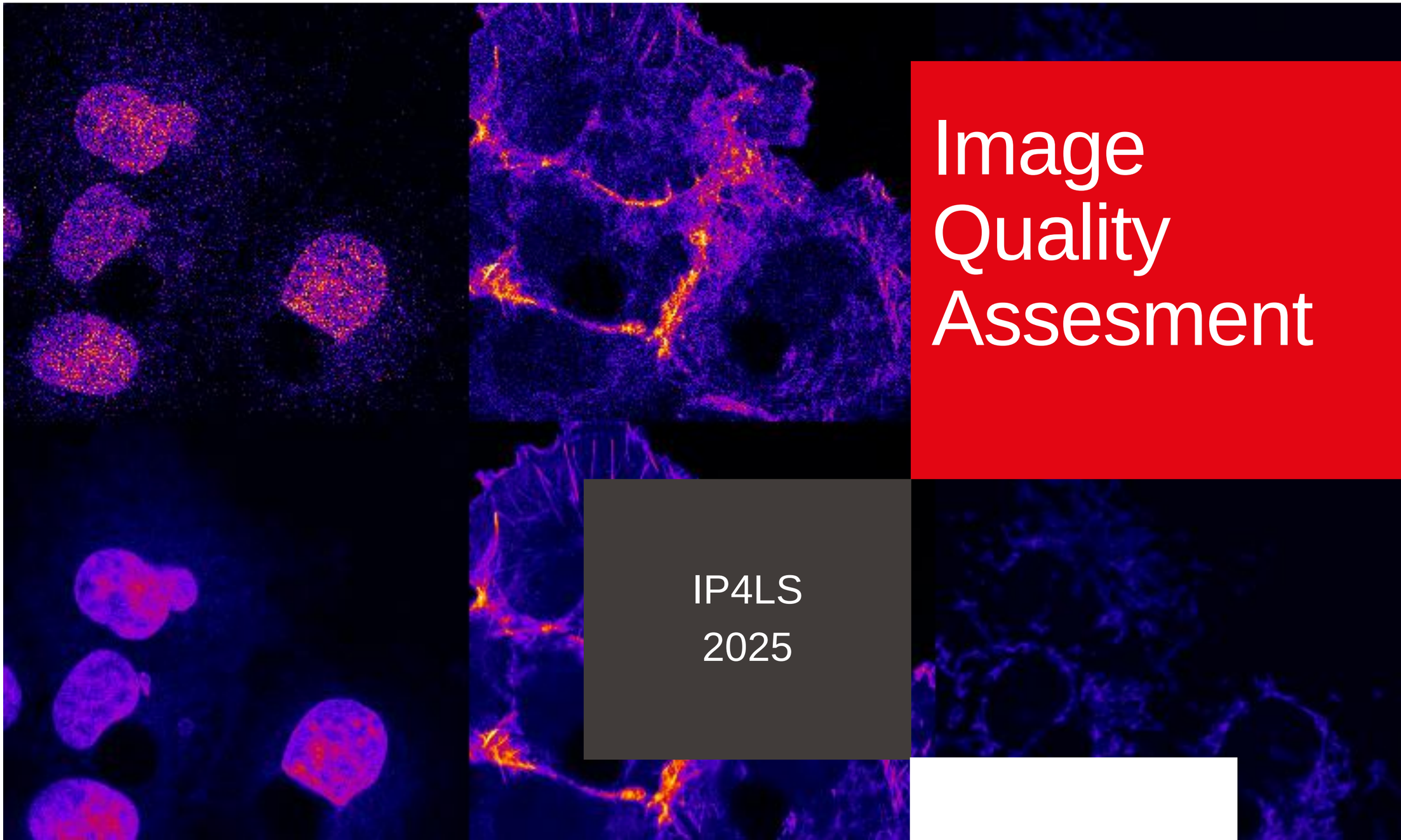

Image Quality Assesment

IP4LS
2025

École
polytechnique
fédérale
de Lausanne

Image Quality

- What are the parameters defining the quality of an image?
- What metrics can be used to report on image quality?
- How relevant is the quality of an image for the downstream analysis?
- How is image quality affecting segmentation?

- Image Quality depends on…
  - Imaging Modality
  - Acquisition Parameters
  - Sample and its preparation
  - Image processing
  - File format
  - Many more…

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Visual Inspection

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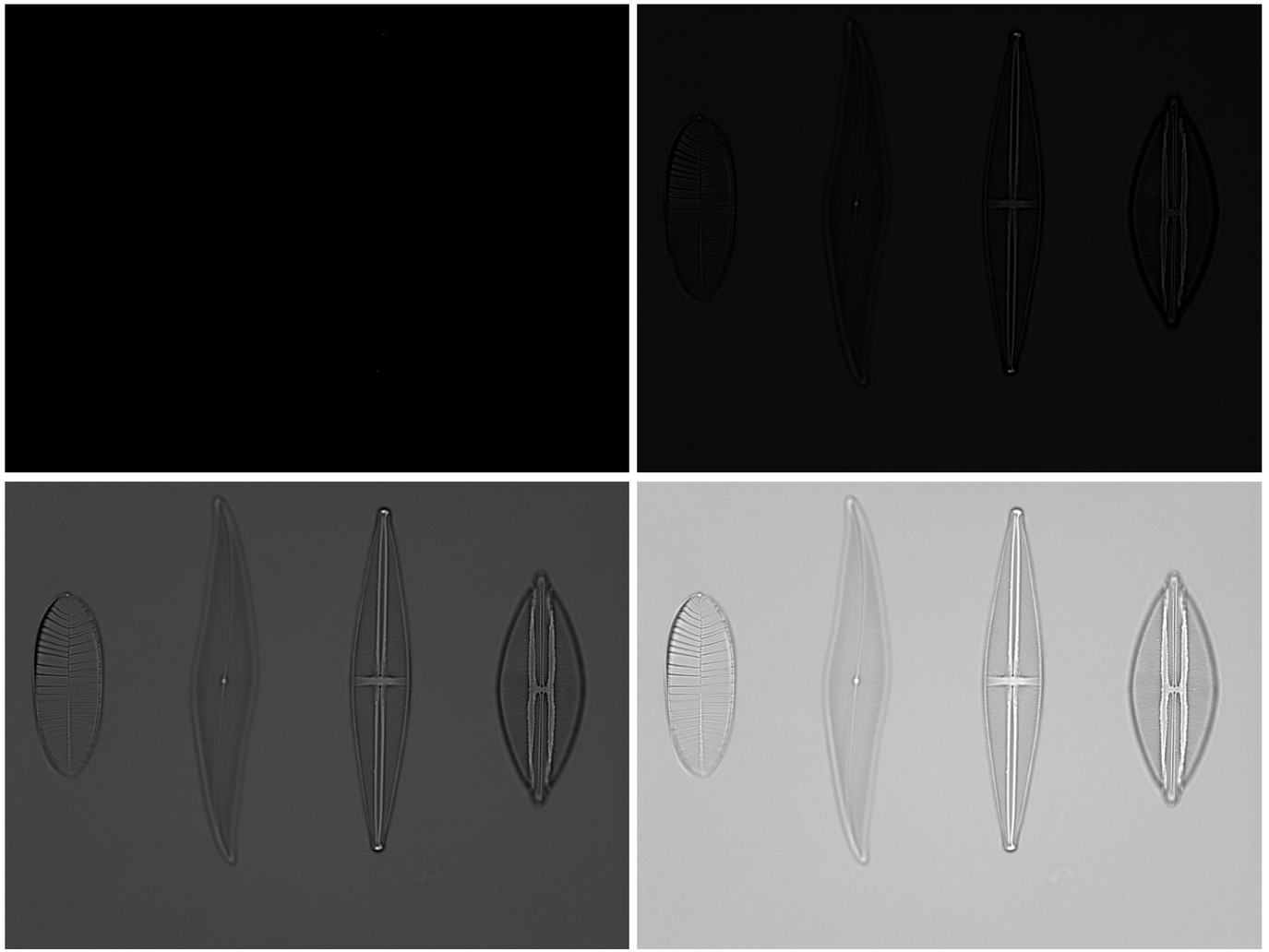
Visual inspection



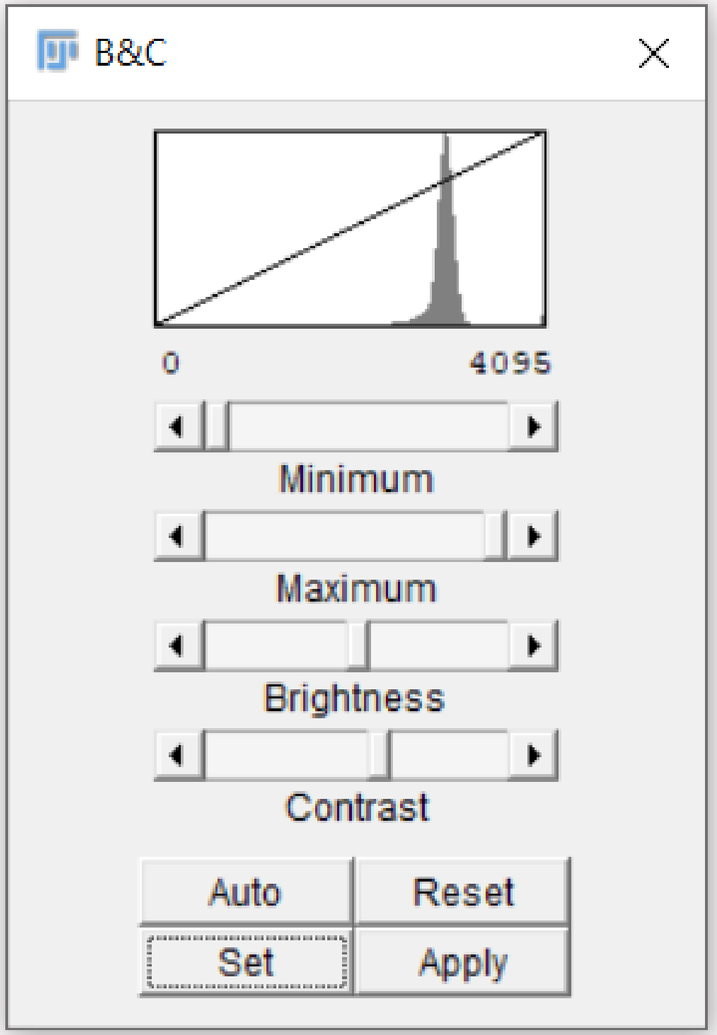


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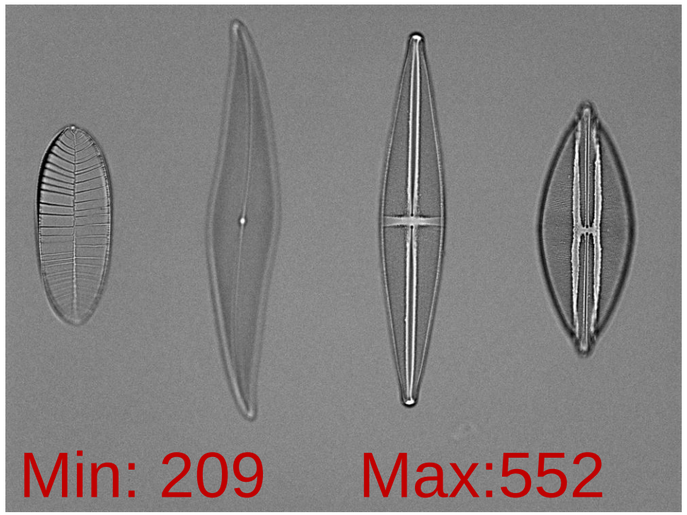
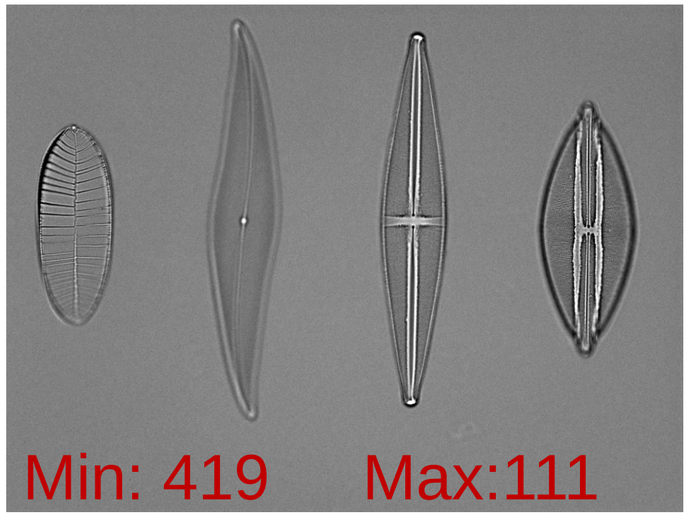
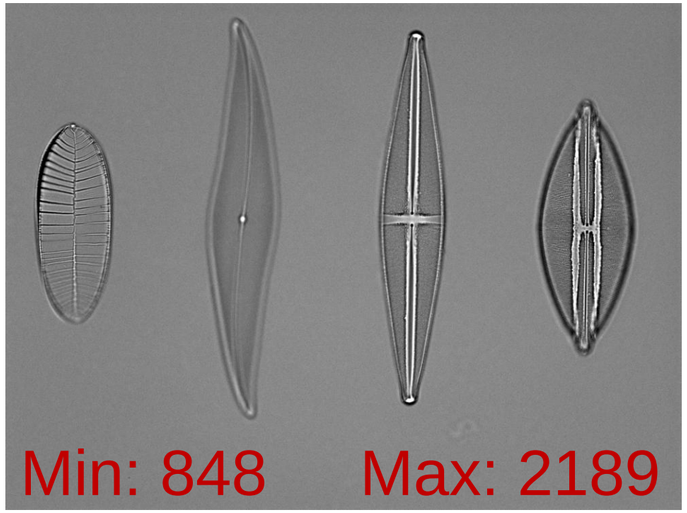
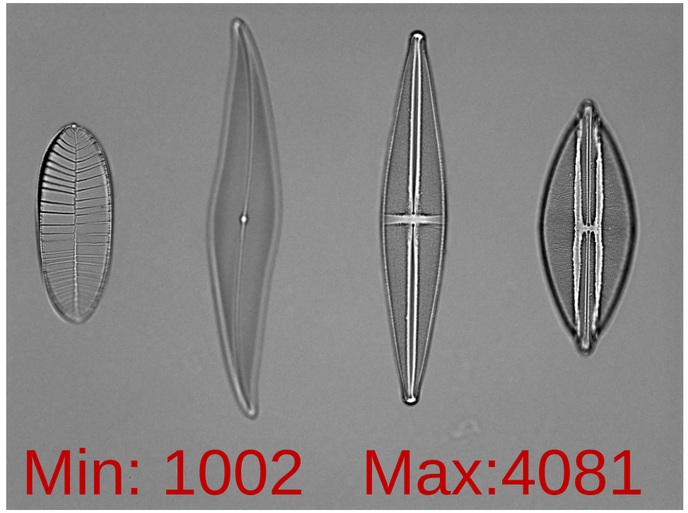
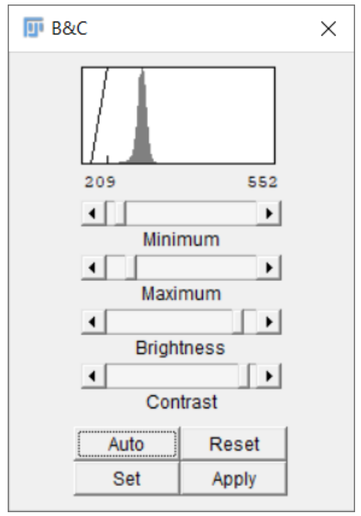
Image display

