	512×512×86	975×1425×86	350 MB (RGB)	1:20 min
24	1024×1024×68	3570×5211×70	1200 MB (8 Bit)	22:43 min

http://fiji.sc/wiki/index.php/Stitching#Stitch_Image_Grid_Sequence

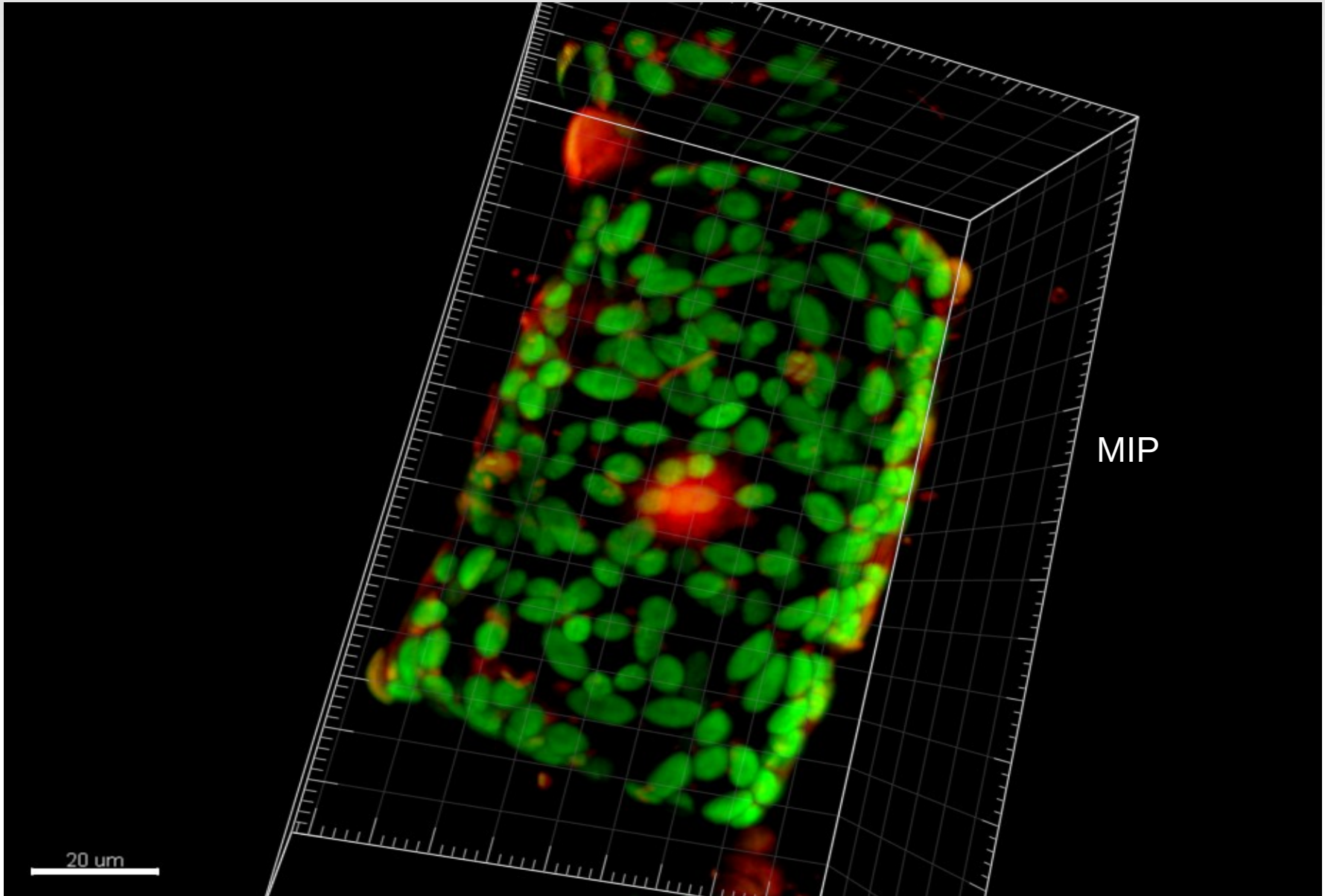
Visualization

- how to understand multidimensional data?
  - reduce dimensionality in a sensible way
- methods
  - volume rendering
    - methods that use the raw data directly without geometrical representation
      - ray tracing
        - maximum intensity projection (MIP)
        - blend (calculated from all information along the ray)
  - surface rendering
    - take into account only surfaces of objects
    - needs a description of the object in terms of geometrical entities

