Image Analysis Basics
-
Introduction to Processing
- Filters and Background Reduction -

PoL BioImage Analysis Symposium

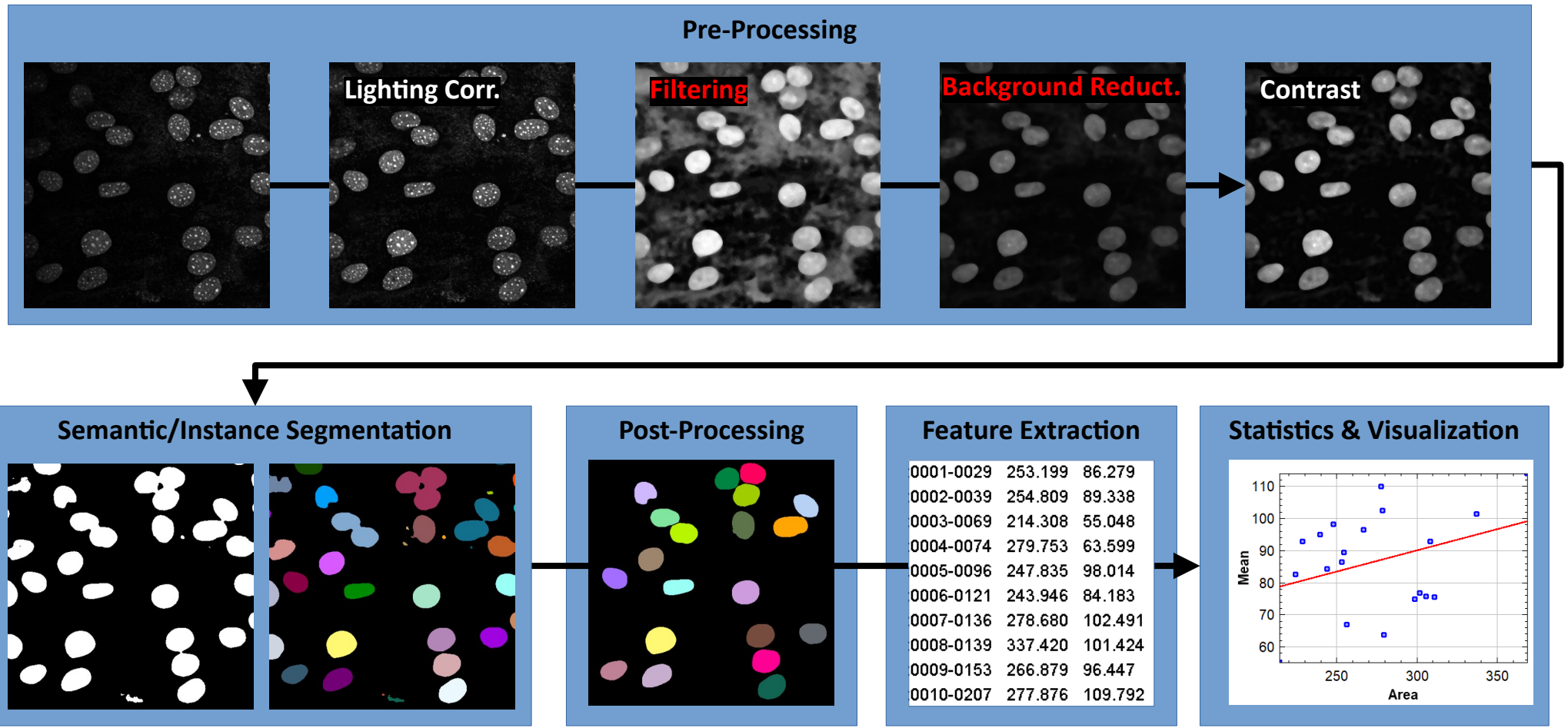
- Training School -

Jan Brocher

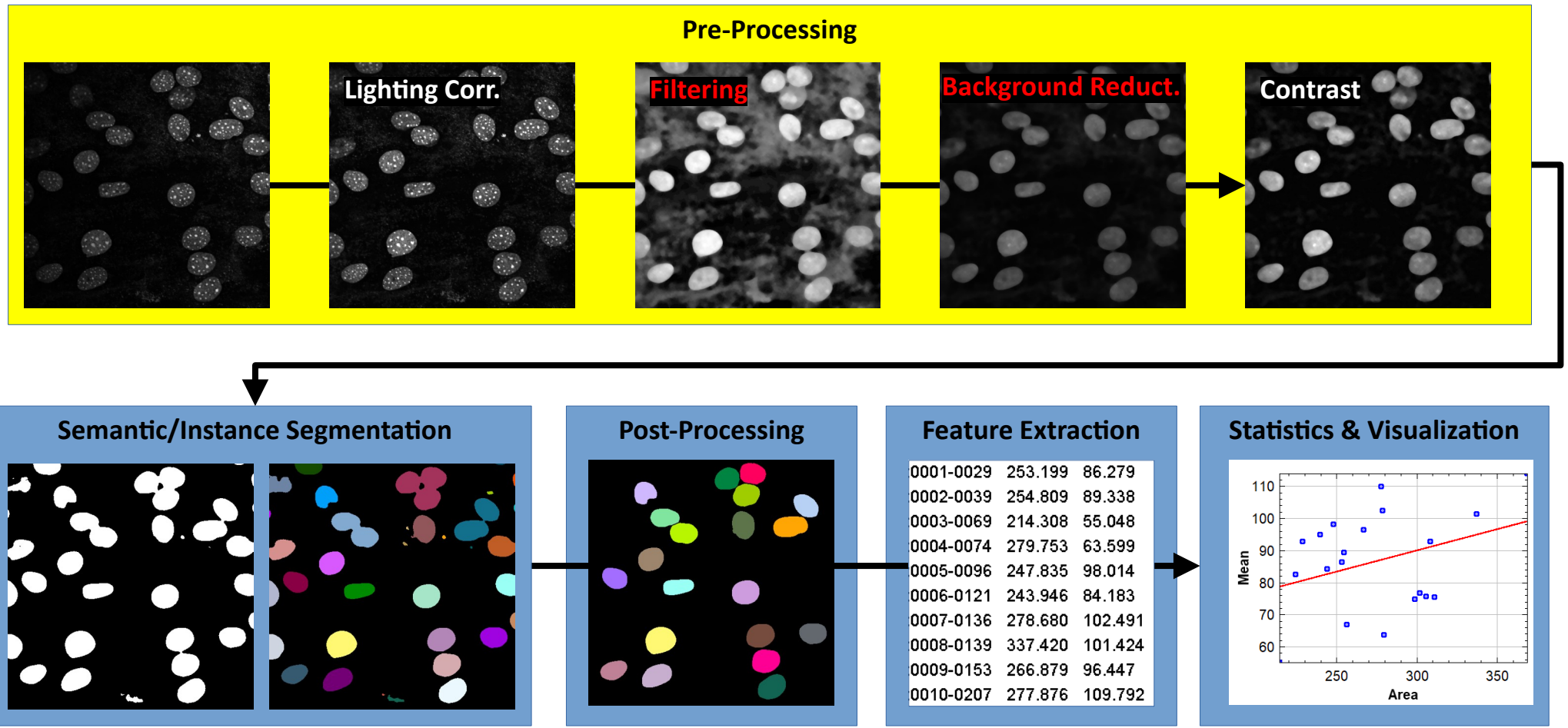
PoL
Physics of Life
TU Dresden

BioVoxxel

Classical Image Processing and Analysis Workflow

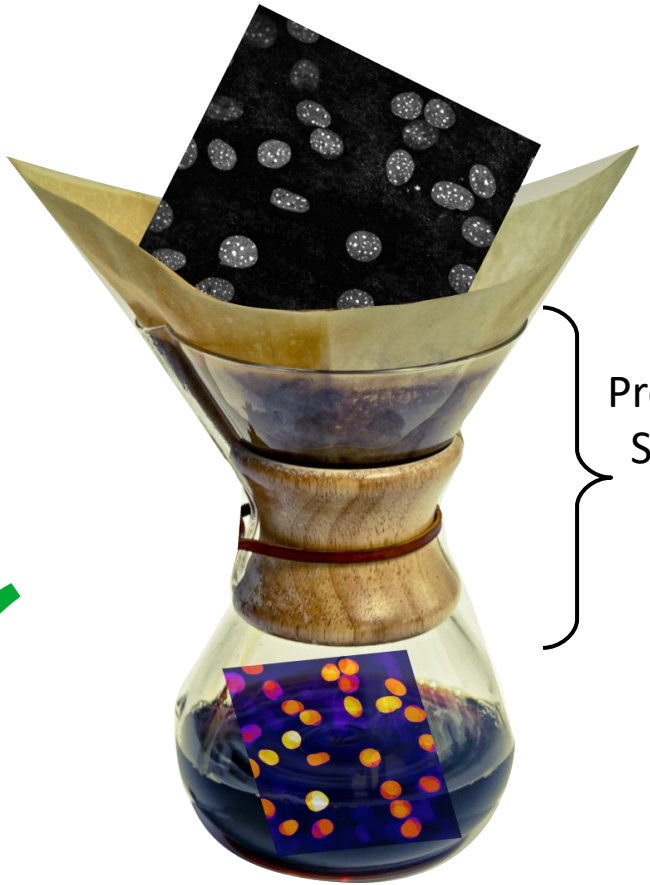


Classical Image Processing and Analysis Workflow



Why Do Pre-Processing and Image Filtering ?