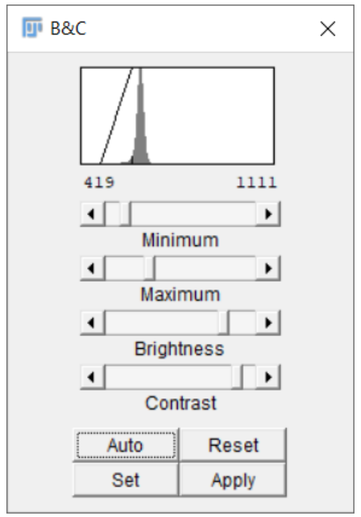


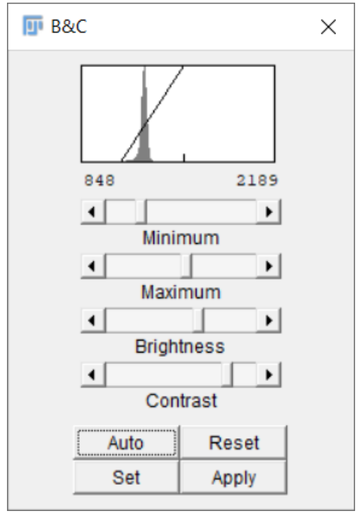


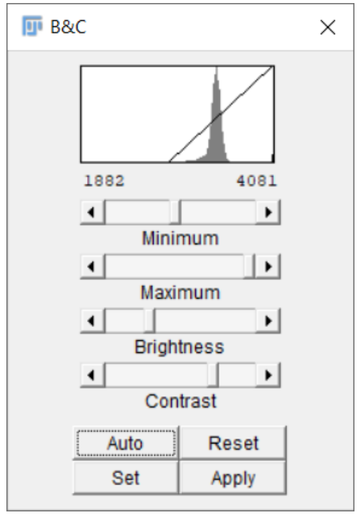












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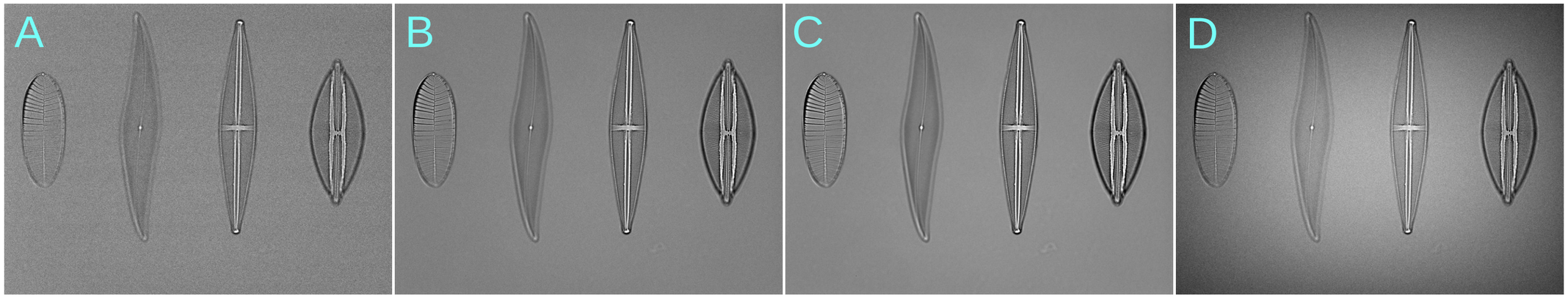
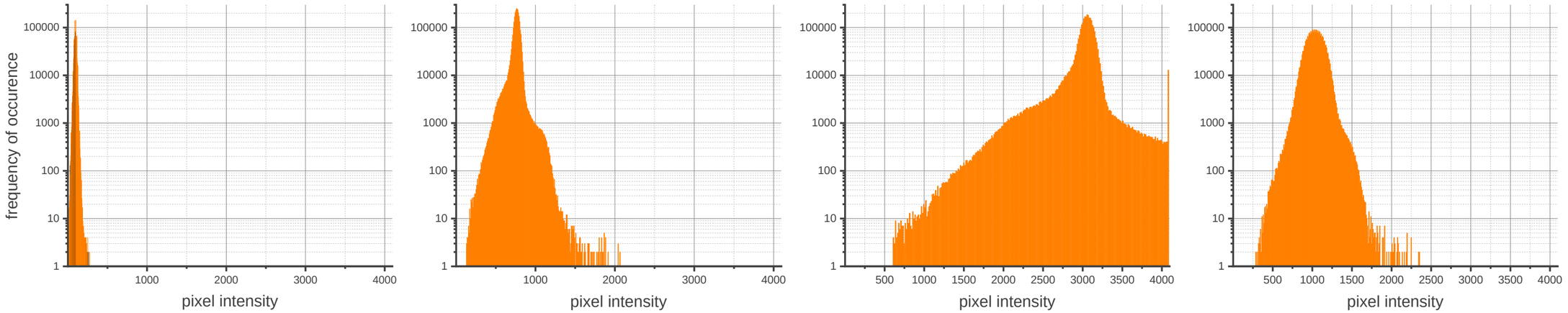
Visual inspection quizz





noise/low intensity — A

illumination/background — D

saturation — C

optimal — B

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Qualitive assesment

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Signal, Noise and Background

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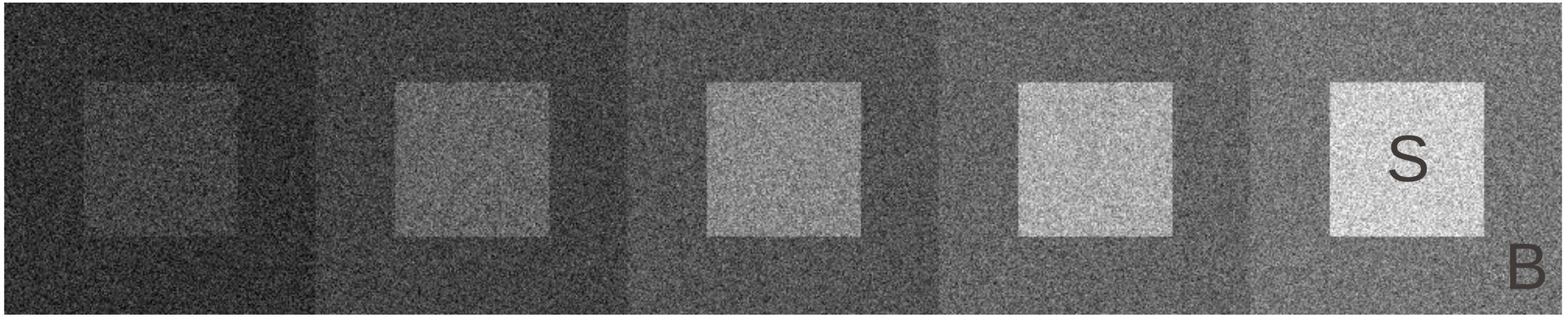

$$N_{tot}^2 = N_s^2 + N_d^2$$

$$N_S = \sqrt{N_{photons}}$$

N_{tot} : total noise
N_d : detector noise
N_s : signal (shot) noise
N_{ph} : number of photons

Signal, Noise and Background

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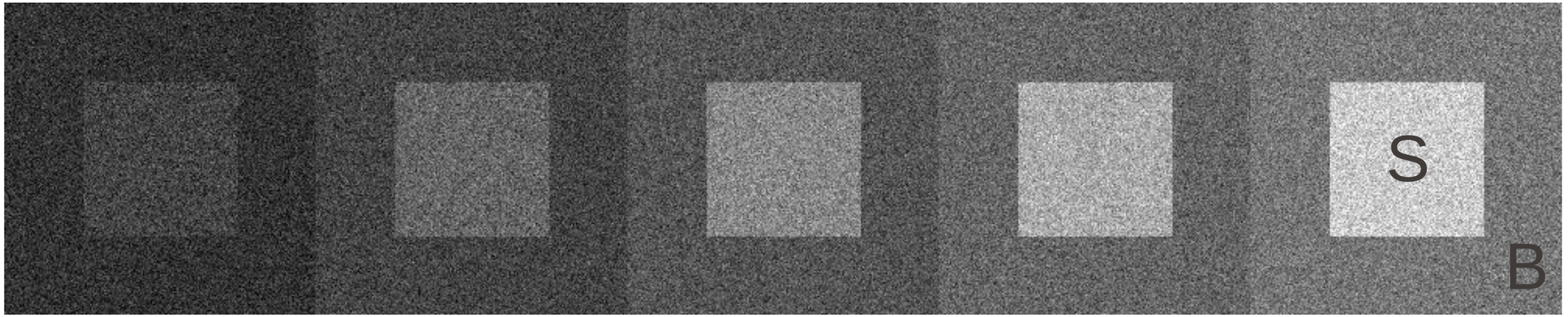
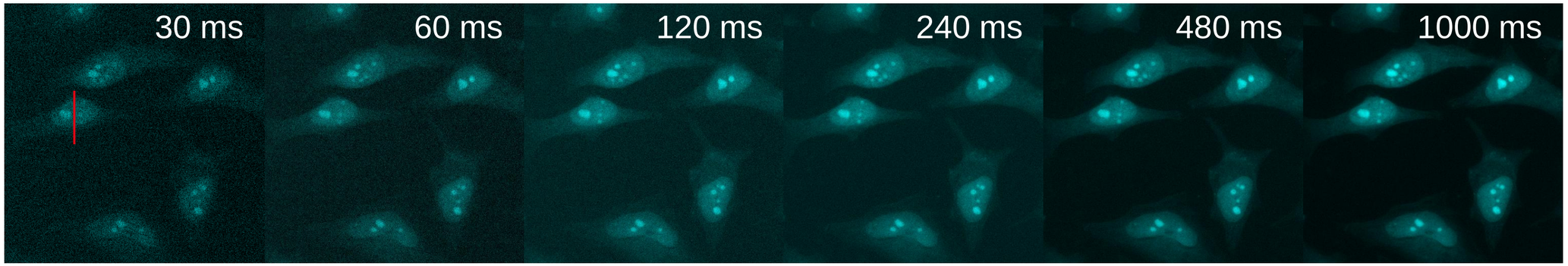


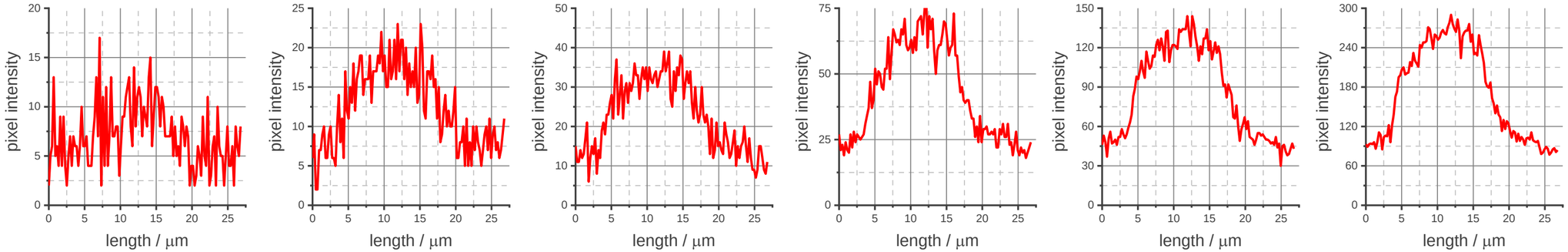
$$N_{tot}^2 = N_s^2 + N_d^2$$

$$N_S = \sqrt{N_{ph}}$$

- Calculating the photon noise properly requires the knowledge of photon counts. Calibration is needed to convert pixel intensities to photon counts.
- Photon noise is depending on the imaging conditions. Longer exposure times, and averaging are reducing the photon noise contribution.
- Reducing detector noise is in most cases difficult to achieve.
- Signal Amplification also amplifies noise contributions.