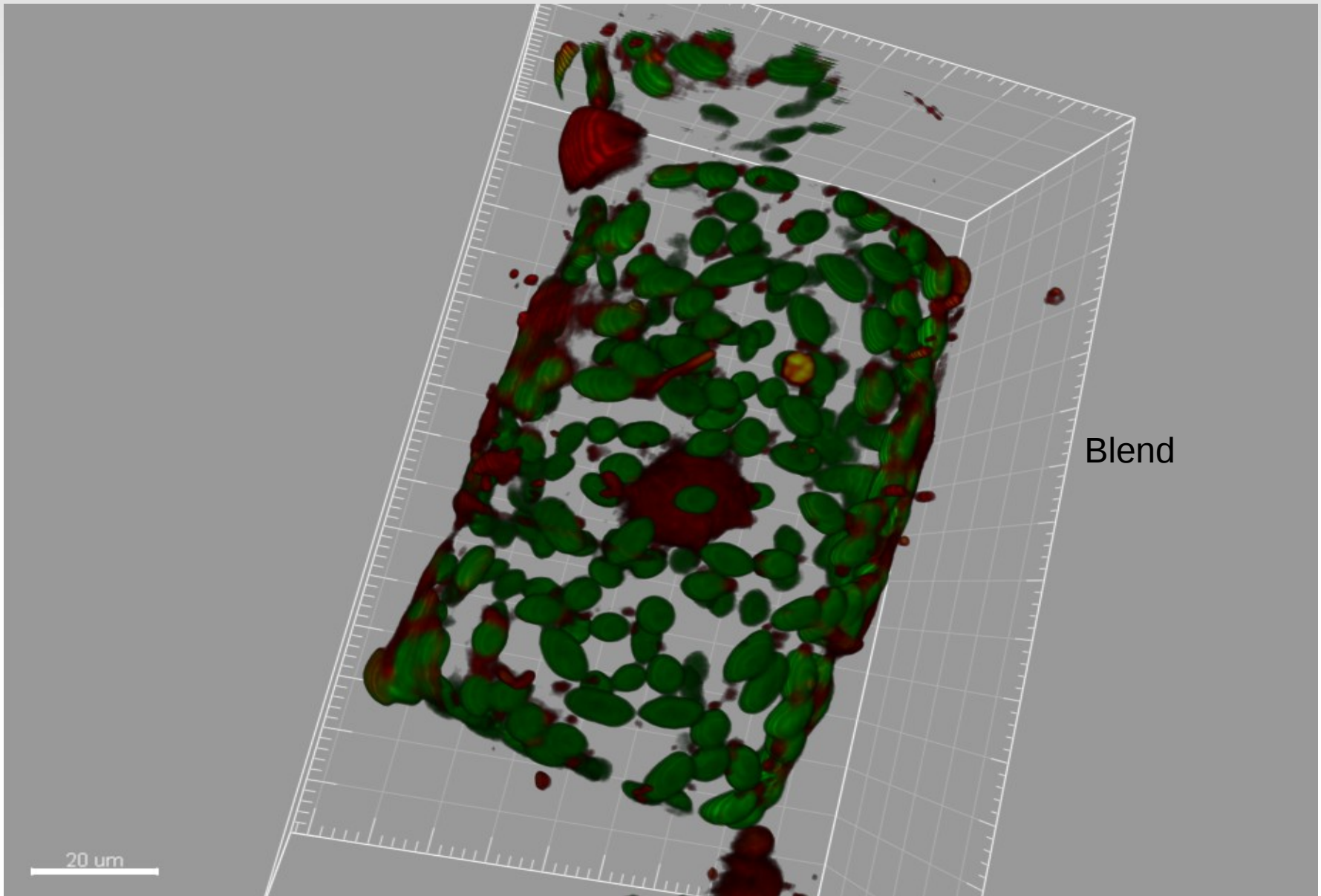
Visualization - Volume Rendering

- how does the volume interact with a ray of light
  - given position and parameters of the light source
  - given the position of the observer