Input material quality !!!

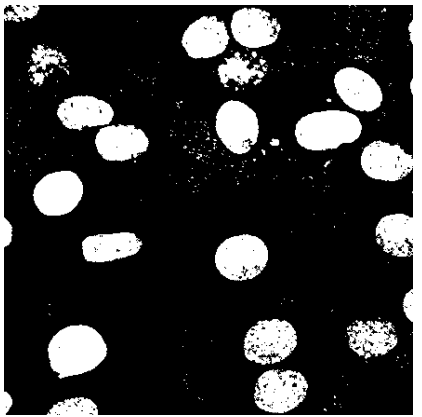


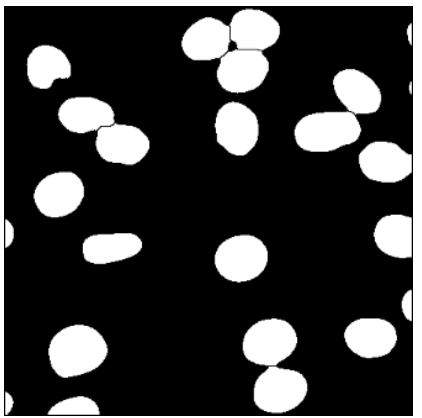
Processing Strategy & Tools

original

filtered

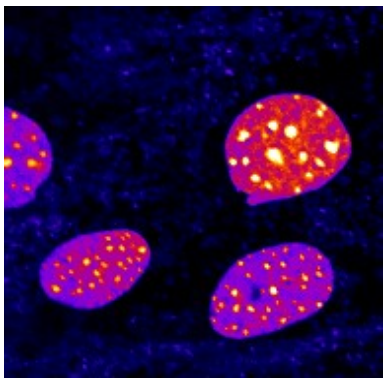
Object Detection



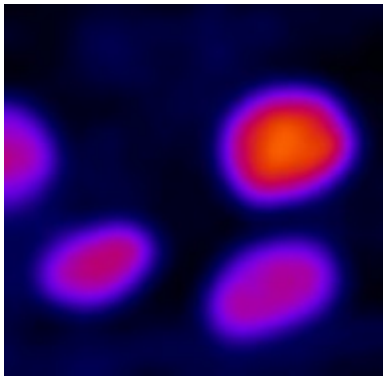


Pre-Processing of Images using Filters changes Image Data

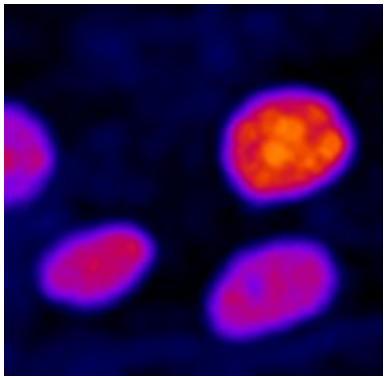
Original



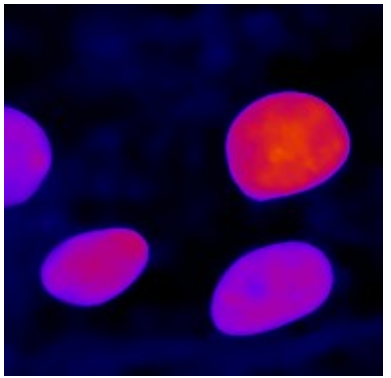
Gaussian Blur



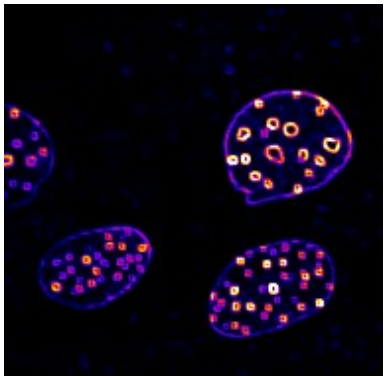
Mean



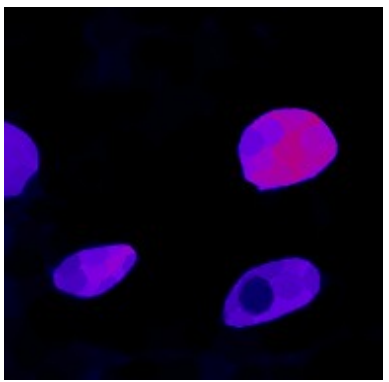
Median



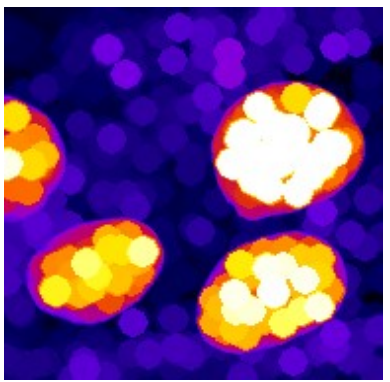
Variance



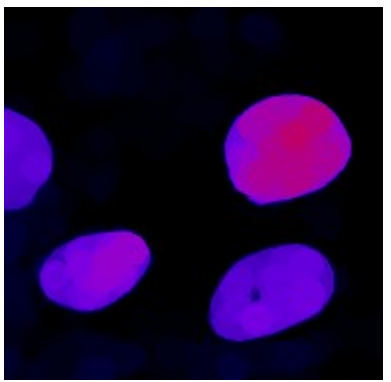
Minimum



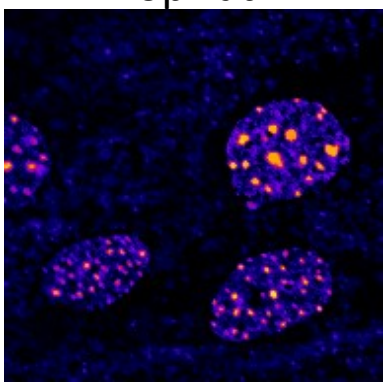
Maximum



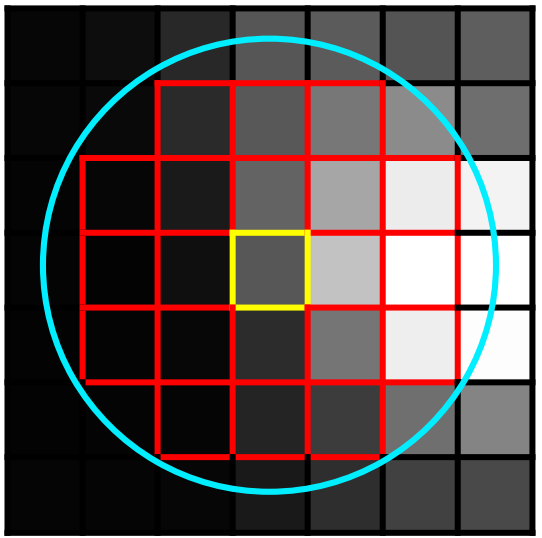
Min & Max



TopHat



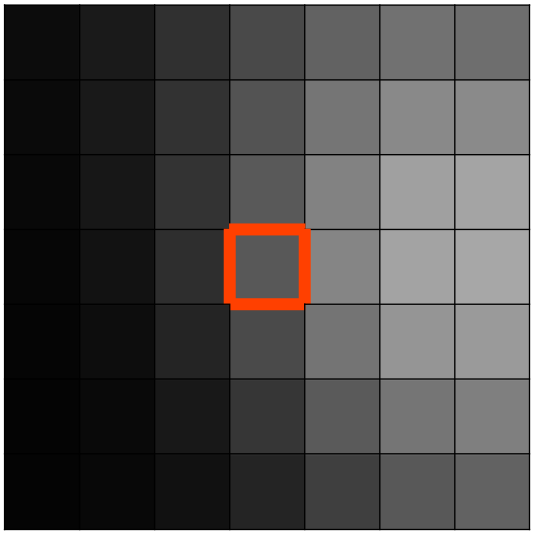
Filters calculate New Pixel Values based on a Neighborhood