Signal, Noise and Background





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Signal, Noise and Background

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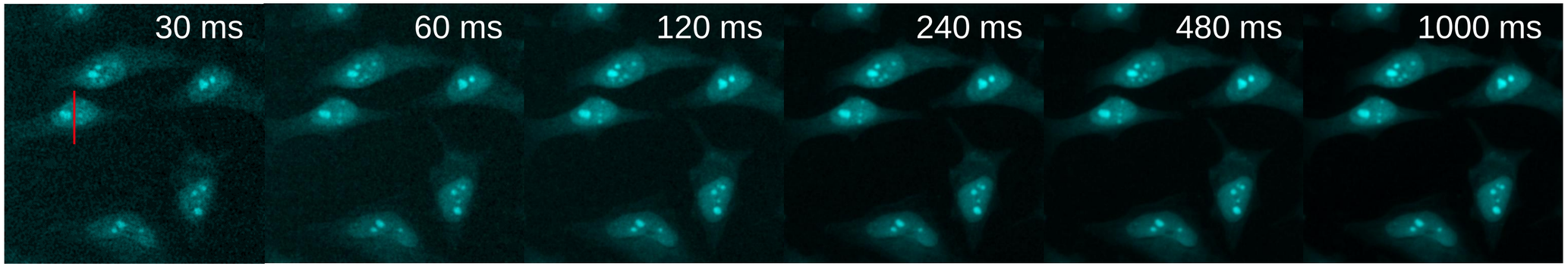
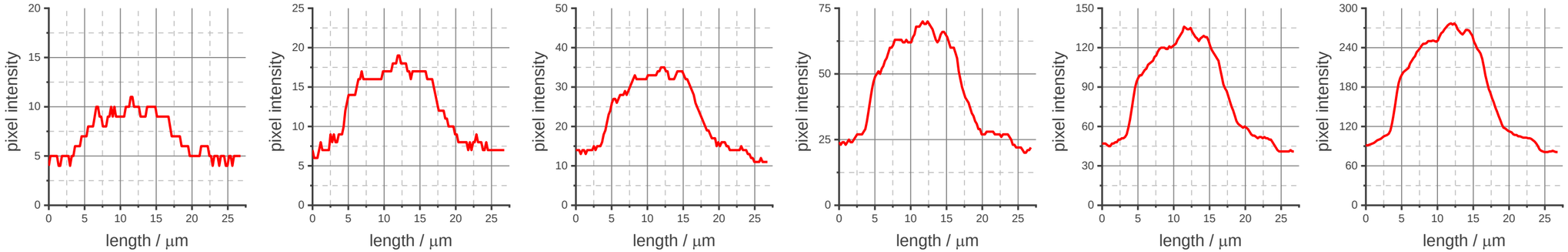
Filter: mean, 2px





Signal, Noise and Background

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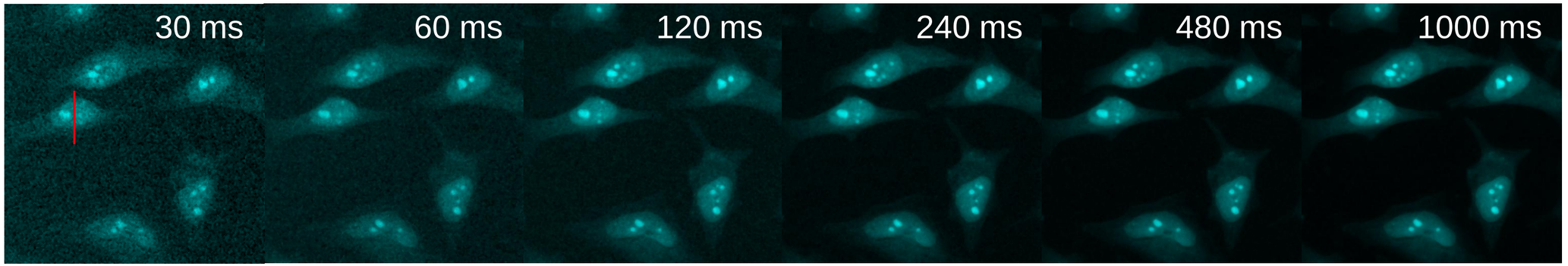
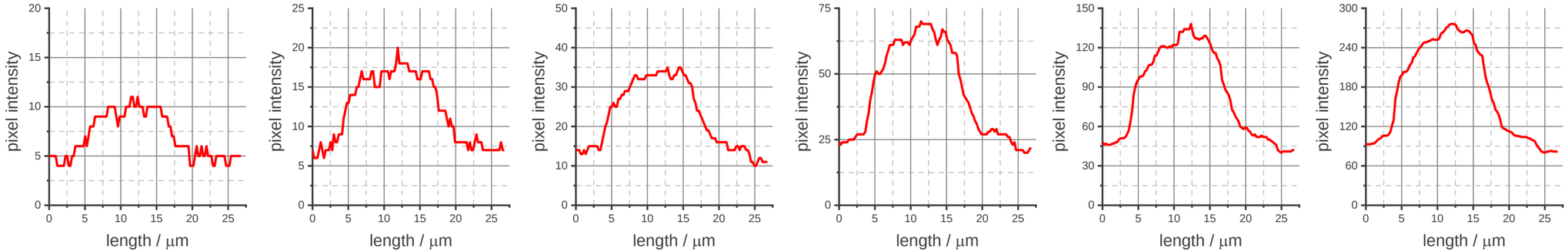
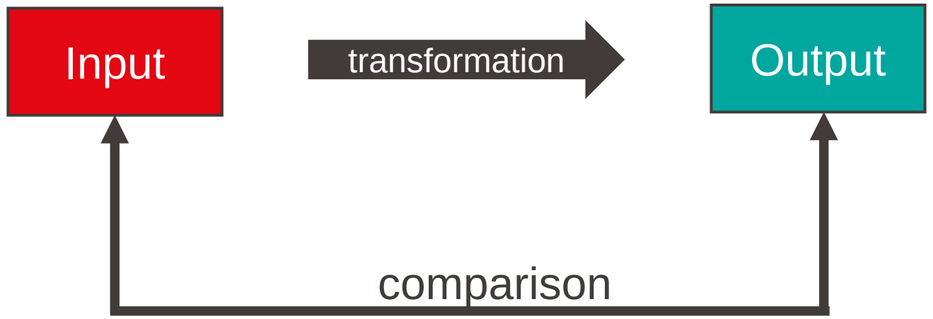
Filter: median, 2px





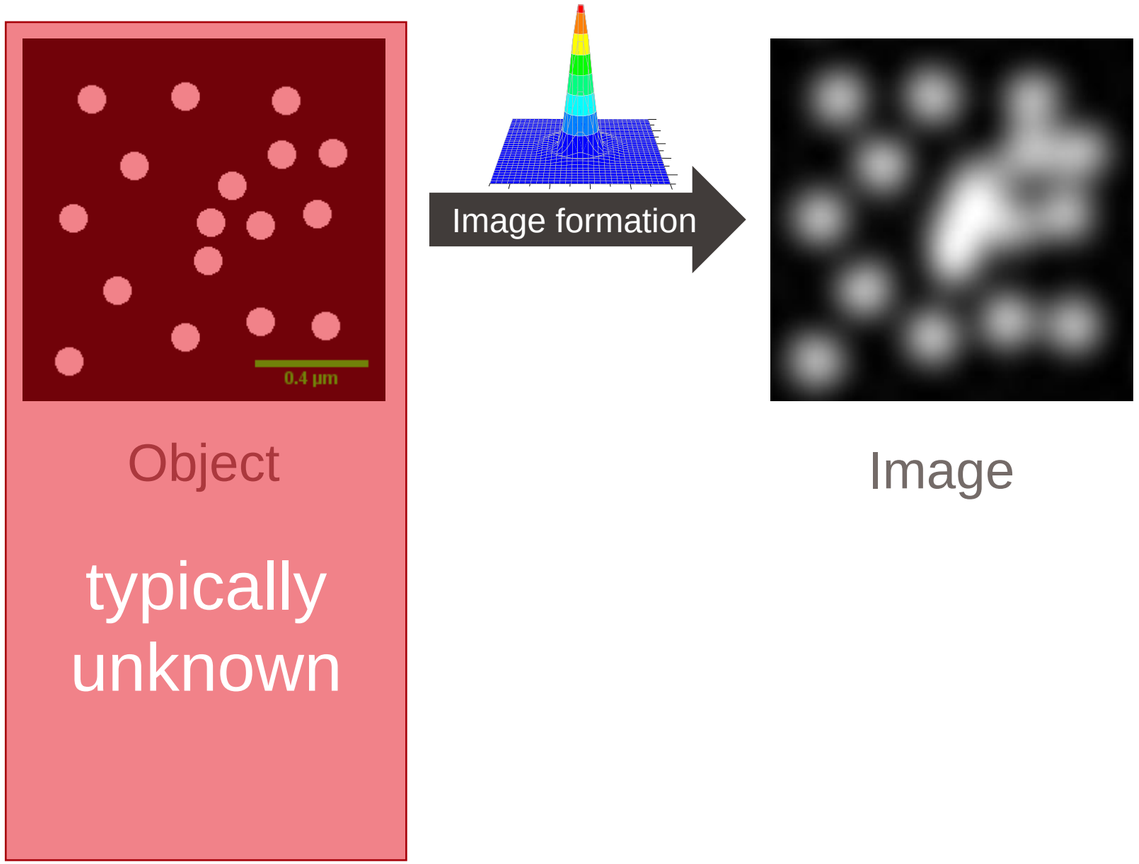
Signal and Image Quality

- Engineer perspective



- Sender/Receiver in telecommunication
- Signal Amplification

- Imaging



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Mean Square Error (MSE)

$$MSE = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[f(x,y) - \hat{f}(x,y) \right]^2$$

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Mean Square Error (MSE)

Noise

Resolution

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Peak Signal-to-Noise Ratio (PSNR)

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

$$= 20 \cdot \log_{10}\left(\frac{MAX_I^2}{\sqrt{MSE}}\right)$$

$$MAX_I = bit\ depth$$

σ=20 PSNR=22.24 dB

σ=10 PSNR=16.42 dB

Noise

σ=2 px PSNR=27.06 dB

σ=4 px PSNR=23.78 dB

Resolution

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Exercise

- Design a workflow/macro that calculates the MSE/PSNR between two images without looping over the pixel intensities

$$MSE = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left[f(x,y) - \hat{f}(x,y)\right]^2$$

```
/*****************************
* Quality metric calculation
*****************************/

imageCalculator("Subtract create 32-bit",
fileName,stemName+"_"+qualityFactor+".jpg");
//subtract input and compressed image

selectWindow("Result of "+fileName);
//select the calculated image

run("Square"); //calculate the square of the difference

getStatistics(area, mean, min, max, std, histogram);
//image measurements

psnr=10*Math.log10(bitD*bitD/mean); //calculate PSNR

writeTable(row); //output results
```


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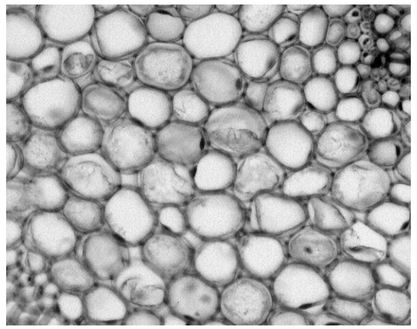
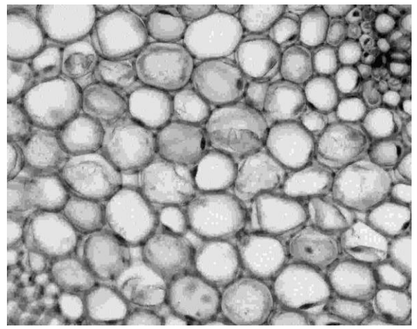
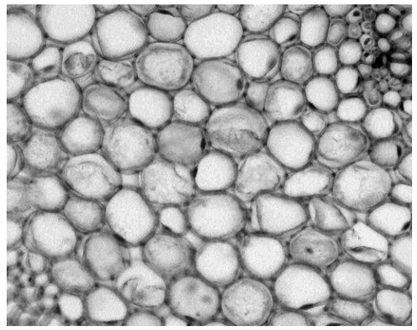
JPEG compession



Original



5%



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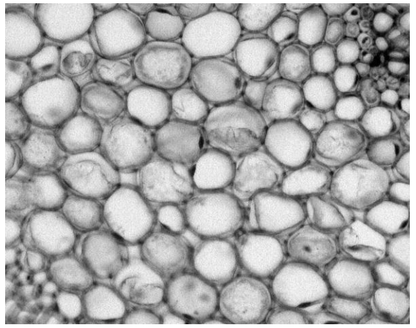
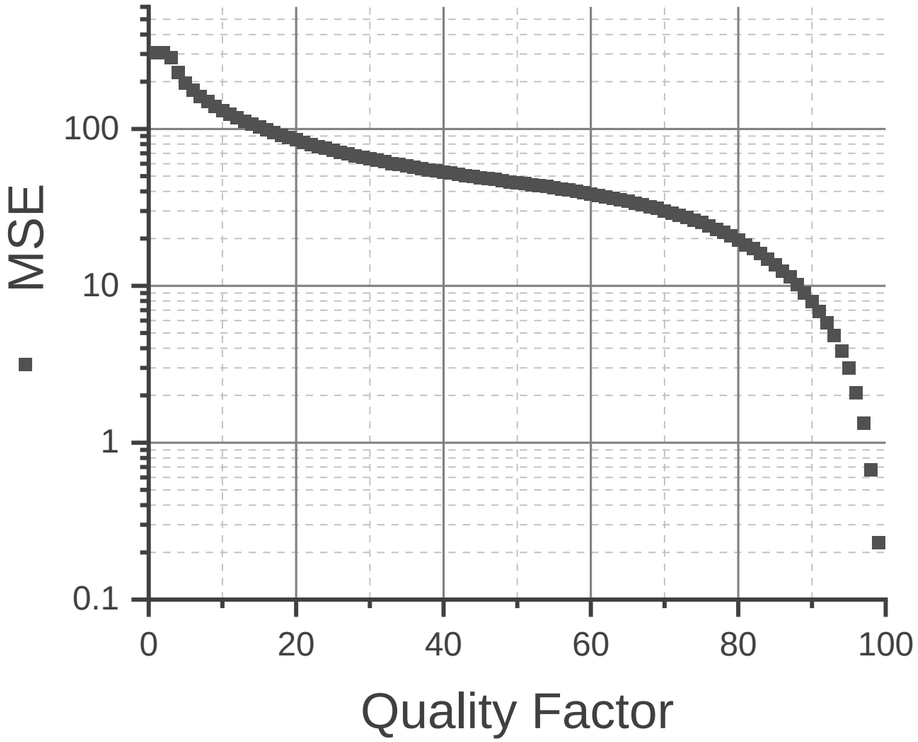
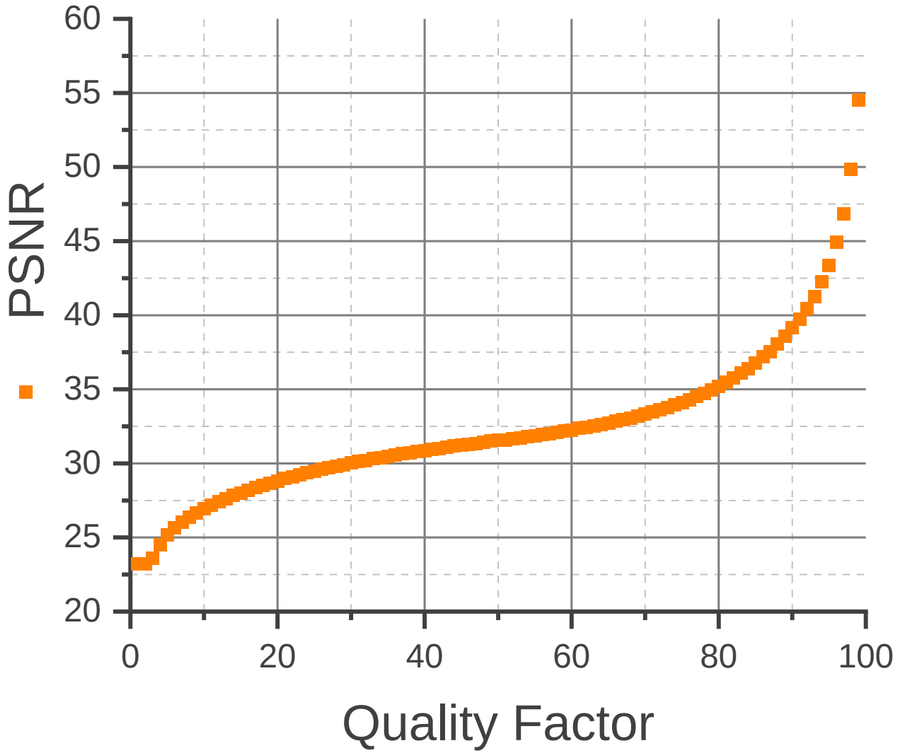