Visualization - Volume Rendering



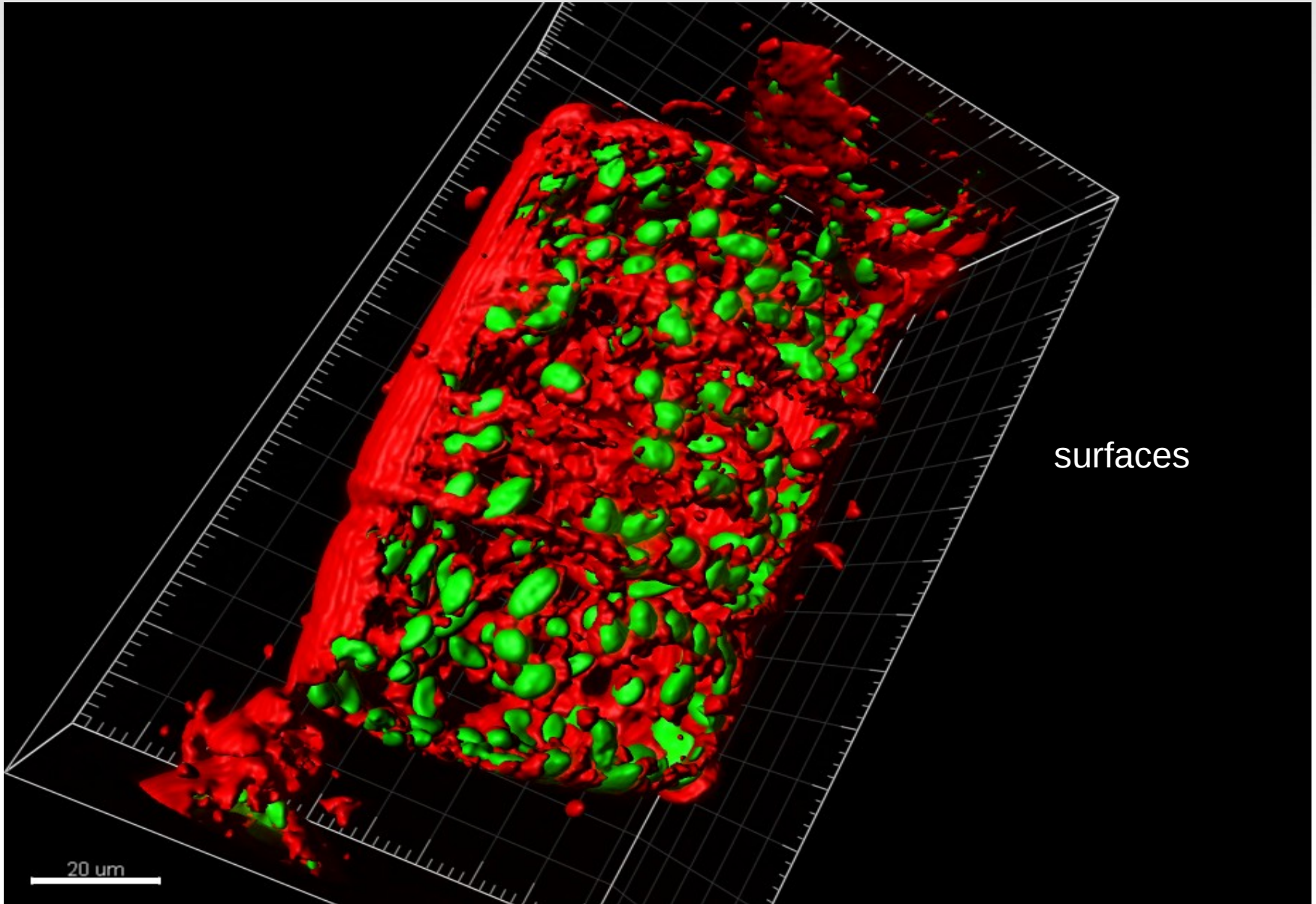
Visualization - Volume Rendering



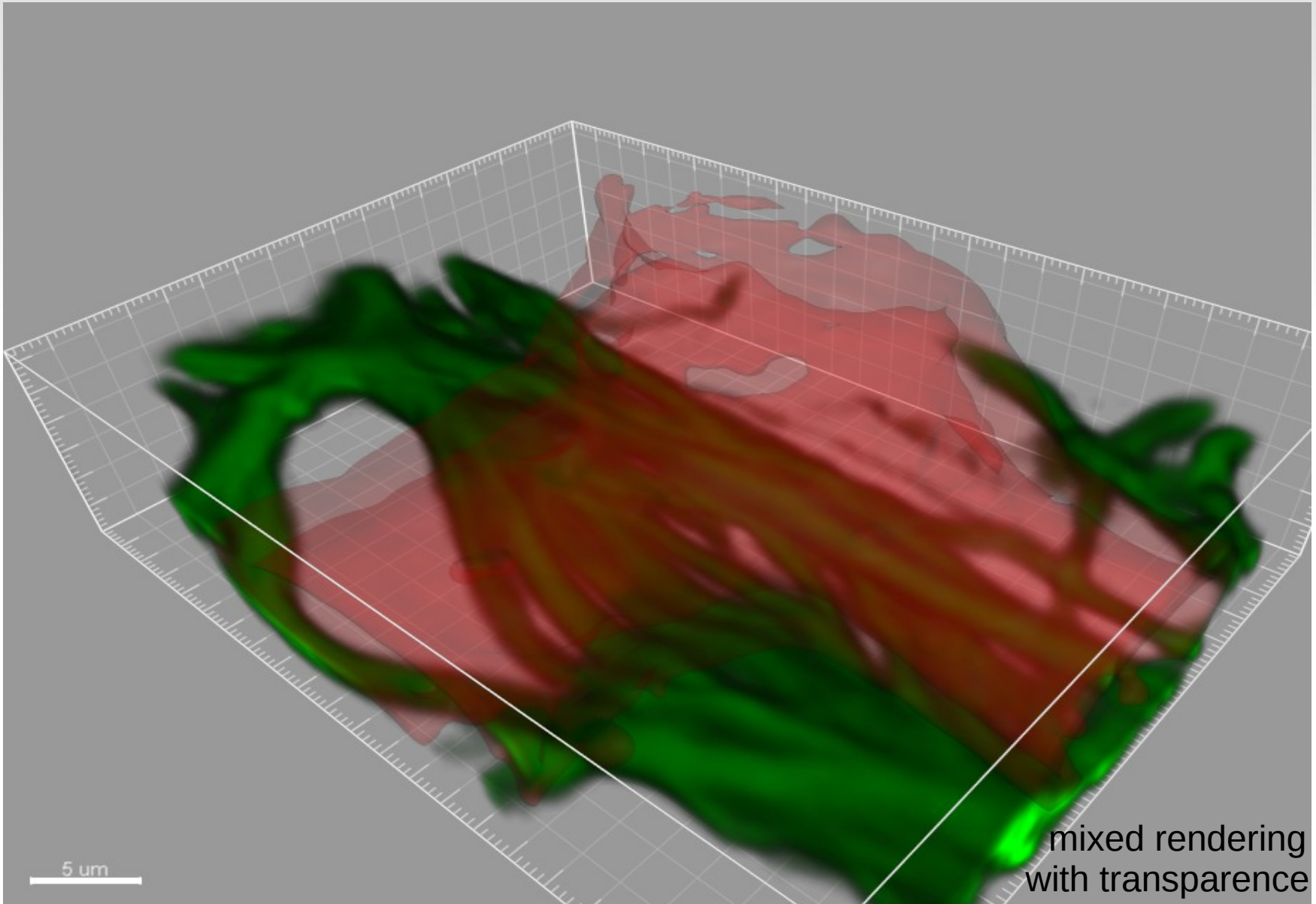
Visualization - Surface Rendering

- segmentation of the object
- surface triangulation
    - marching cubes algorithm

Visualization - Surface Rendering



Visualization - Mixed Rendering



Visualization - multi-scale data

- imagine you could in one image
  - zoom smoothly from
    - organism to
    - organ to
    - tissue to
    - cells to
    - molecules
- see for example msv-project
  Multiscale Spatiotemporal Visualisation
  (http://www.msv-project.eu)