6	13	40	86	91	84	94
6	9	42	88	119	139	110
4	6	26	99	166	236	243
4	3	15	87	194	255	255
3	4	7	44	117	238	253
3	4	5	36	60	111	132
5	5	6	25	46	65	73

Mean Filter

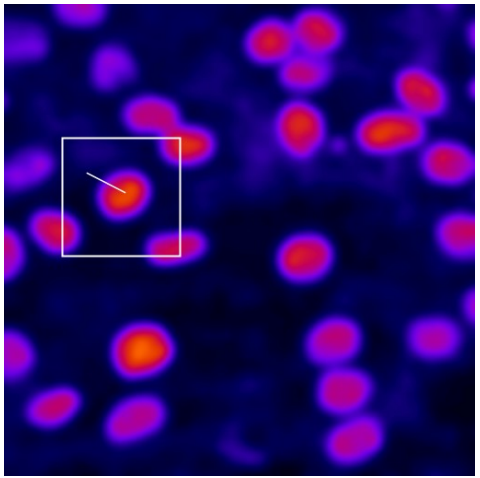
radius = 2

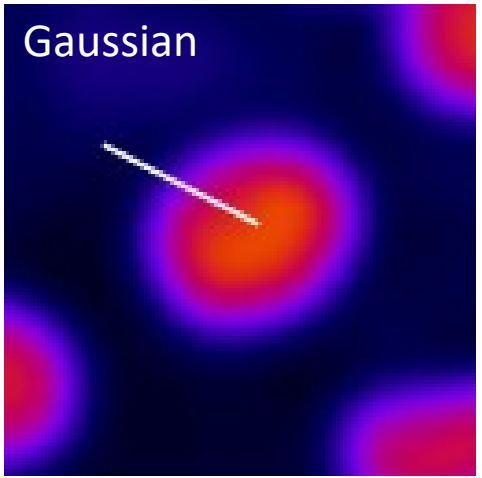


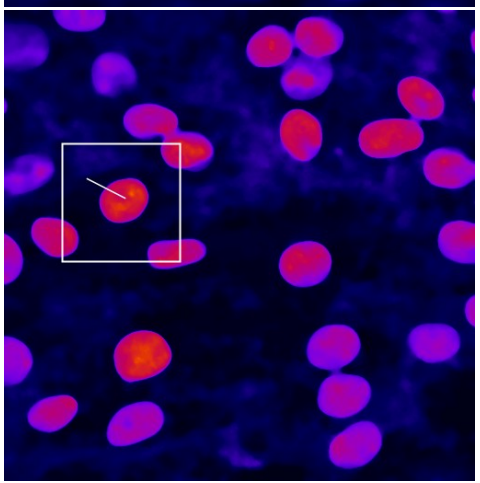
12	26	48	73	98	113	110
10	25	50	83	117	137	138
8	23	51	89	130	160	164
6	18	46	88	133	163	167
5	13	36	74	116	149	154
4	9	24	54	90	117	127
4	8	17	36	63	88	98