20%





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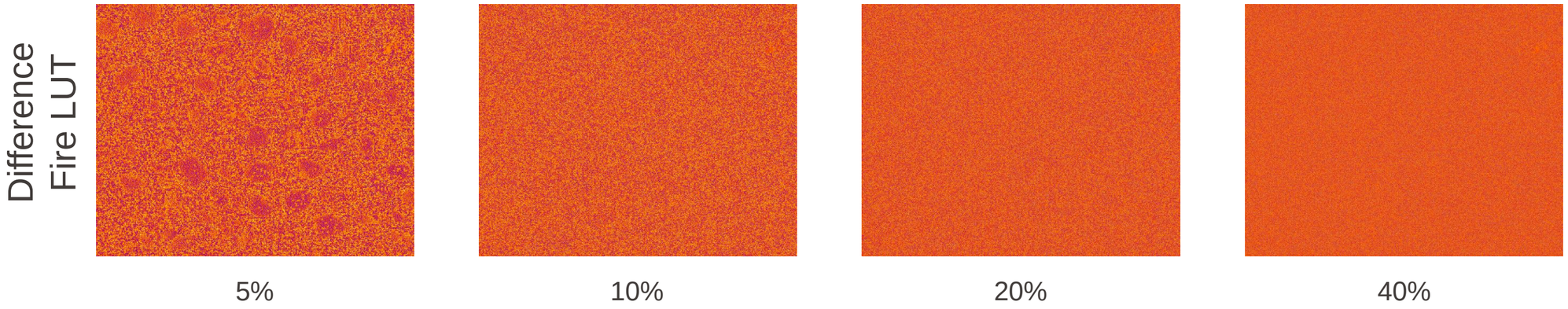
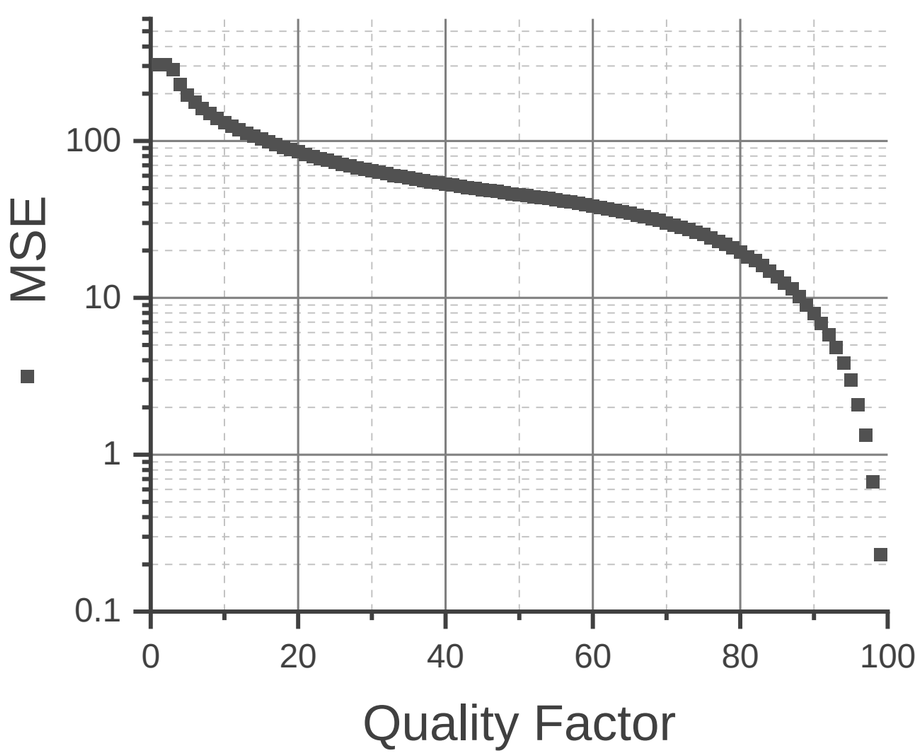
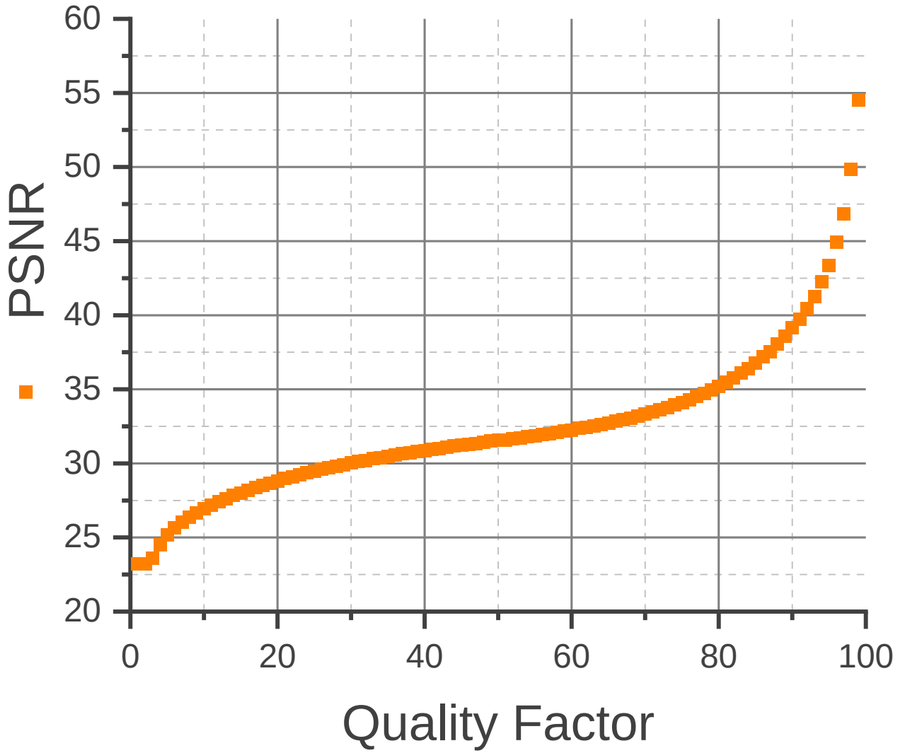
JPEG compression







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Segmentation quality assesment

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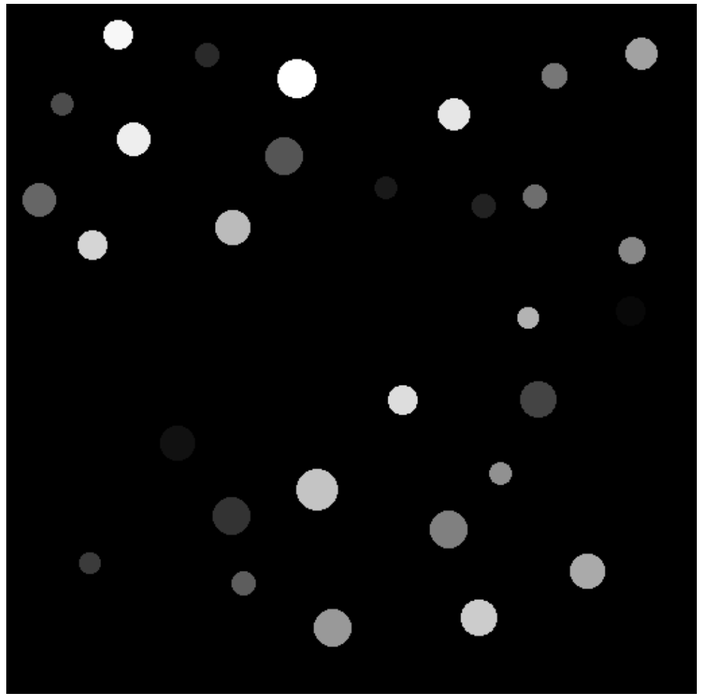
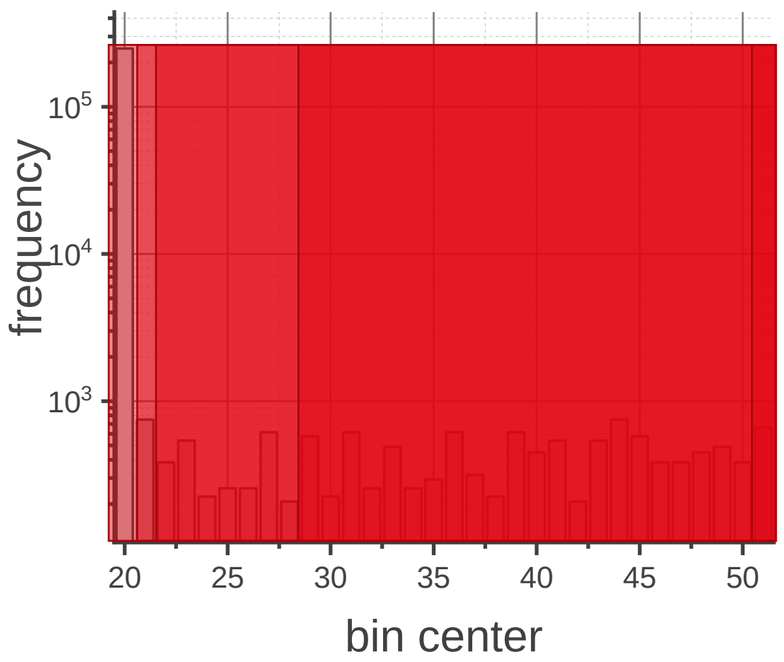
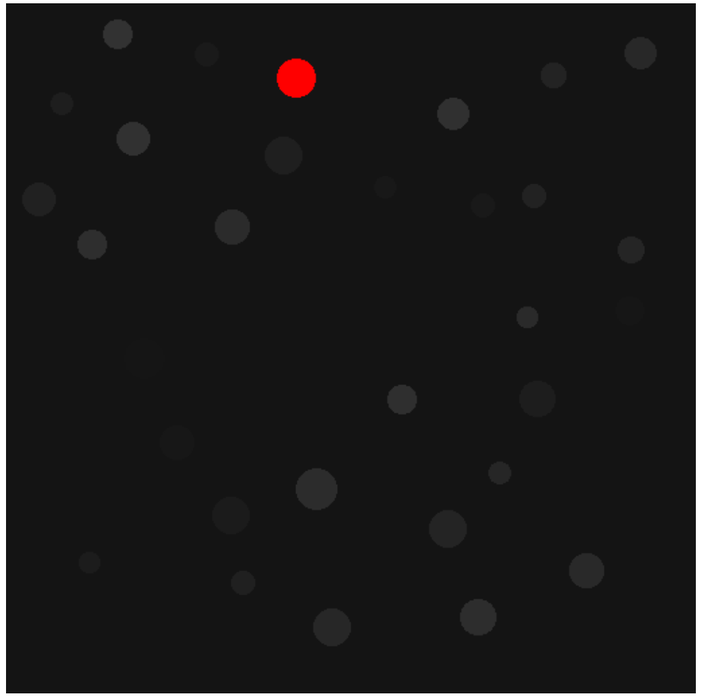
Intenisty based segmentation