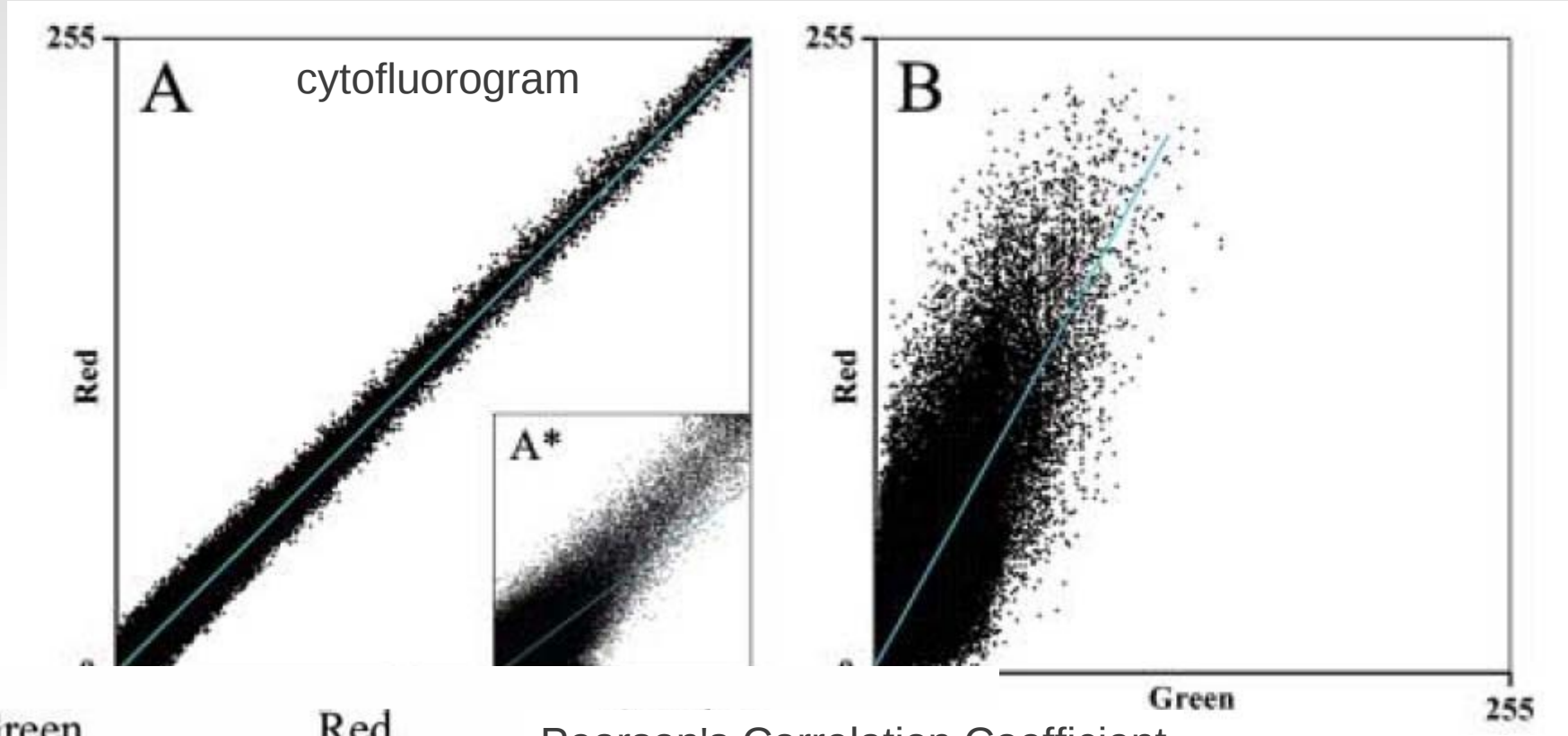
Colocalization Analysis

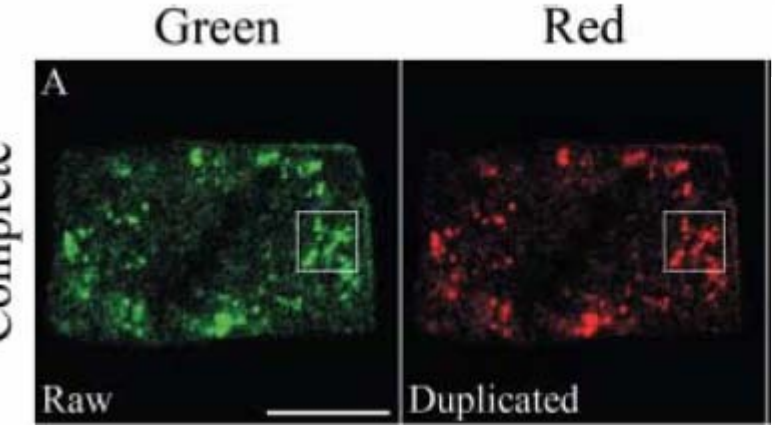
- Wikipedia:

  ”colocalization refers to observation of the spatial overlap between two (or more) different fluorescent labels, each having a separate emission wavelength, to see if the different "targets" are located in the same area of the cell or very near to one another. ”

- ”correlation, ... indicative of a biological interaction”