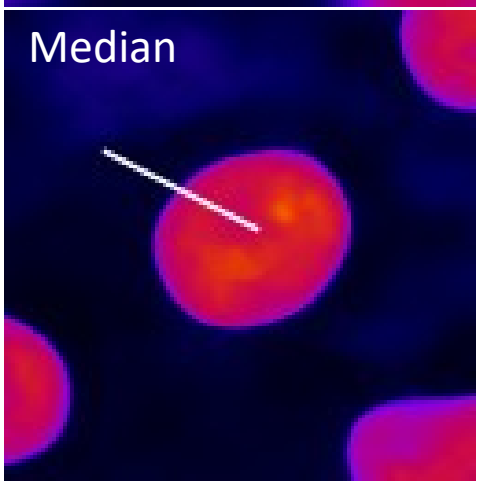
Filter Demo Movie

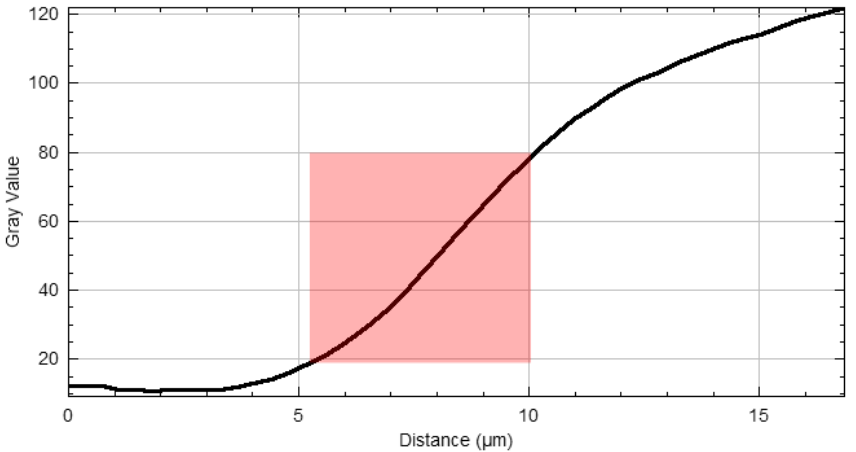
Impact of Filters on Boundary Detection

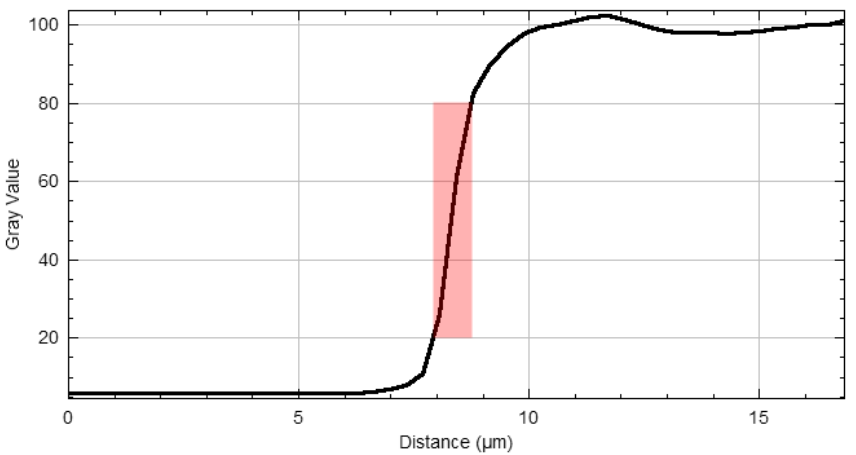






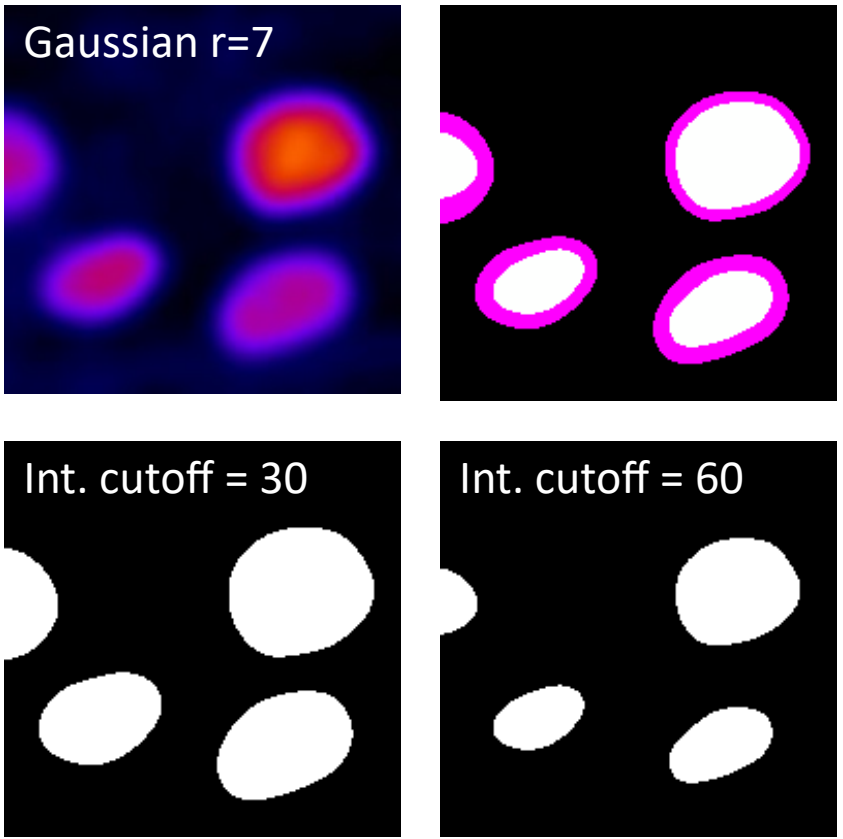




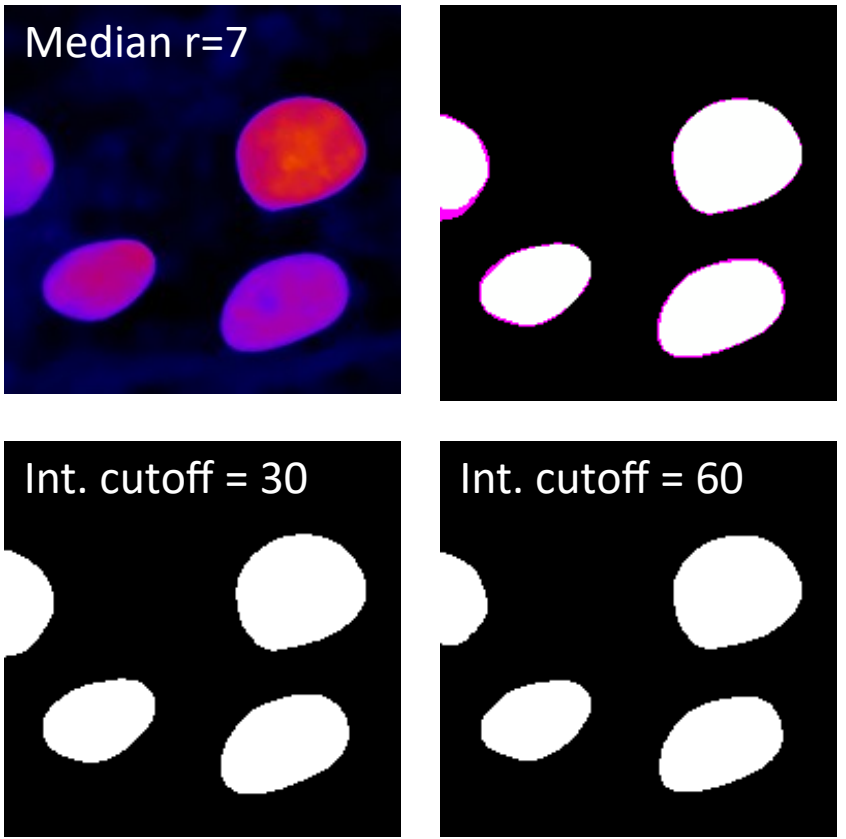


Filter Choice impacts Variabilty in Segmentation Result

Jaccard index (IoU) = 0.566

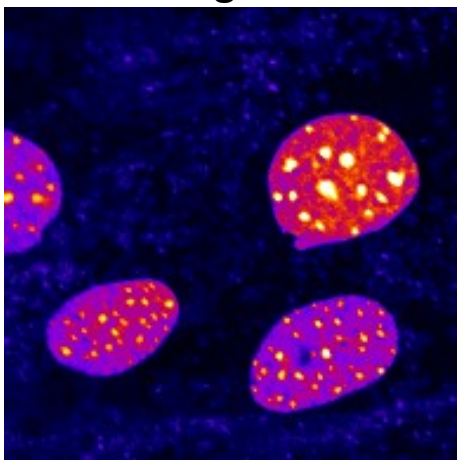


Jaccard index (IoU) = 0.937

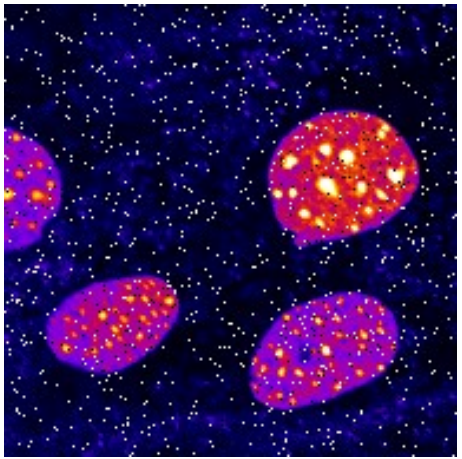


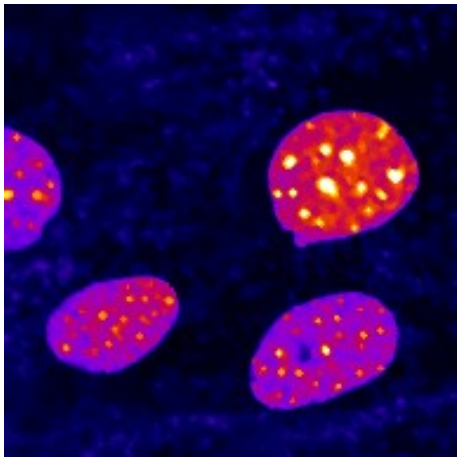
Noise Removal with Filters (Median r=1)