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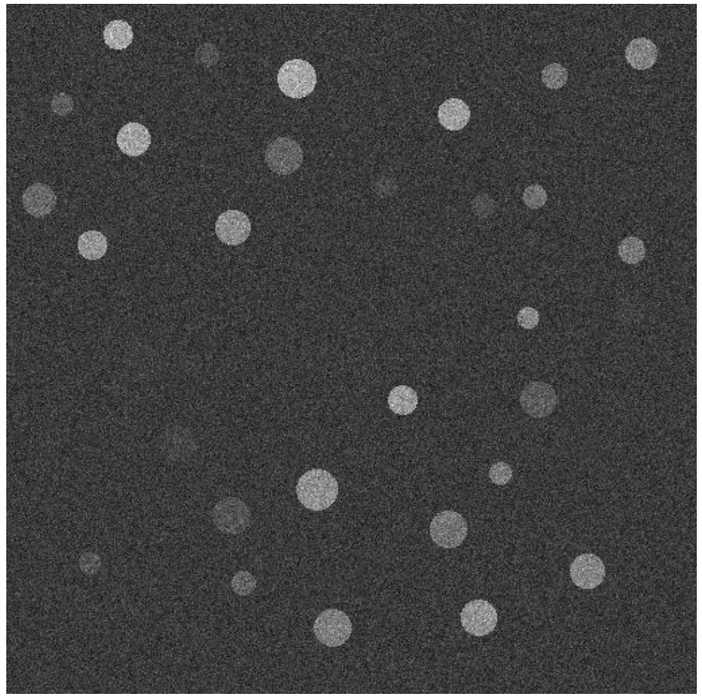
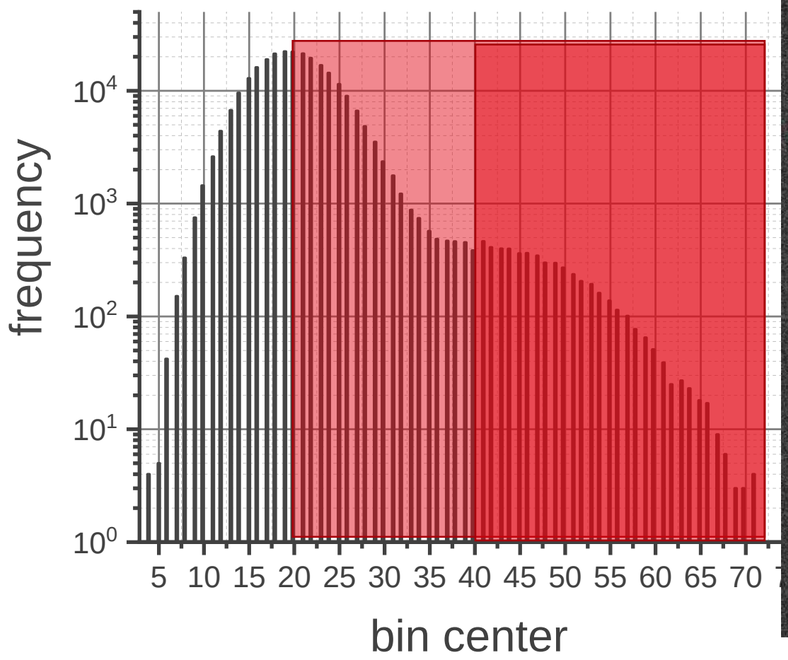
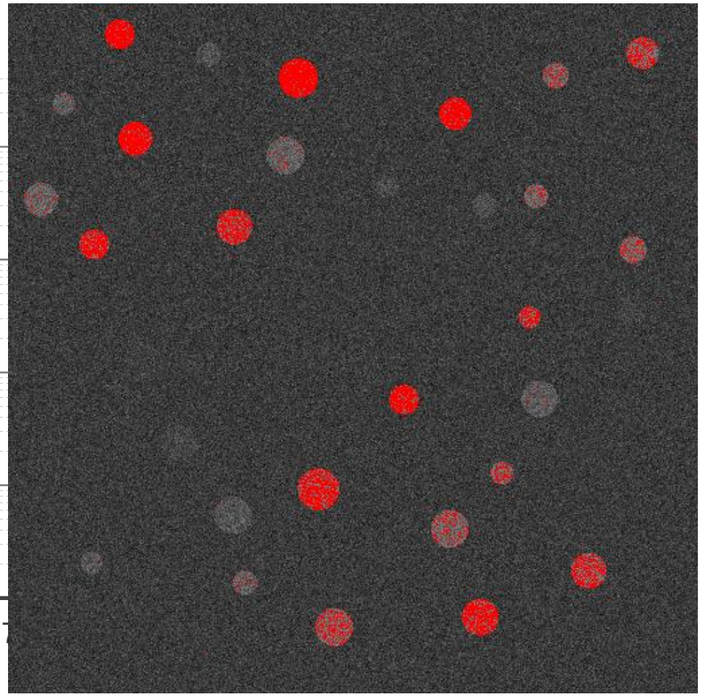
Intenisty based segmentation

Poisson noise







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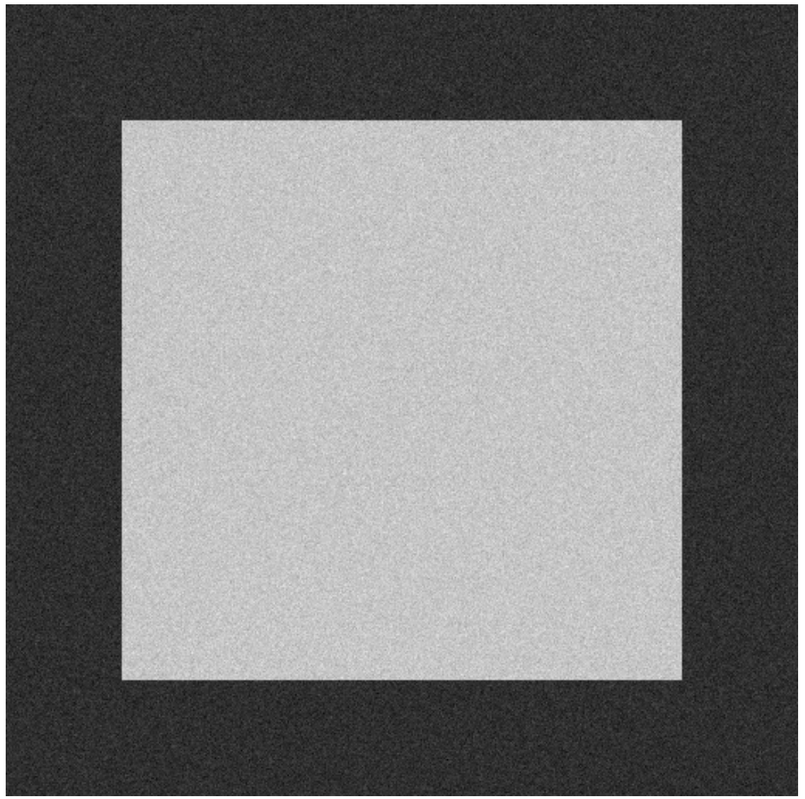
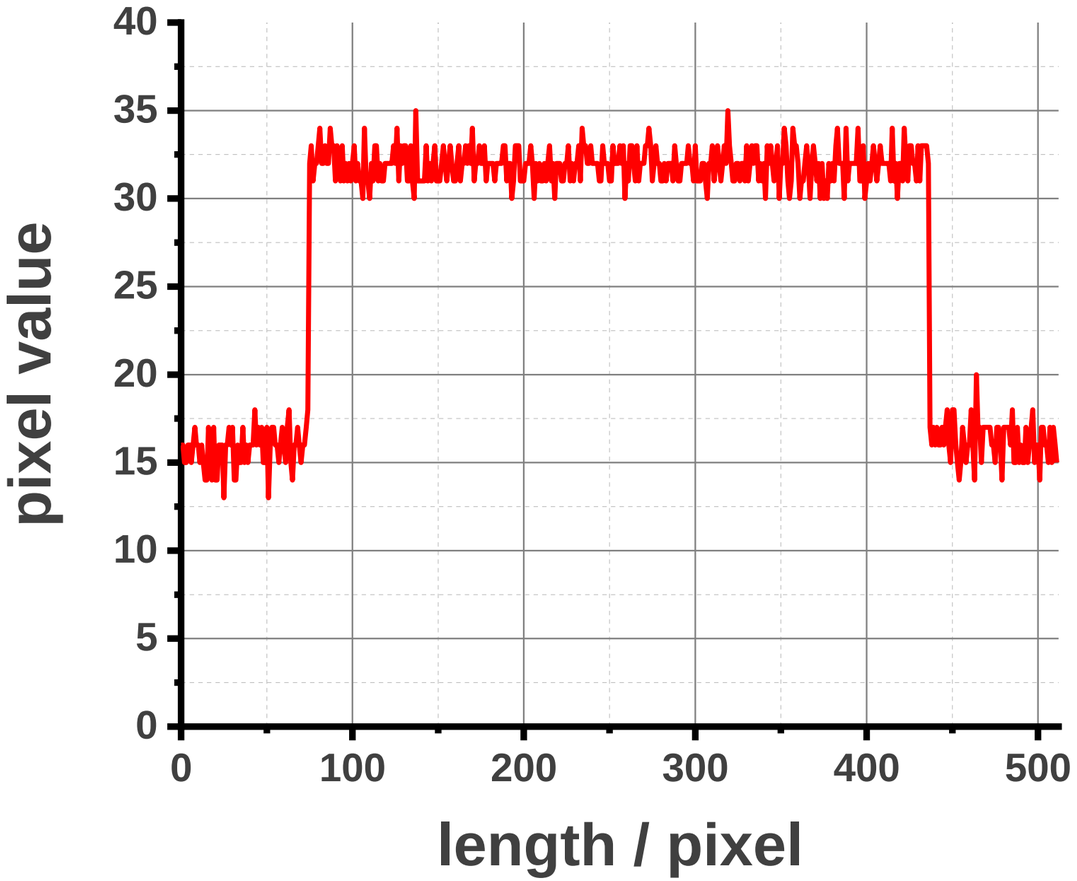
Segmentation and Noise





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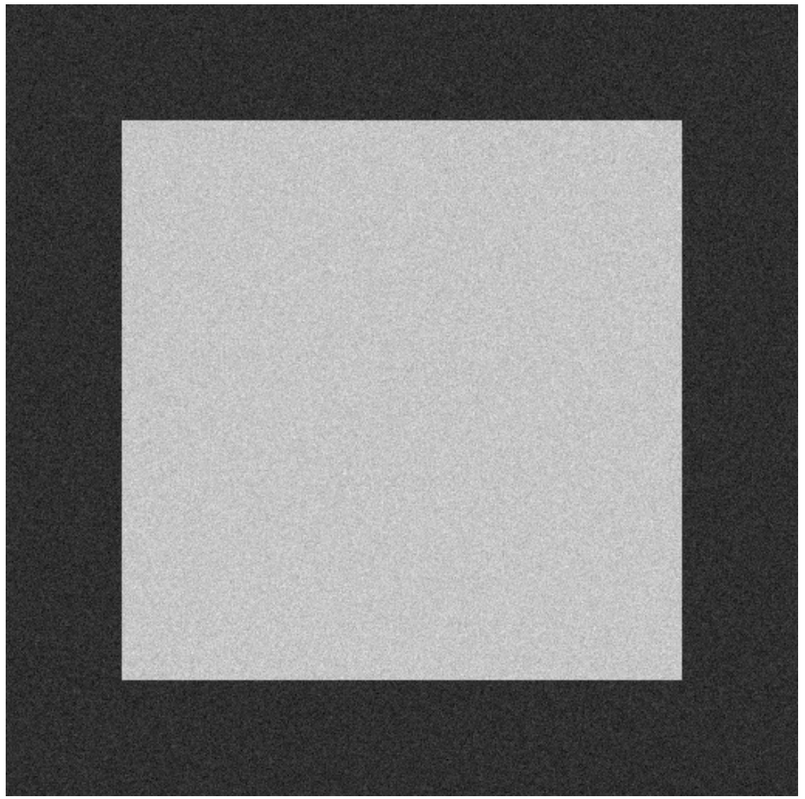
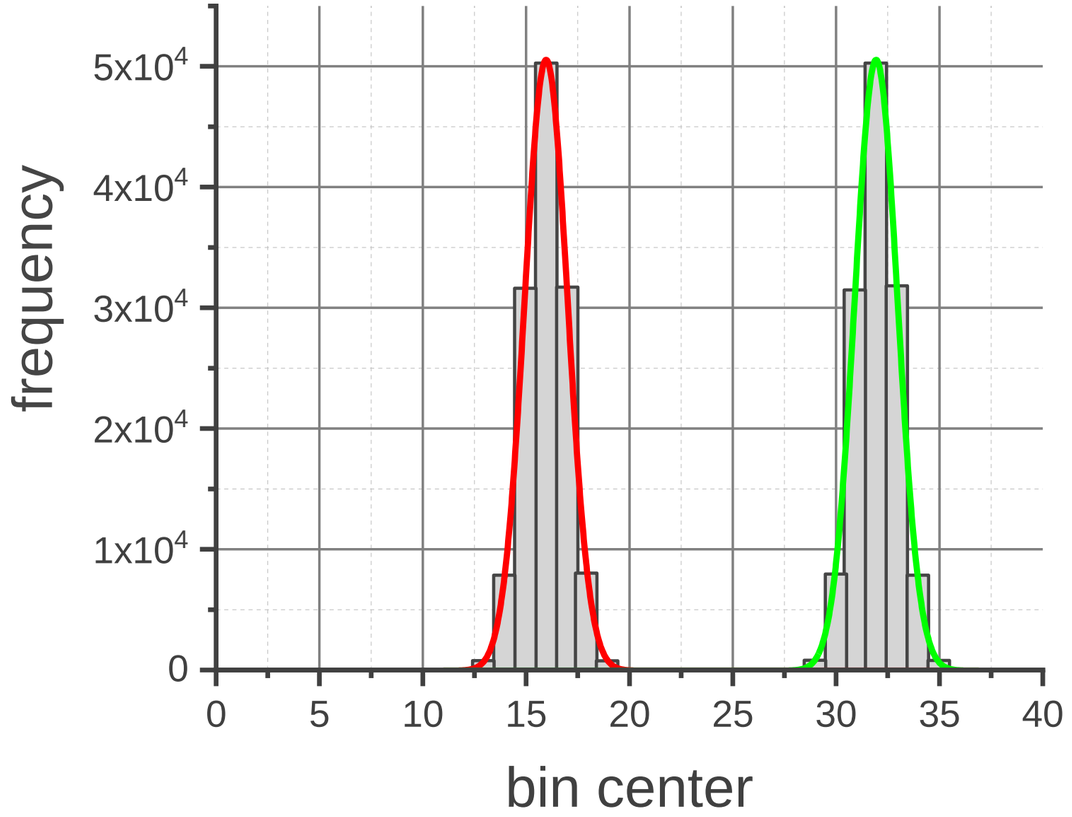
Segmentation and Noise