Colocalization Analysis



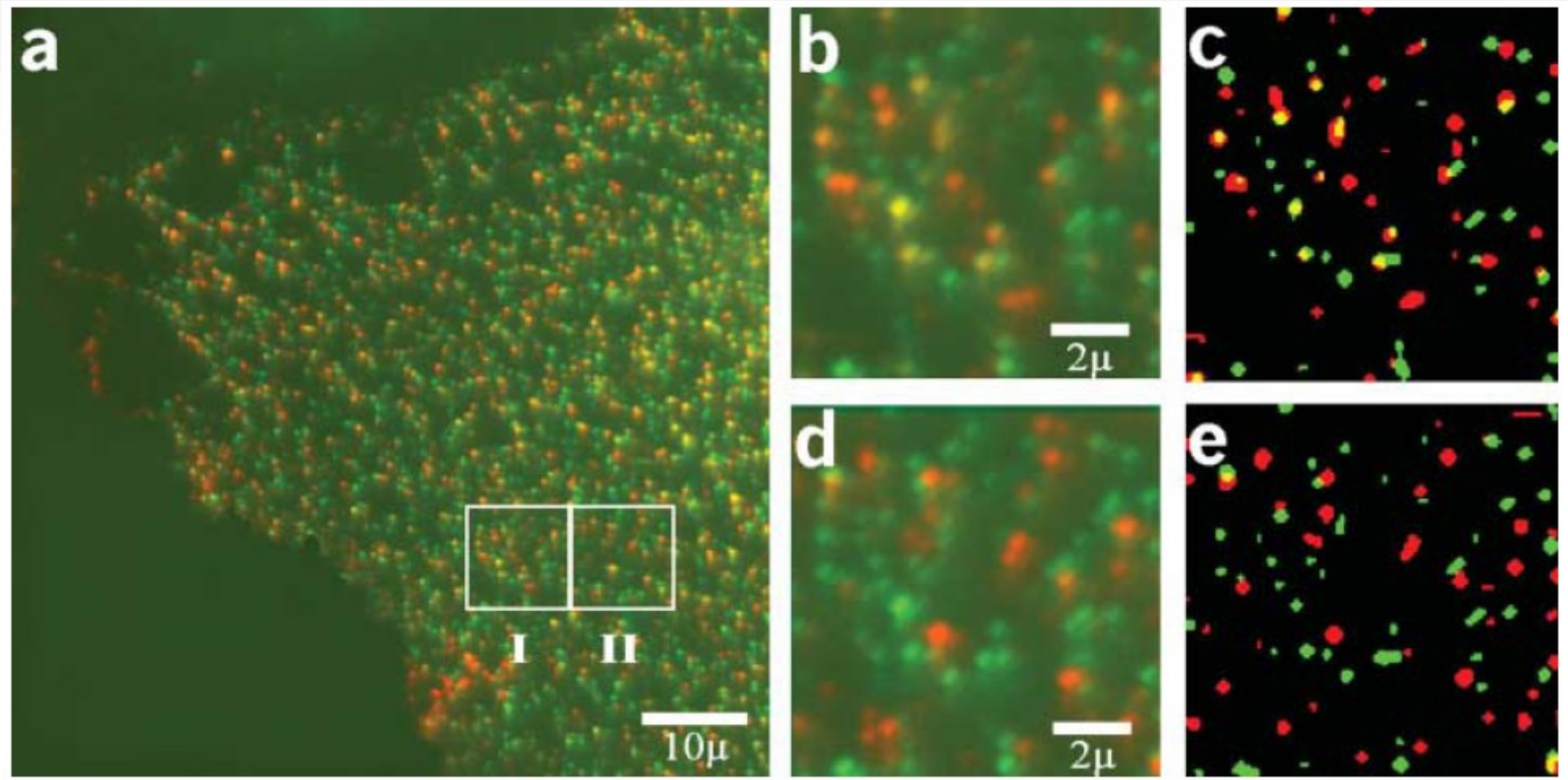


Pearson's Correlation Coefficient

$$r_p = \frac{\sum_i (A_i - a) \times (B_i - b)}{\sqrt{\sum_i (A_i - a)^2 \times \sum_i (B_i - b)^2}}$$