Original

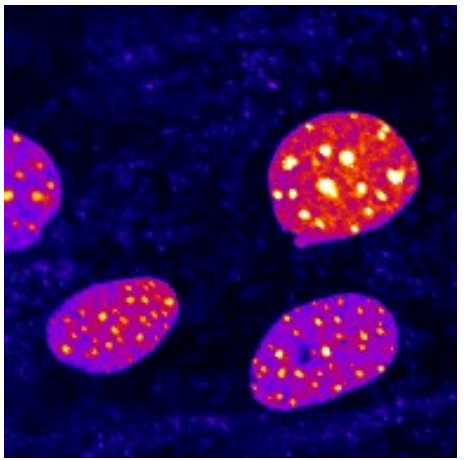


Original + Noise





Median r = 1

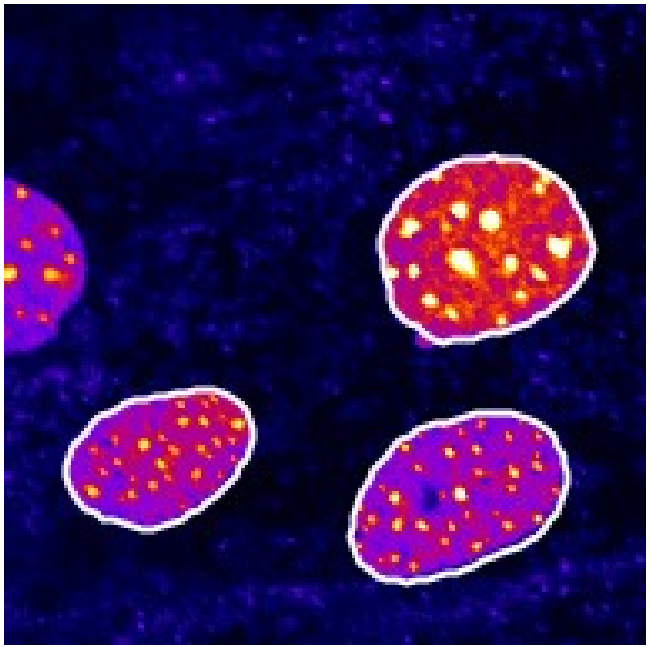


Limited
Median r = 1

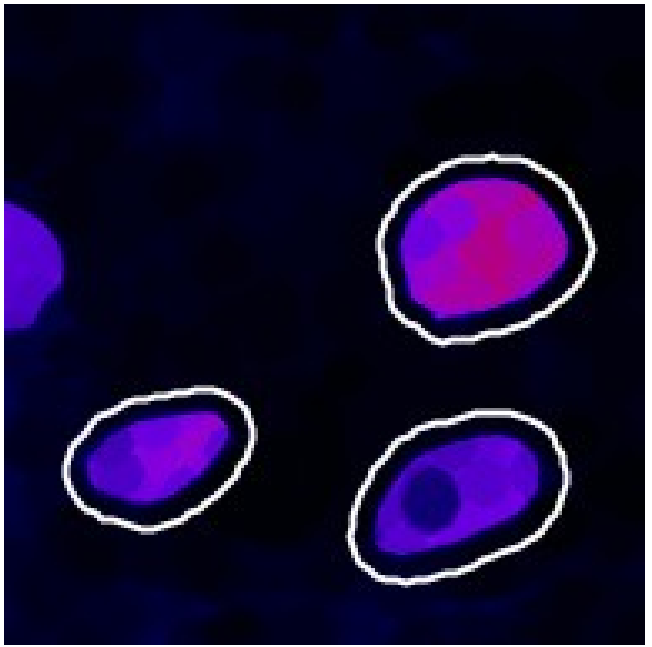
only extreme values will be filtered

Morphological Filters: Minimum (Erosion) or Maximum (Dilation)

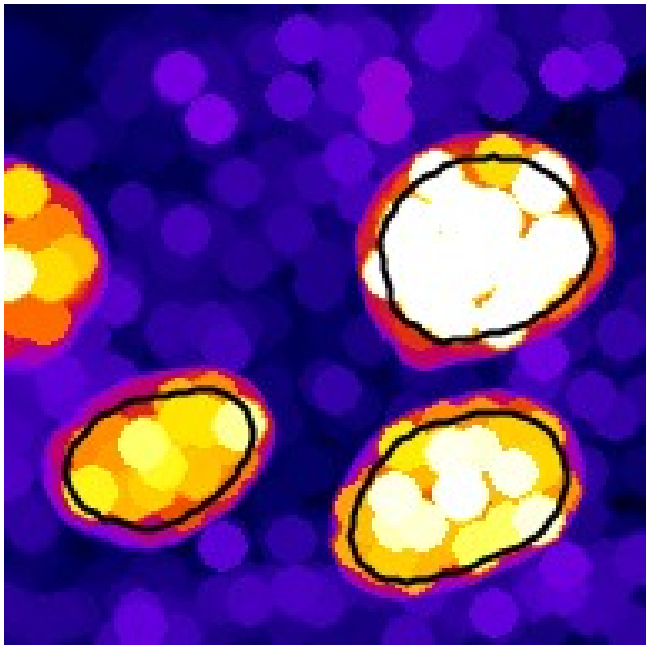
Original



Minimum (Erosion)



Maximum (Dilation)



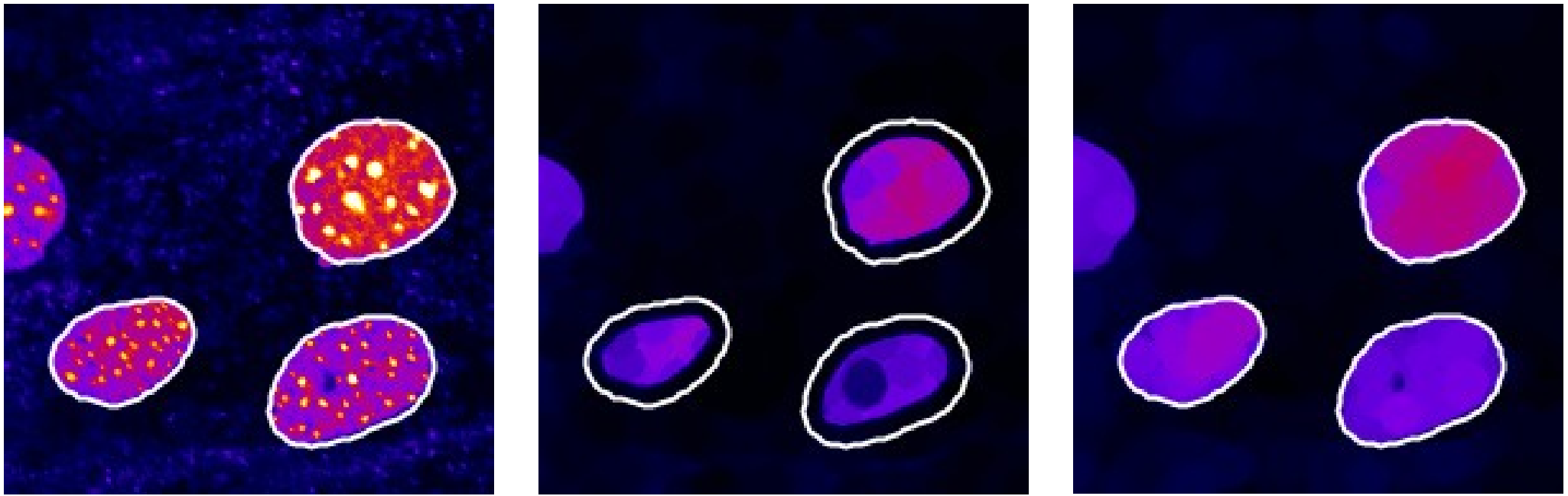
Pixel values are exchanged
for their darkest (minimum)
or brightest (maximum) neighbor

20	5	3
23	15	9
31	28	12

20	5	3
23	15	9
31	28	12

Combining individual Filters: Morphological *Opening*

Original → Minimum (Erosion) → Maximum (Dilation)

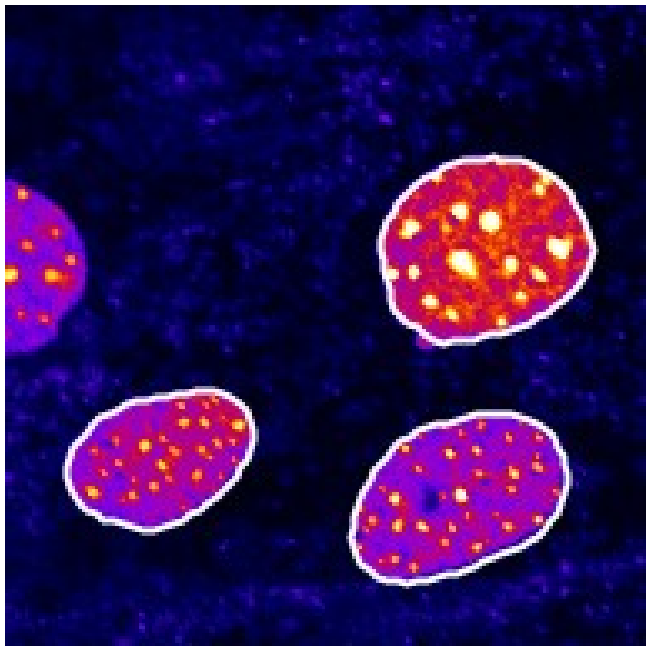


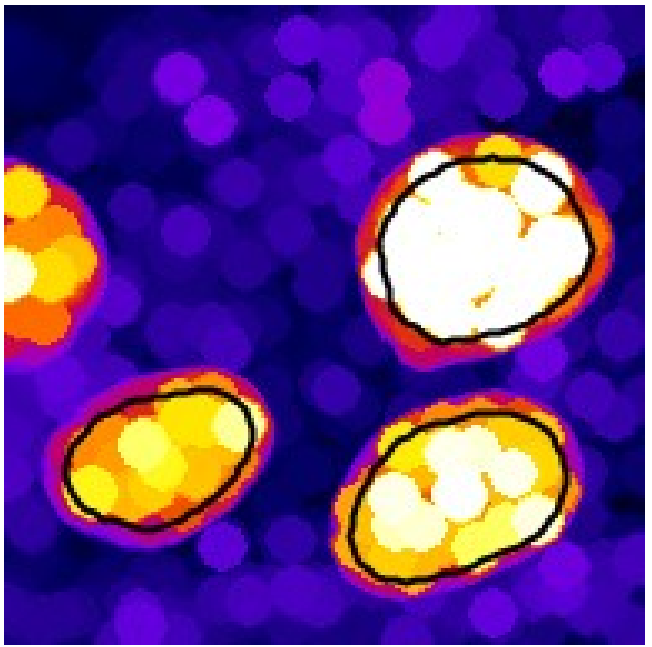
Advantages:

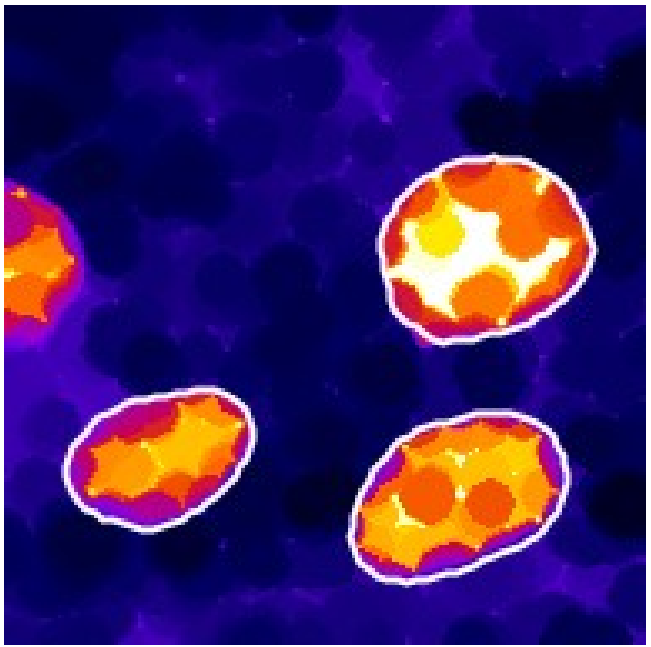
- background and noise reduction
- signal homogenization
- edge preservation

Combining individual Filters: Morphological *Closing*

Original



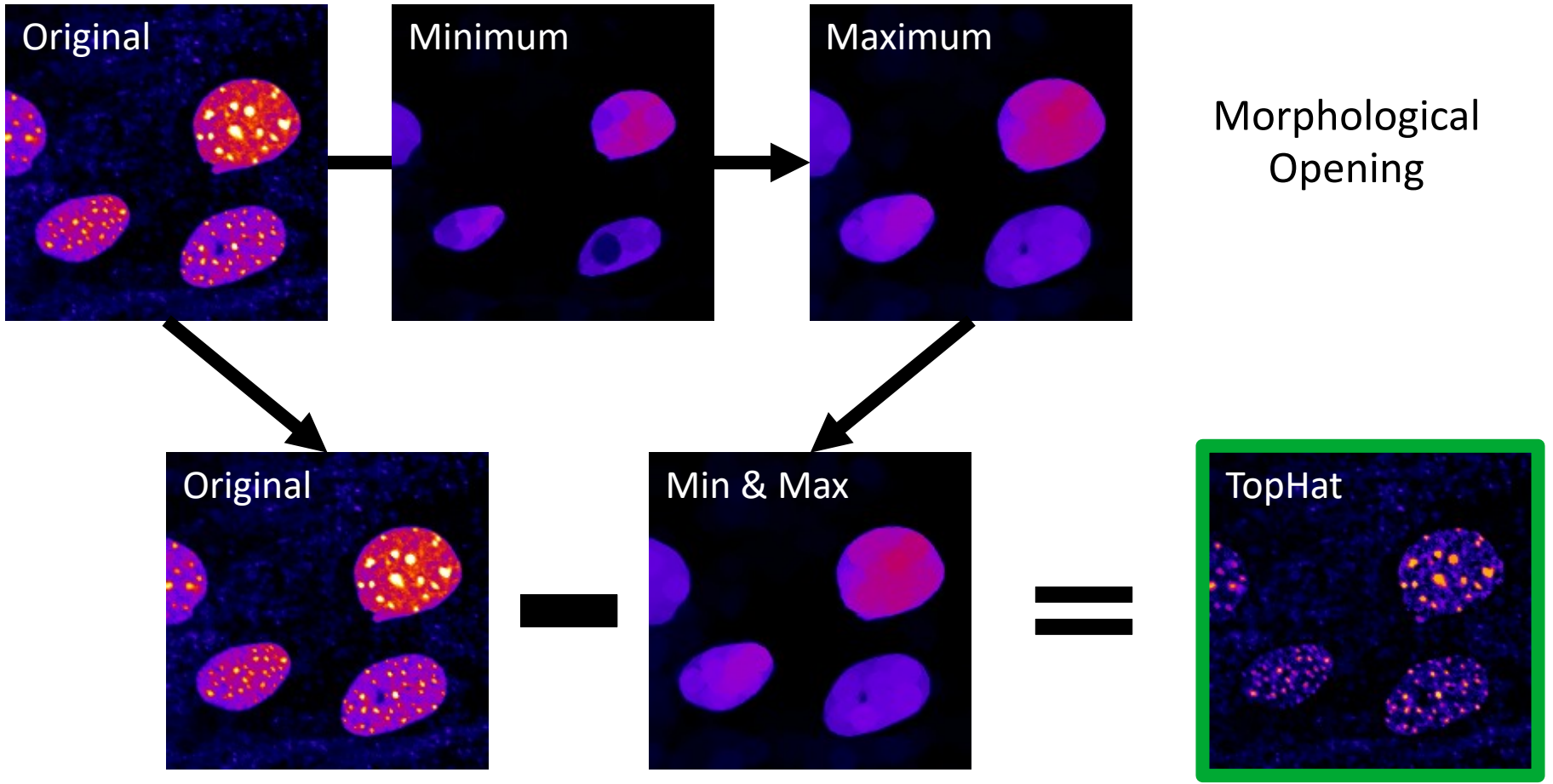




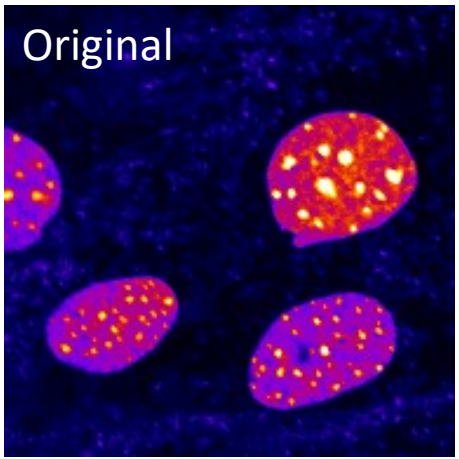
Advantages:

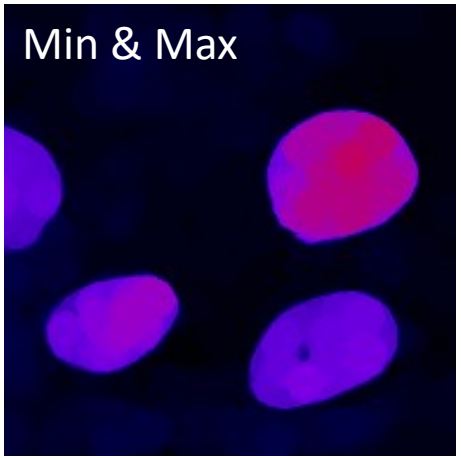
- connecting areas
- signal homogenization

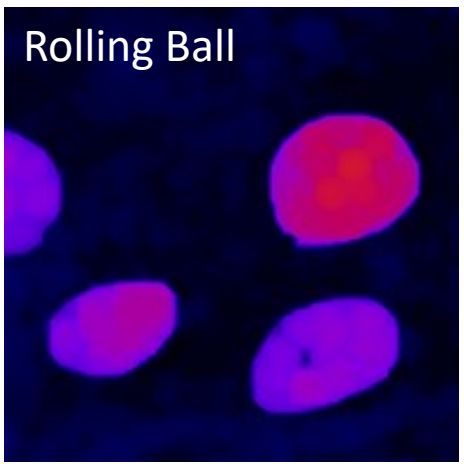
TopHat Filter in Steps

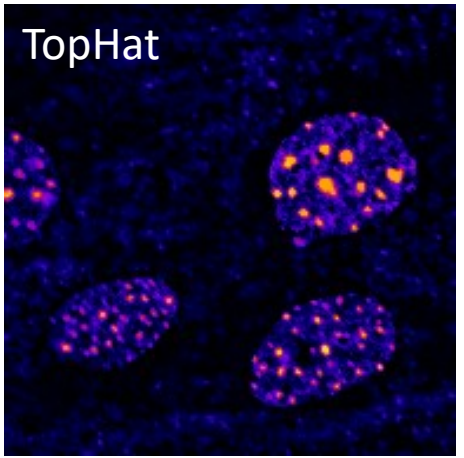


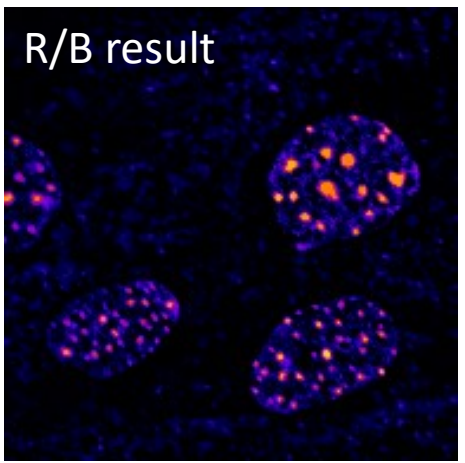
“Unspecificity” Reduction: TopHat vs. Rolling Ball Subtraction