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Segmentation and Noise

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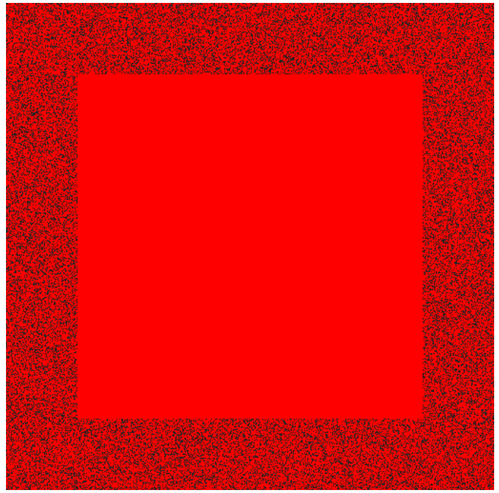
lower threshold: 0

upper threshold: 60

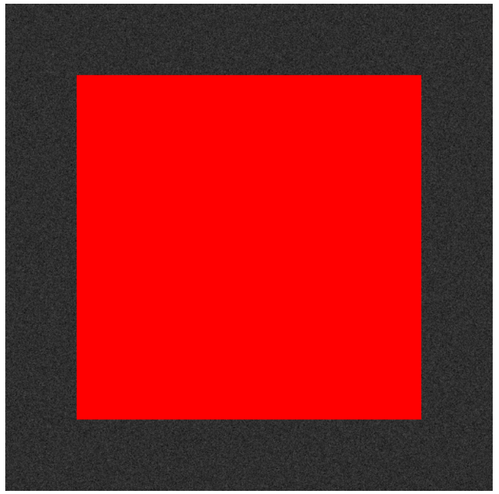
lower threshold: 16

upper threshold: 60



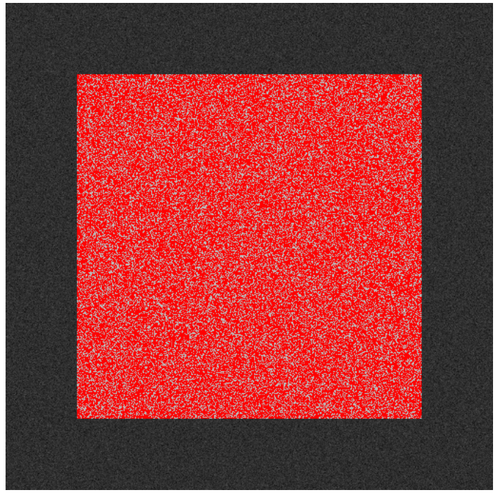
lower threshold: 24

upper threshold: 60

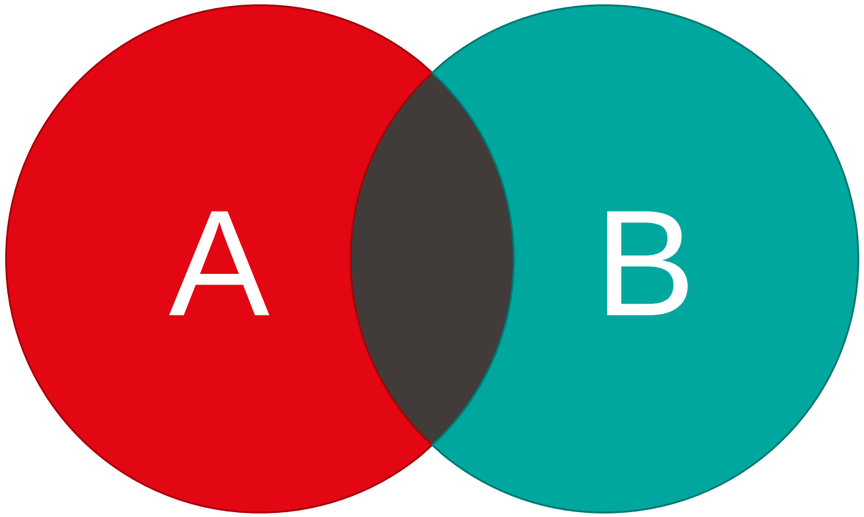


lower threshold: 32

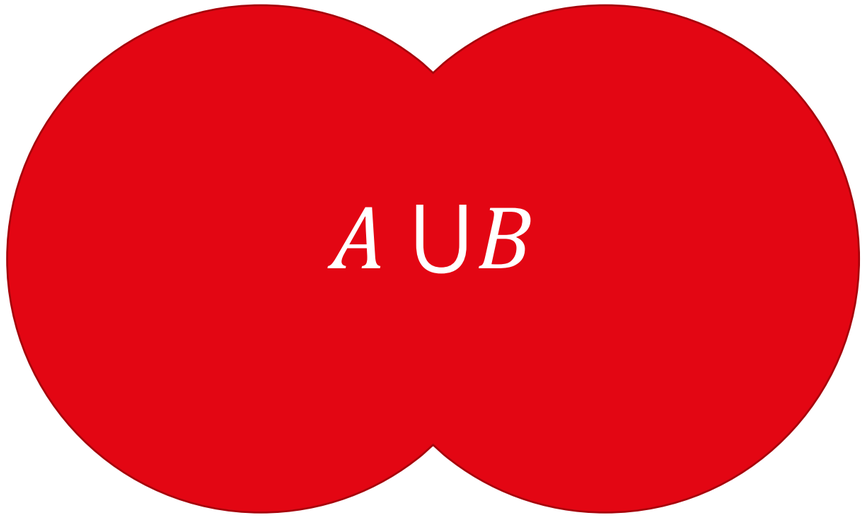
upper threshold: 60



Jaccard similarity coefficient



$A \cap B$



$$J(A,B) = \frac{|A \cap B|}{|A \cup B|}$$

Intersection over Union (IoU)

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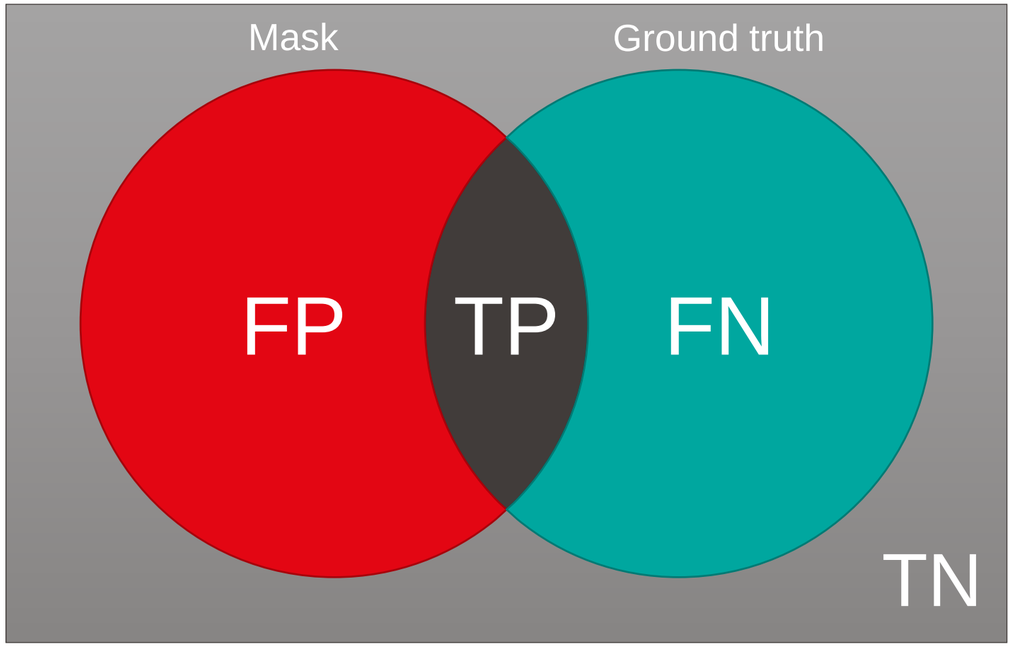
Overlap metrics



TP: true positive
TN: true negative
FP: false positive
FN: false negative

$$DSC = \frac{TP}{TP + FN + FP}$$

$$IoU = \frac{|A \cap B|}{|A \cup B|}$$

$$DSC = \frac{2 \cdot IoU}{1 + IoU}$$

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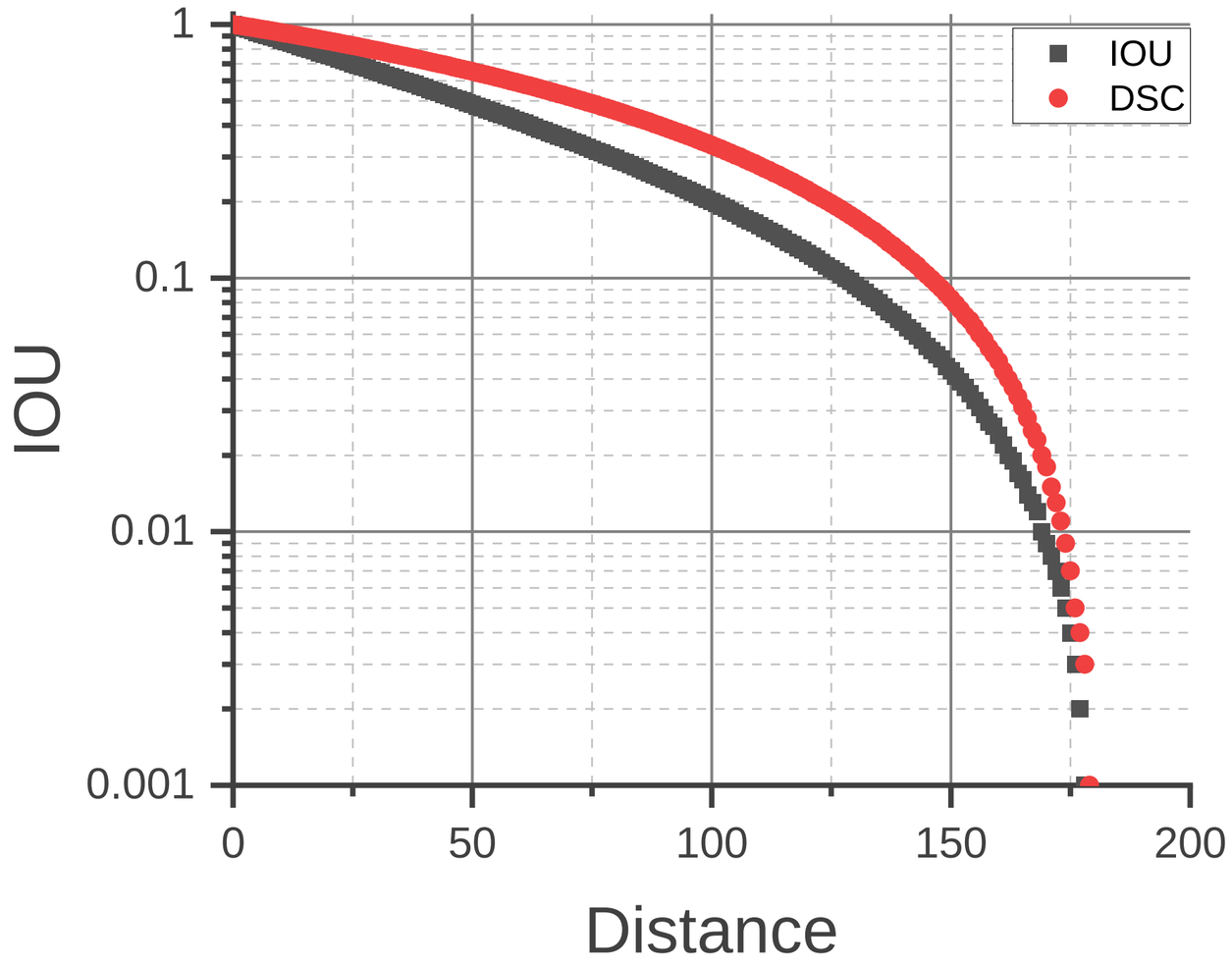
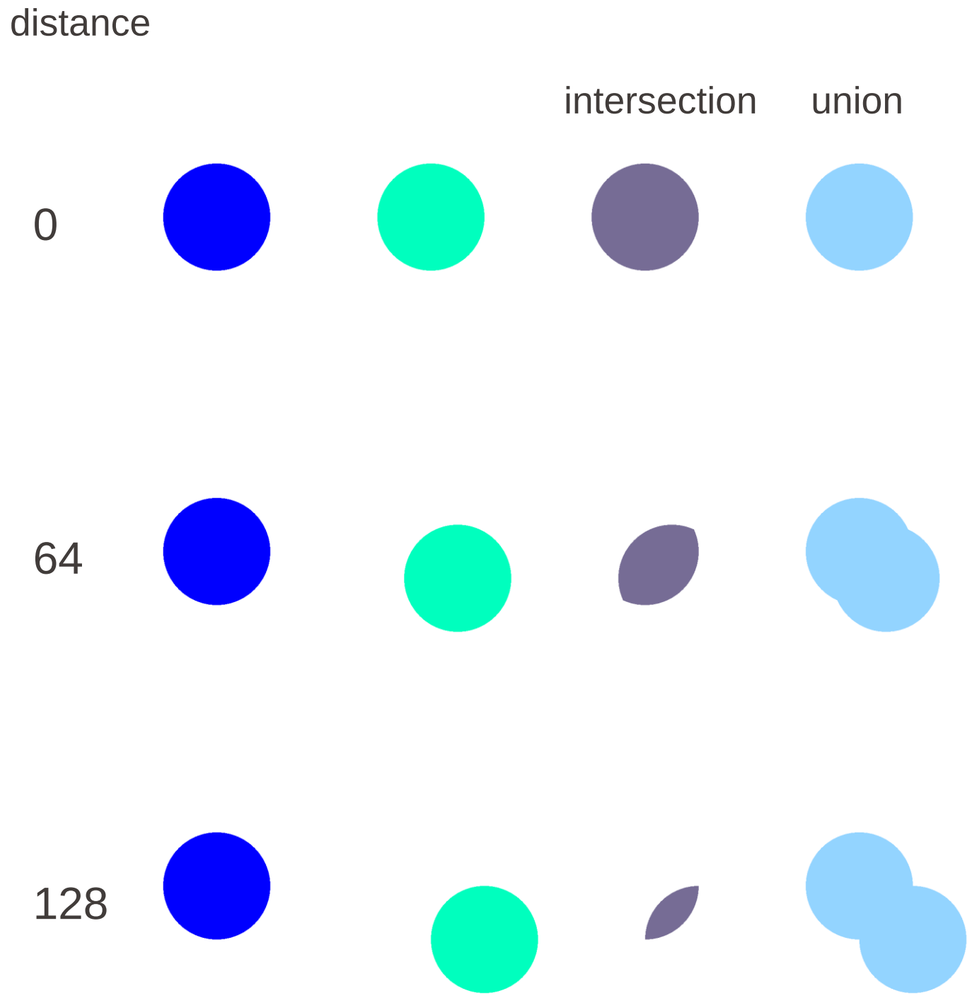
Overlap quantification