Colocalization Analysis

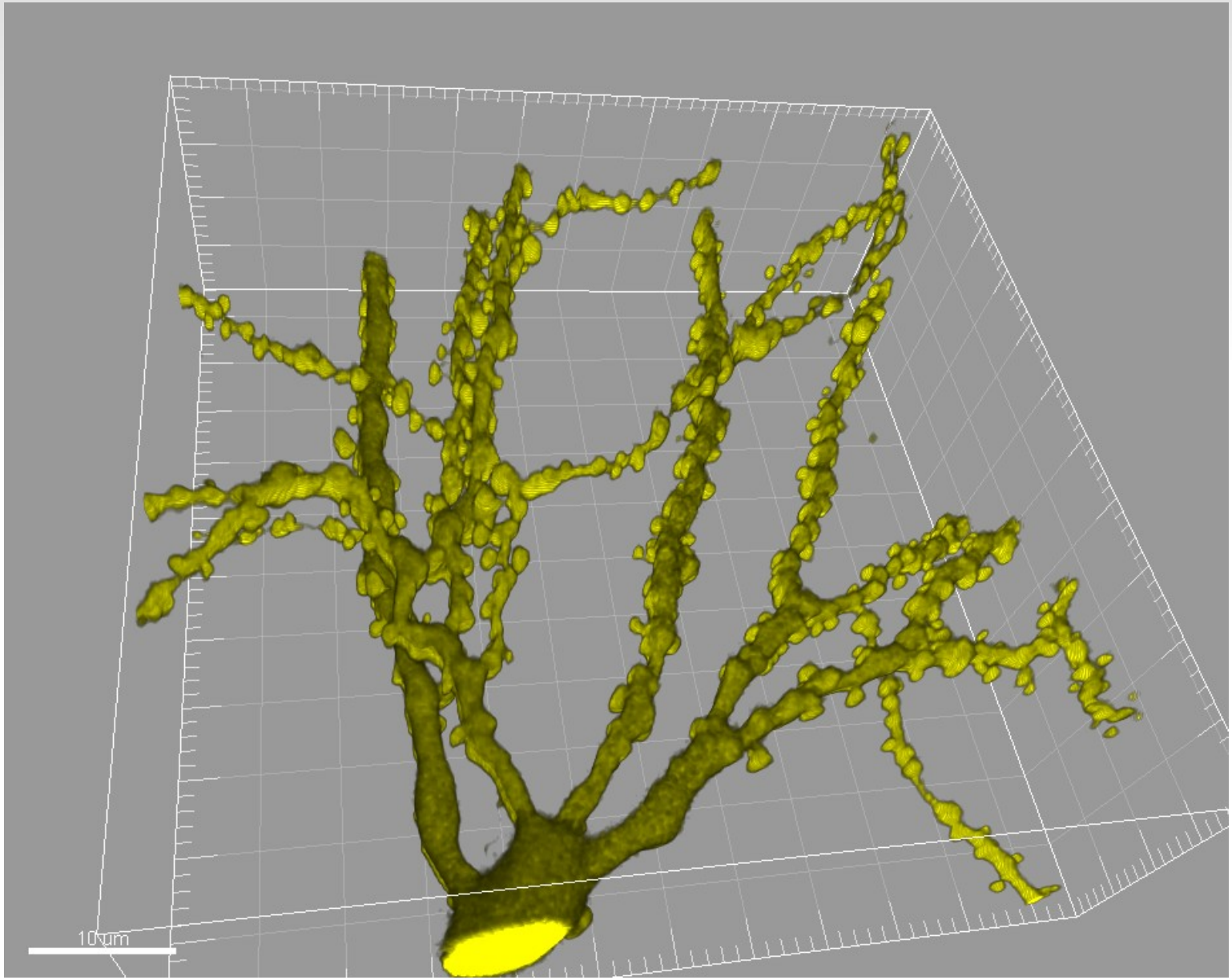
- object based colocalization
- test if distance between centroids is at resolution limit



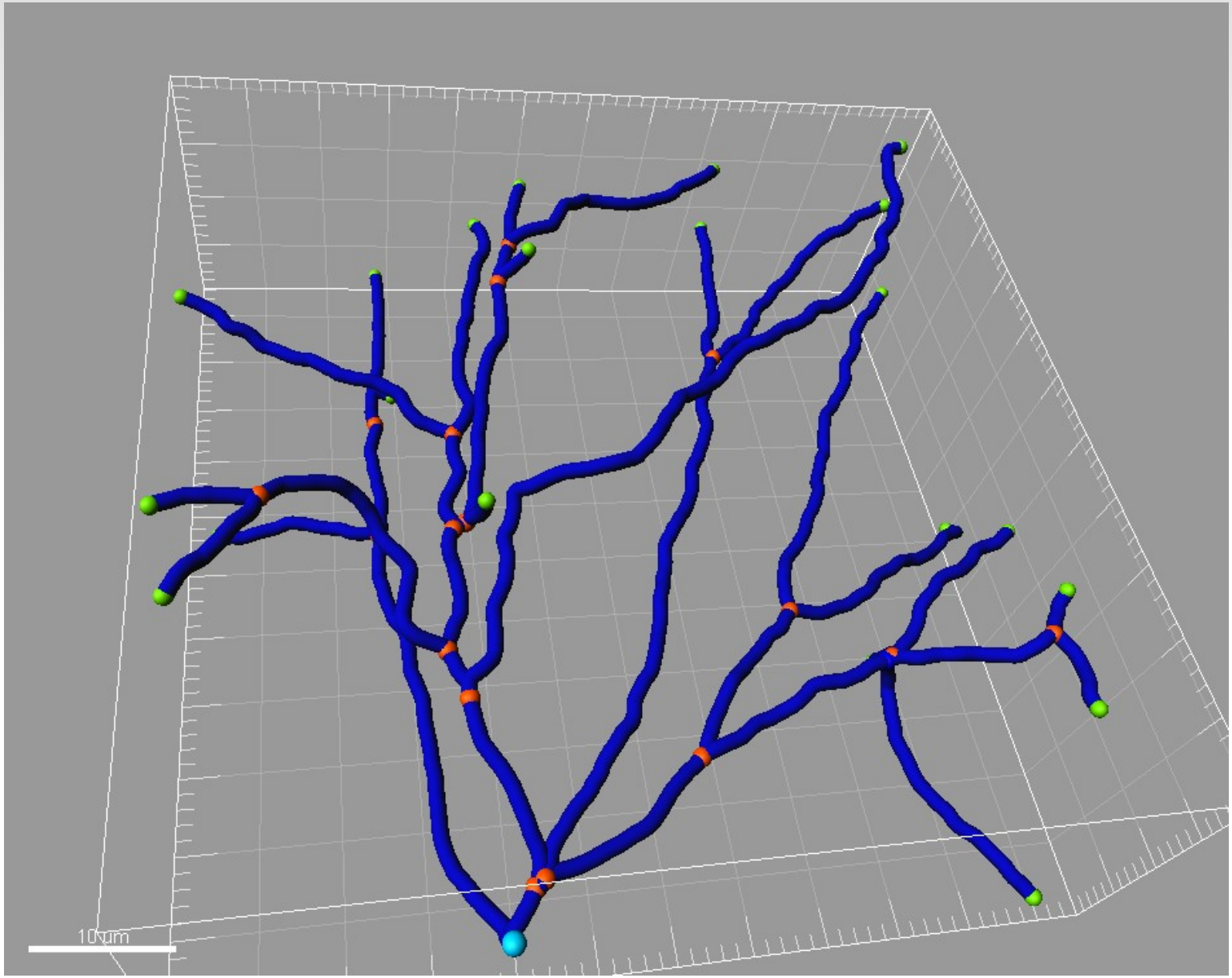
Filament tracing and analysis

- possible approach
  - second order derivatives (hessian matrix)
  - cost image
  - shortest paths
- automatic or semi-interacitve
- spine detection