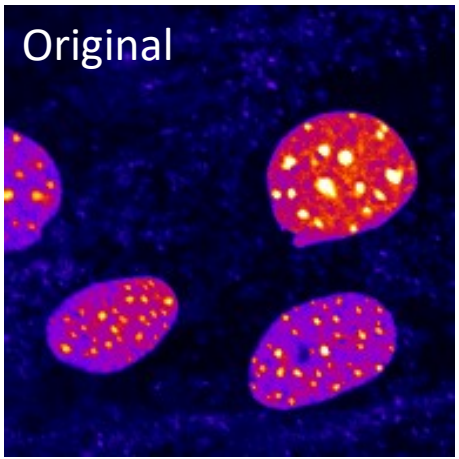


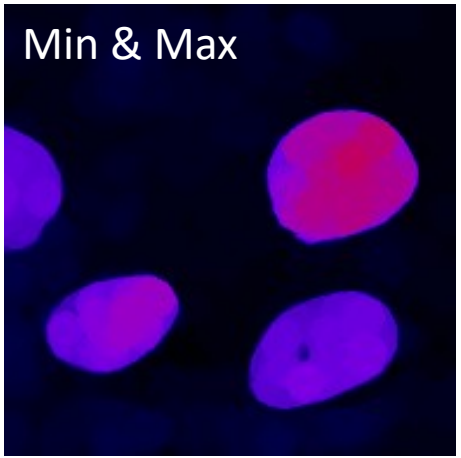


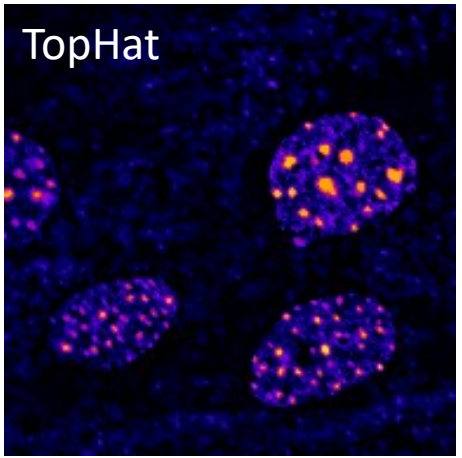


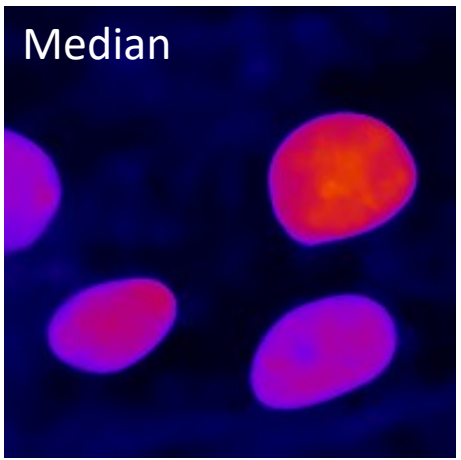


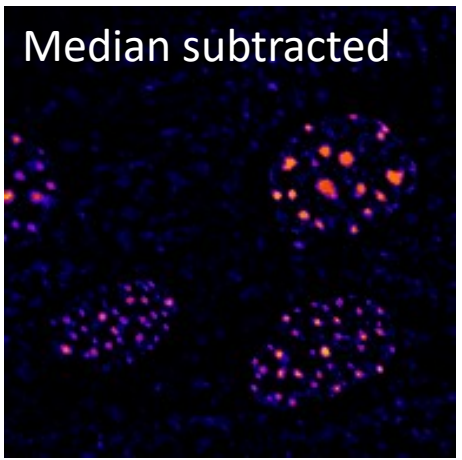
“Unspecificity” Reduction: TopHat vs. Median Subtraction







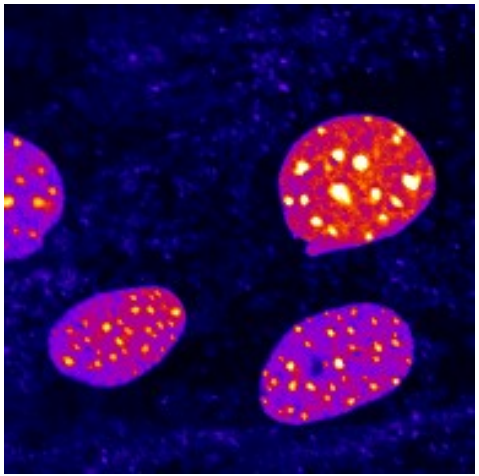


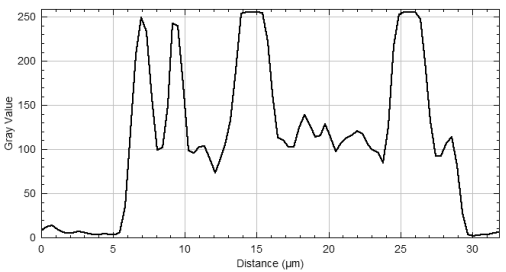


Practical only for highlighting small point-like structures

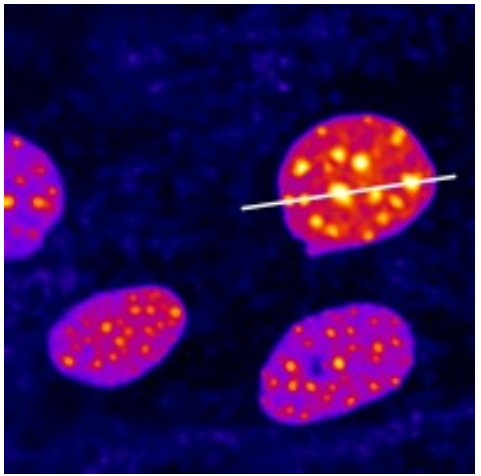
Filter Combinations: Difference of Gaussian