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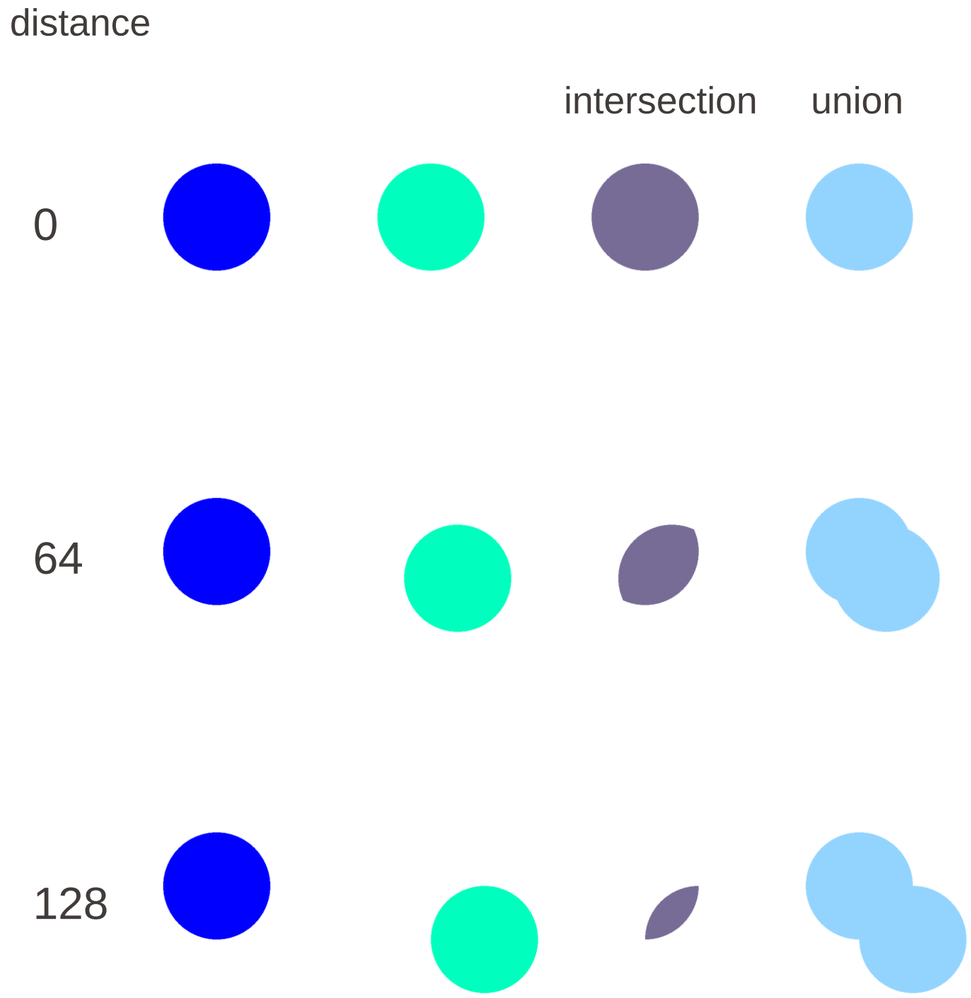
Overlap quantification limitations

- Gets more complicated for several objects (=instance segmentation)
- Gets more complicated if there are more than two categories
- Suffers from class/area imbalance



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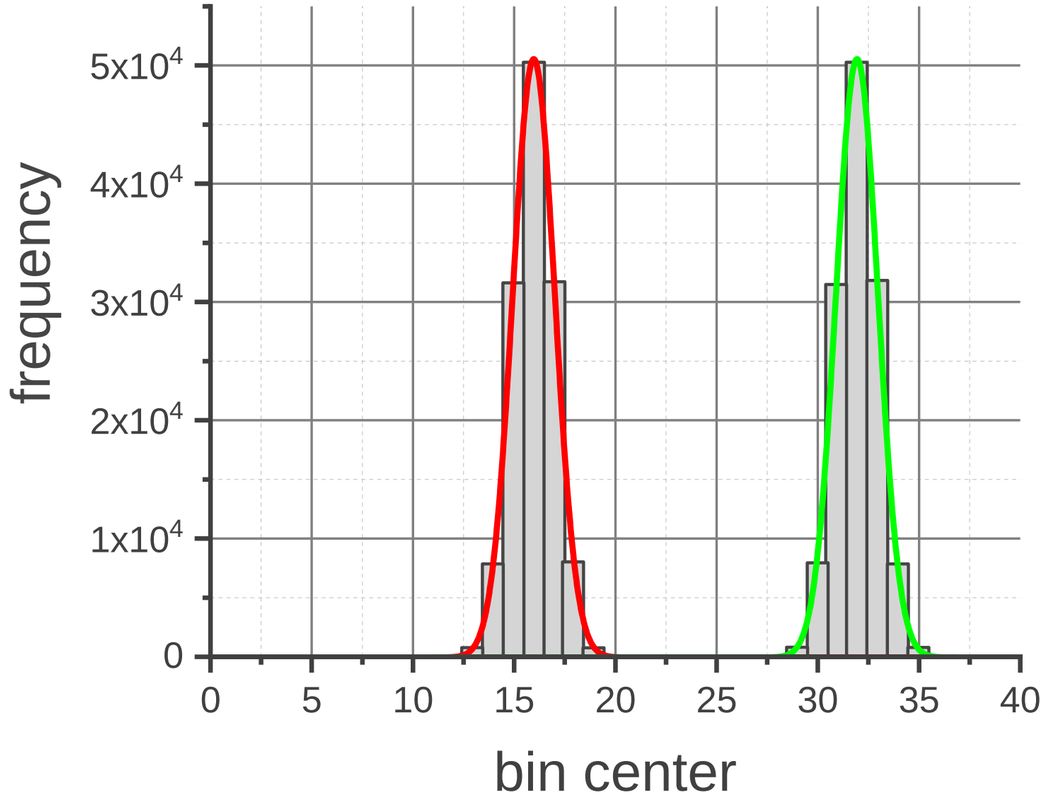
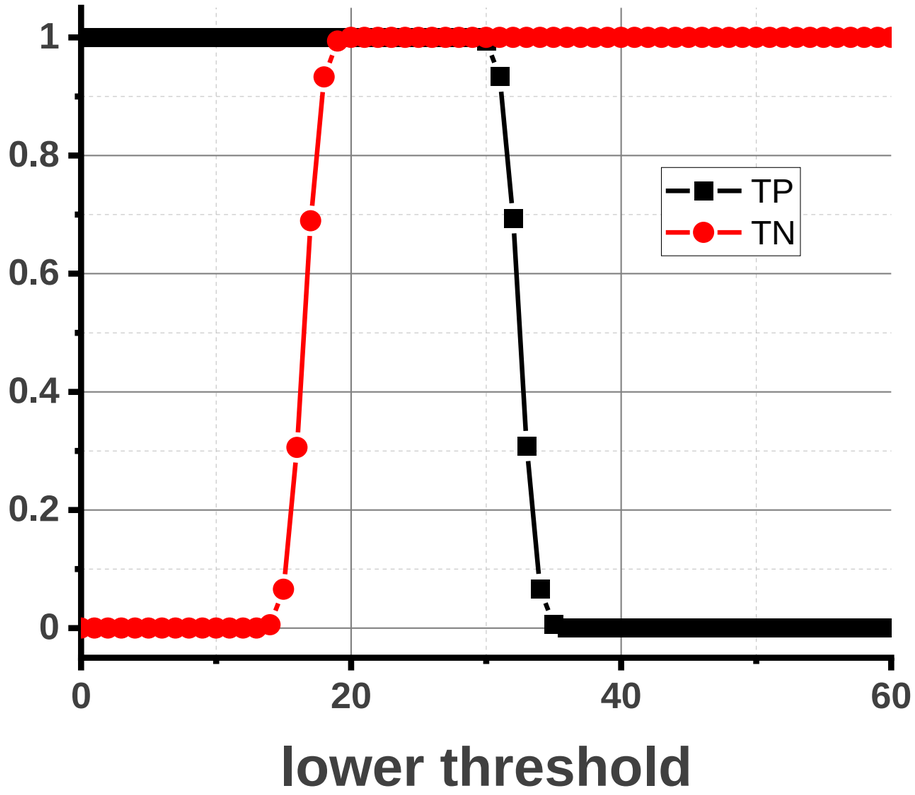
Assessment of segmentation





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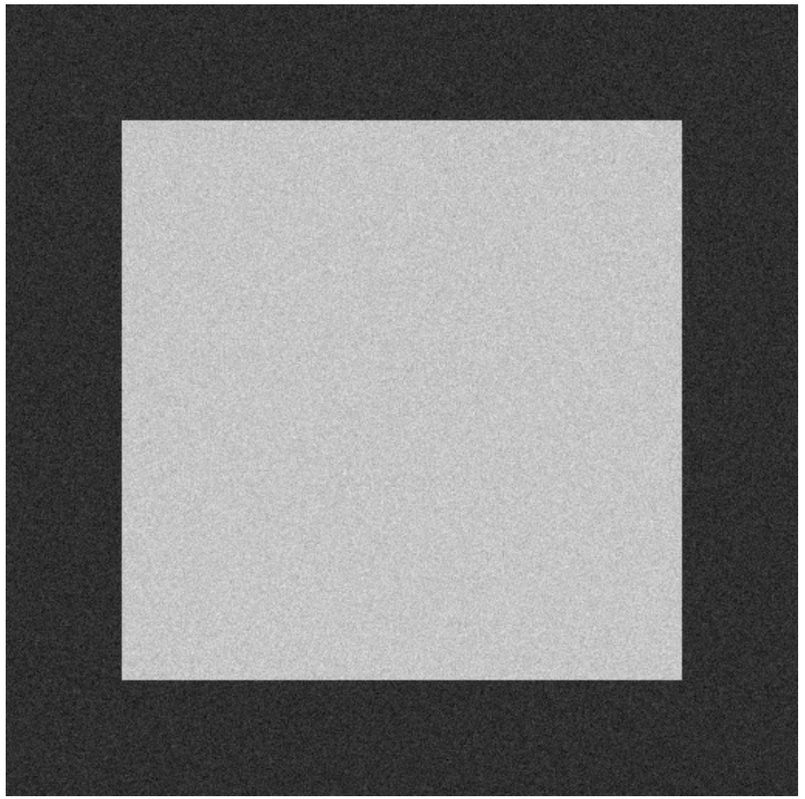
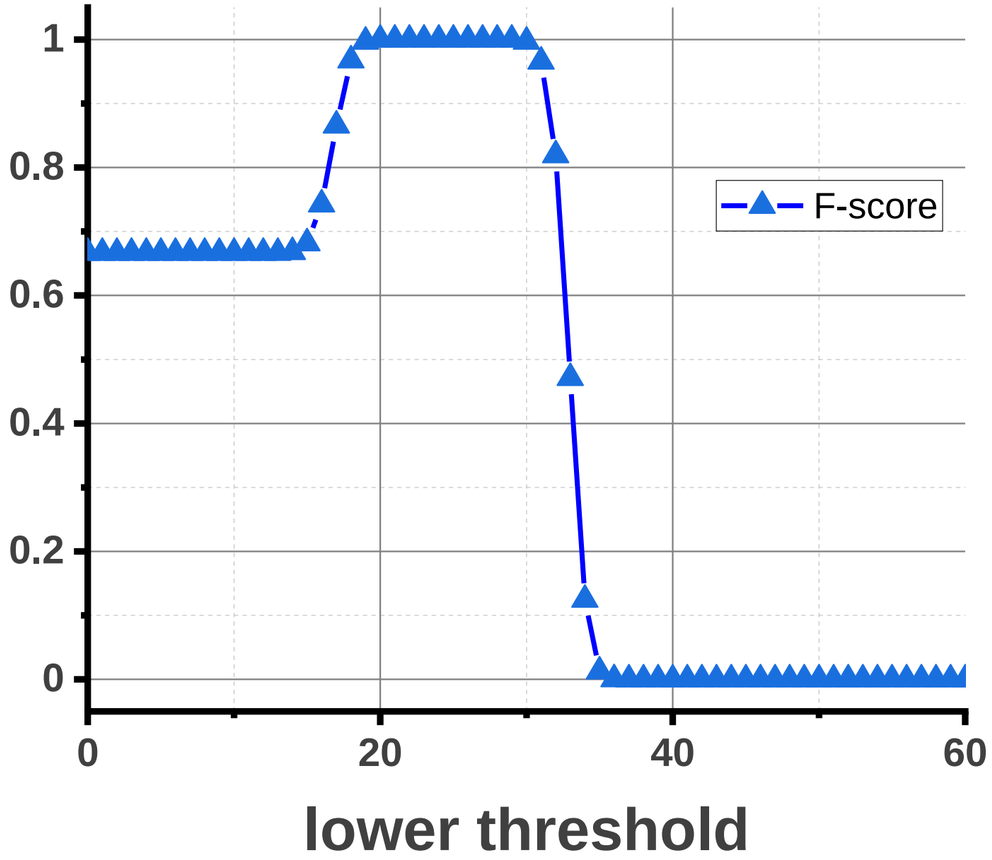
Assessment of segmentation