Filament tracing and analysis



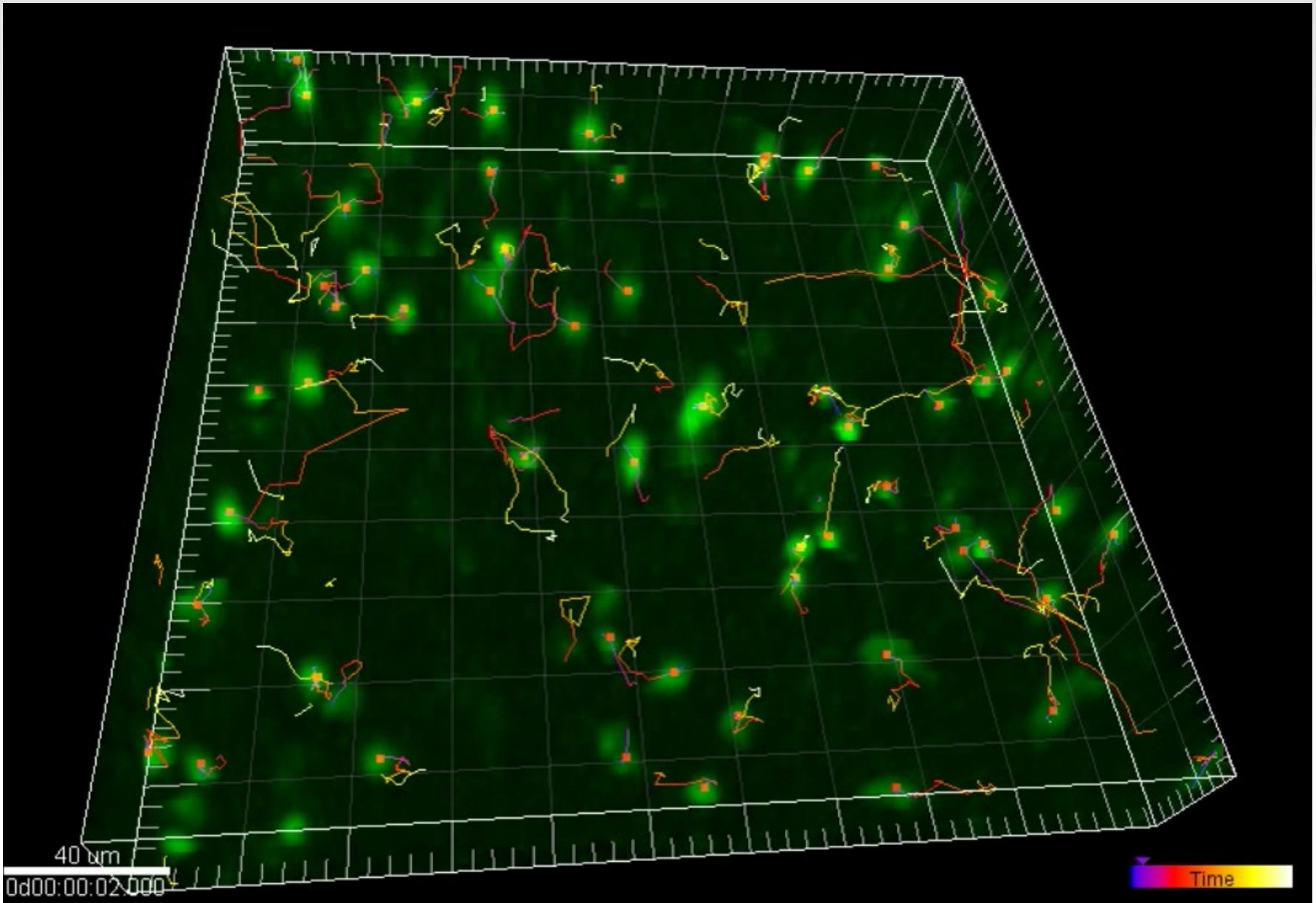
Filament tracing and analysis



Particle detection and tracking

- 2 steps
- detection of particles (spots) per time-frame
  - least-squares fitting of a gaussian mixture model to the image data
- linking of particles in successive frames
  - problem: number not constant over time