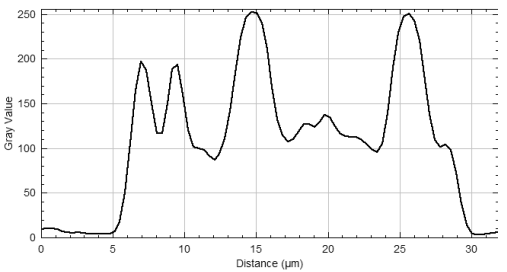
Original



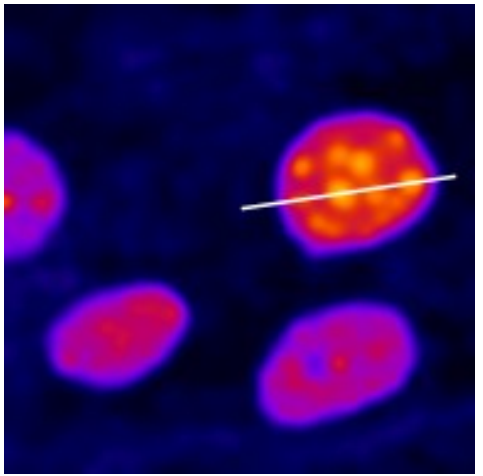


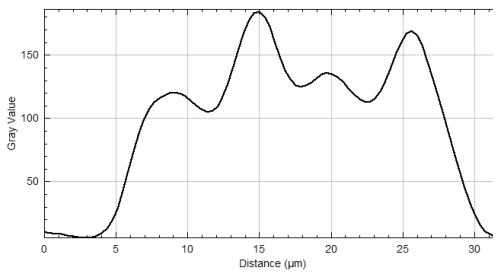
Gauss r = 1



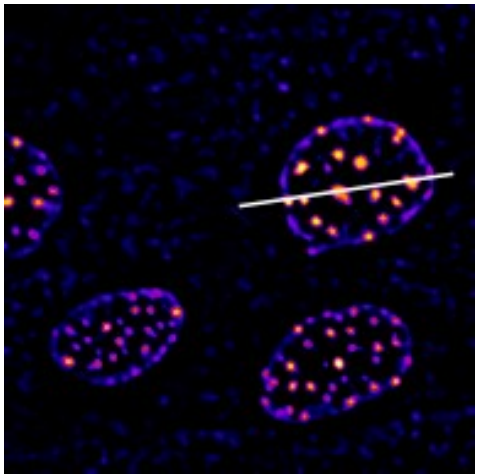


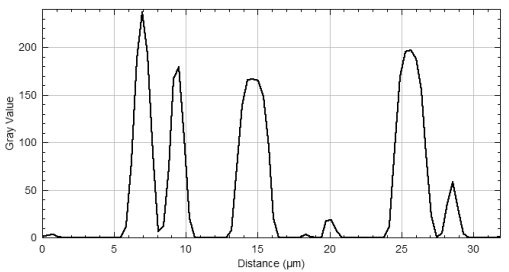
Gauss r = 3





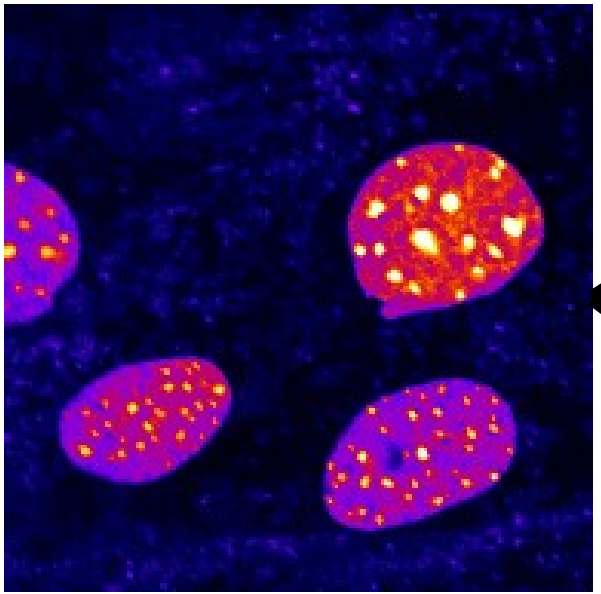
DoG





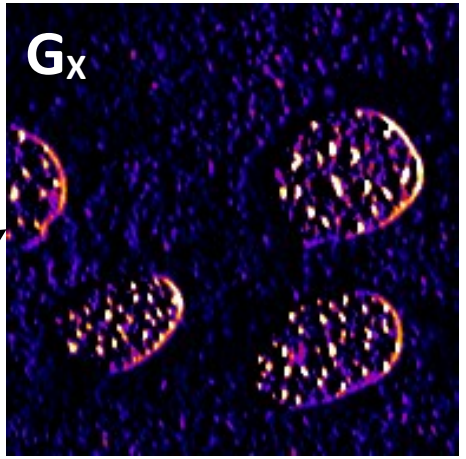
Edge Detection – The Sobel Operator

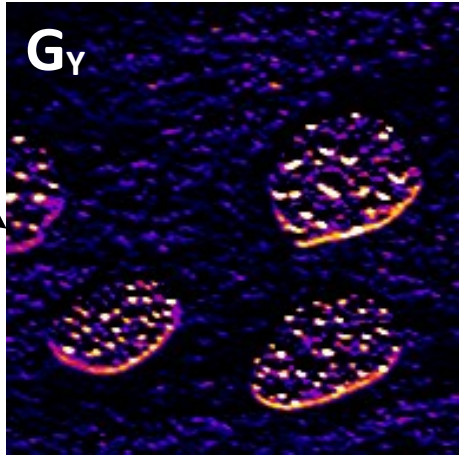
Original



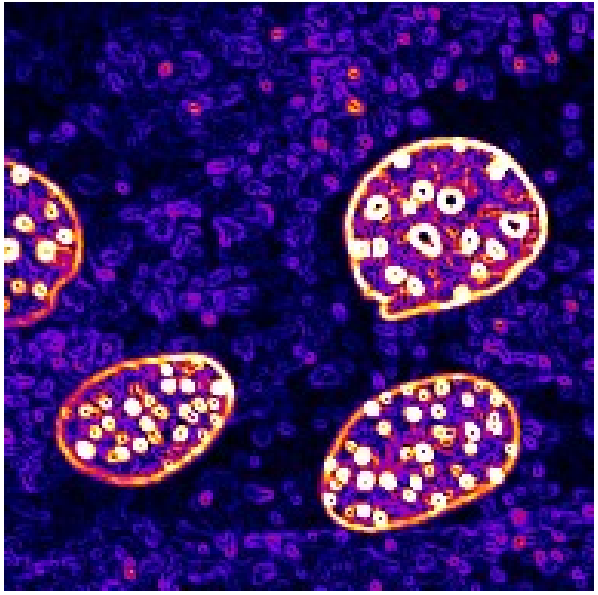
+1	0	-1
+2	0	-2
+1	0	-1

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





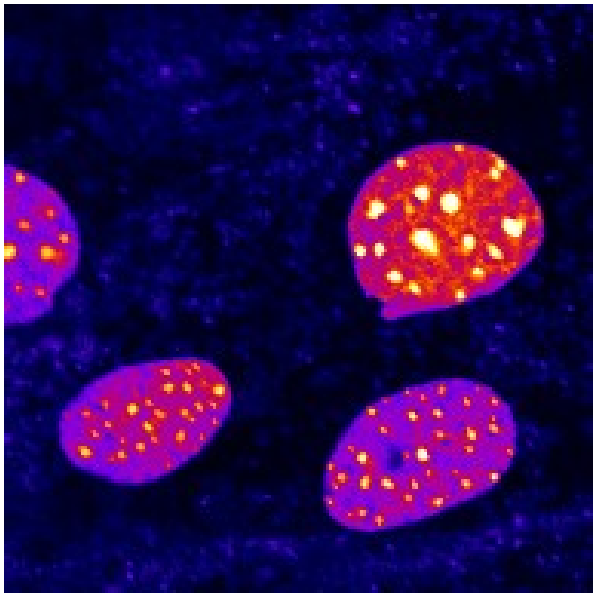
Sobel



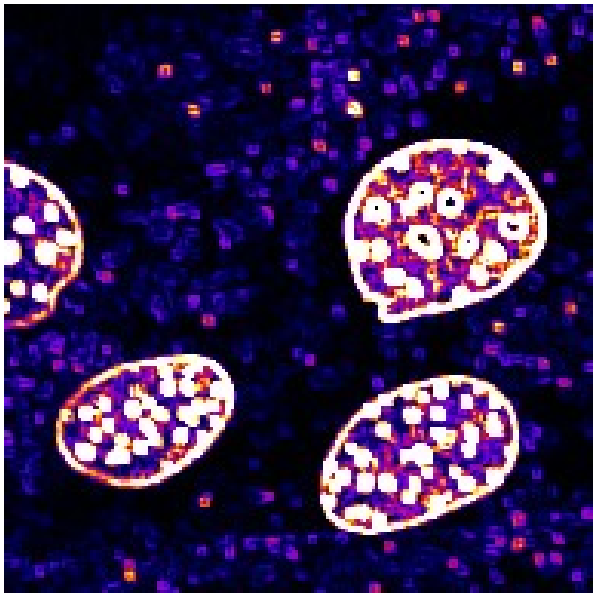
$$\mathbf{G} = \sqrt{\mathbf{G}_x^{\,2} + \mathbf{G}_y^{\,2}}$$

Edge Detection using the Variance Filter

Original



Variance



$$\sigma^2 = \frac{\sum_{i=1}^{n} \left(x_i - \overline{x}\right)^2}{N}$$

where:

x_i = Each value in the data set

$\overline{x}$ = Mean of all values in the data set

N = Number of values in the data set

Special Use Case for Edge Detection (Sobel or Variance Filter)