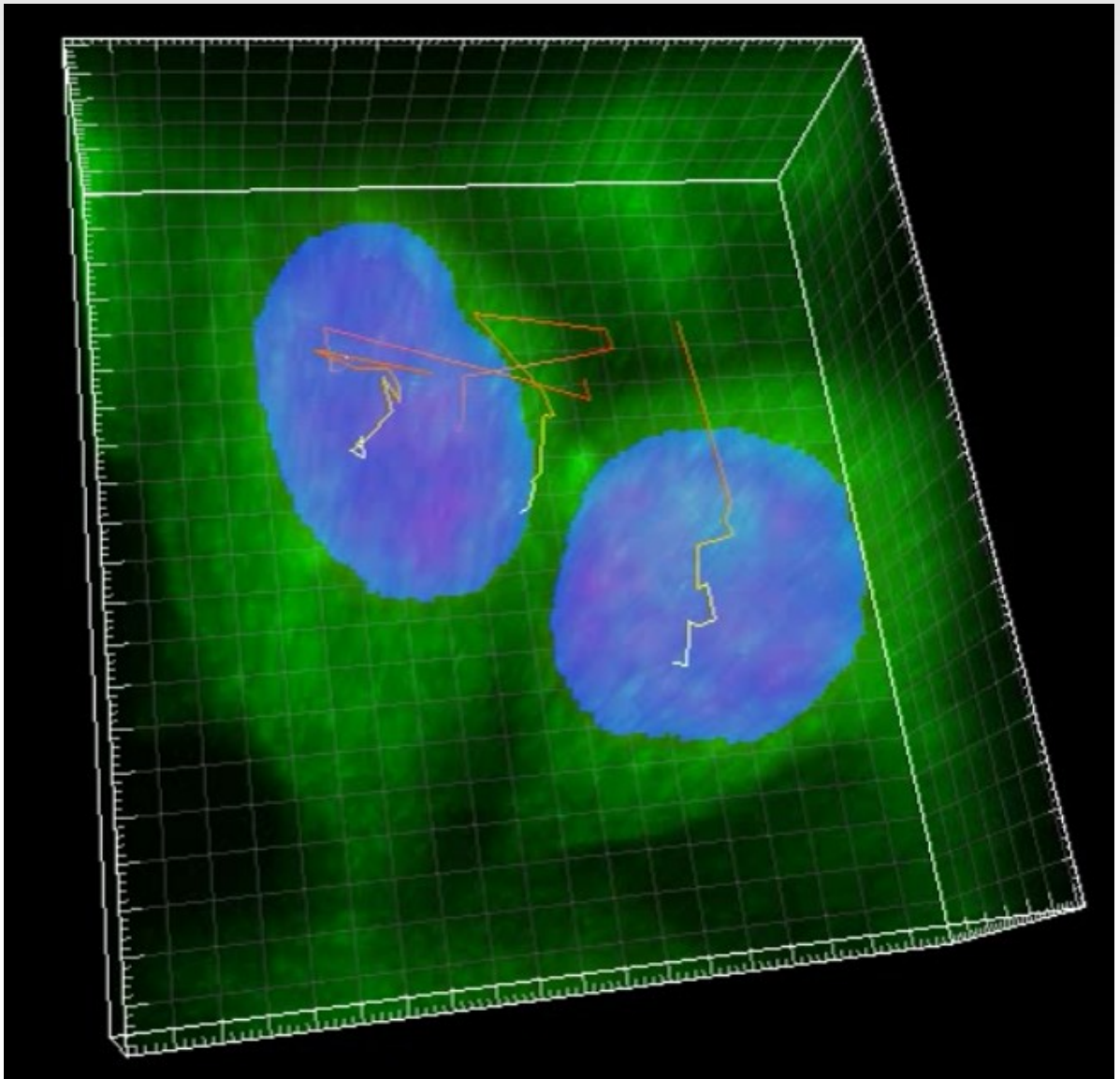
Particle detection and tracking



Cell segmentation and tracking

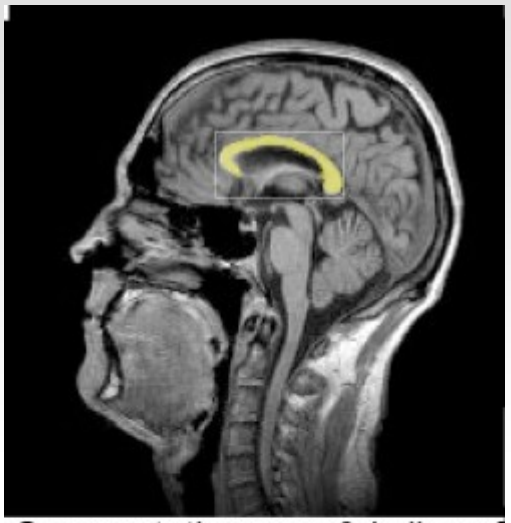
- cells have a distinct shape
- shape may change over time
- use active contours (snakes) to detect cells
  - active surfaces in 3D
  - shape constraint fitting to image data
- tracking
  - use contour of cell at t=n
    as initial contour for cell at t=n+1

Cell segmentation and tracking

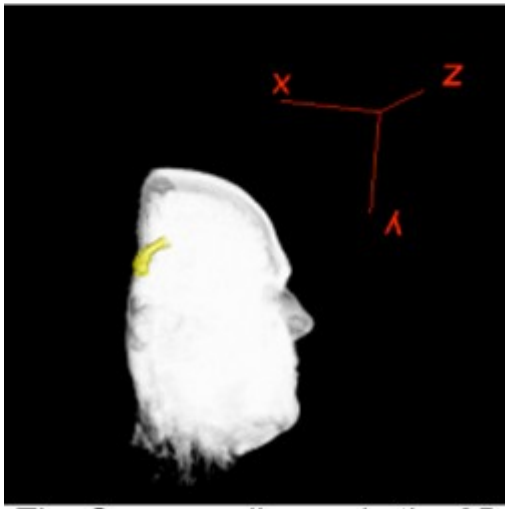


Software Tools

- Imaris (bitplane)
- Volocity (PerkinElmer)
- Avizo (vsg)
- FIJI (open source)
- ImageJ (open source)
- Matlab (MathWorks)
- huygens (svi)
  - hrm (open source)



Segmentation on a 2d slice of the Corpus callosum



The Corpus callosum in the 3D Viewer

Thank you

- Questions?

BiOCampus Montpellier

MRI
Technologies Informatique et Gestion des Ressources
TIGR

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