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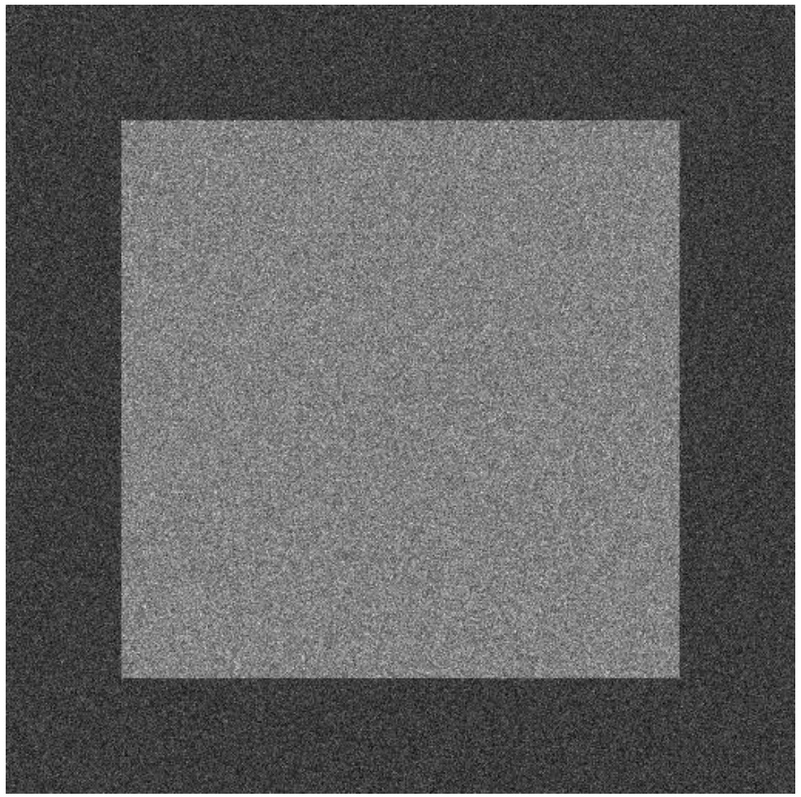
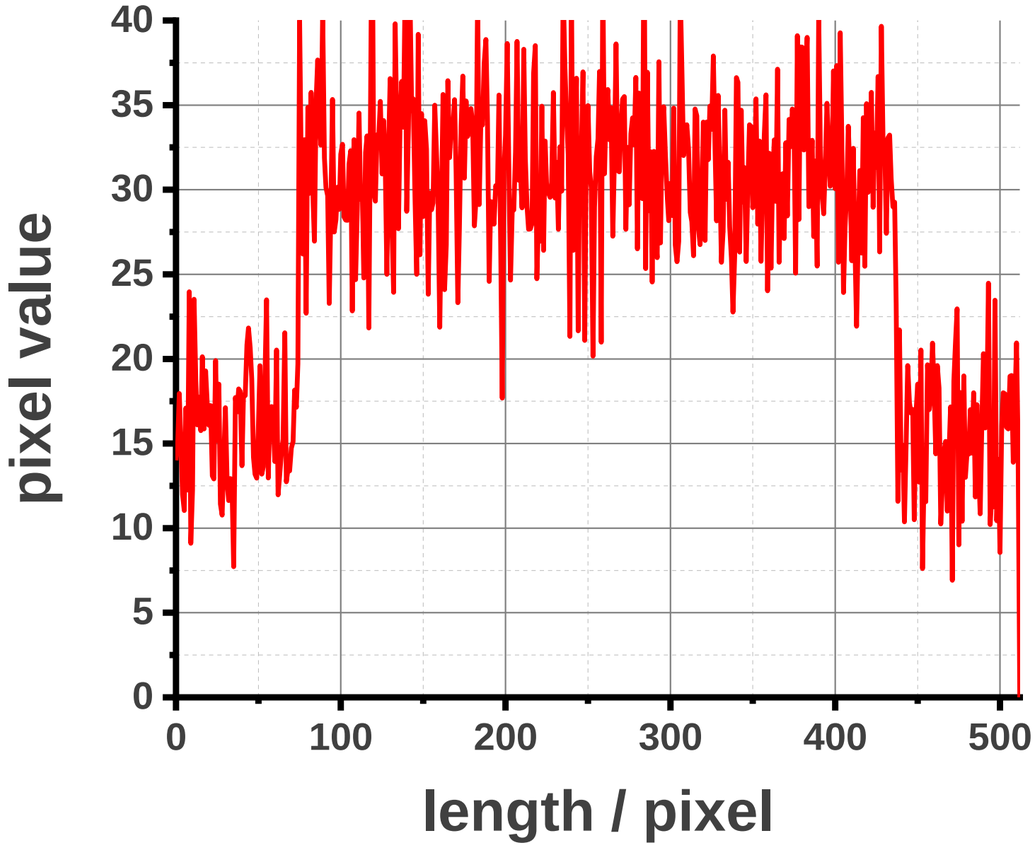
Assessment of segmentation





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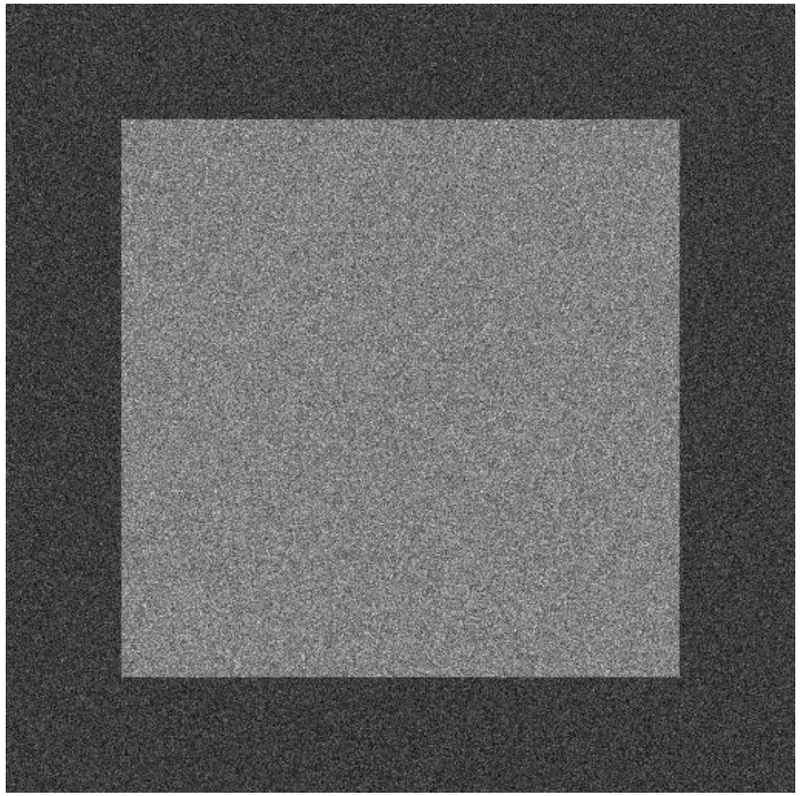
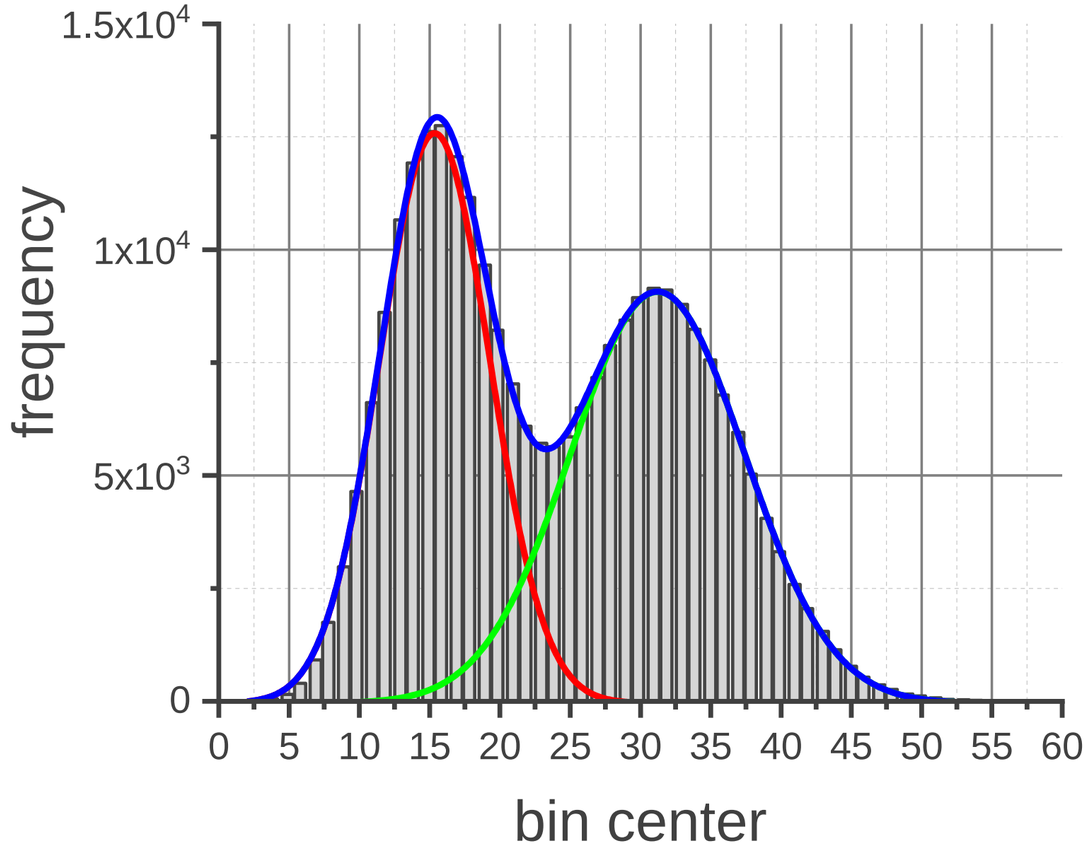
Assessment of segmentation





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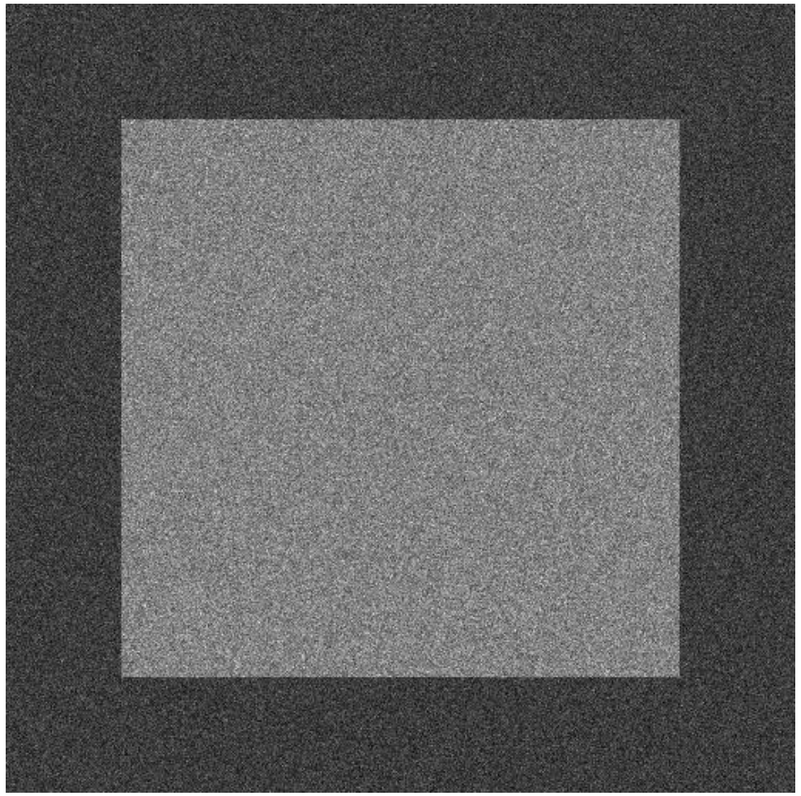
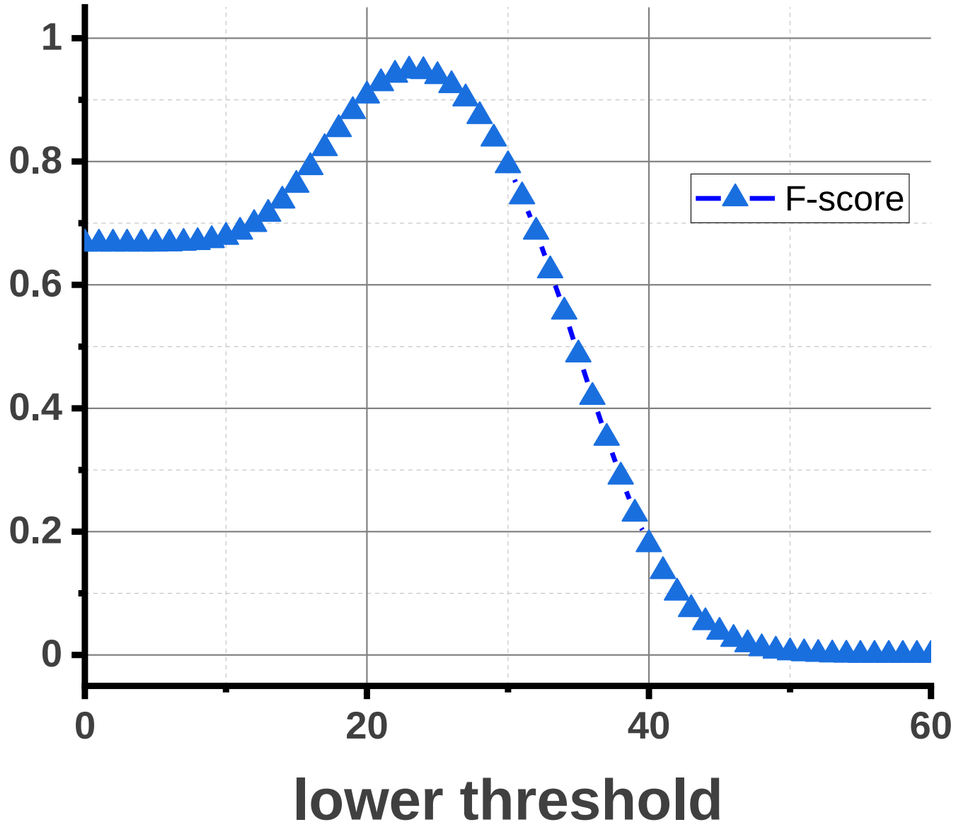
Assessment of segmentation





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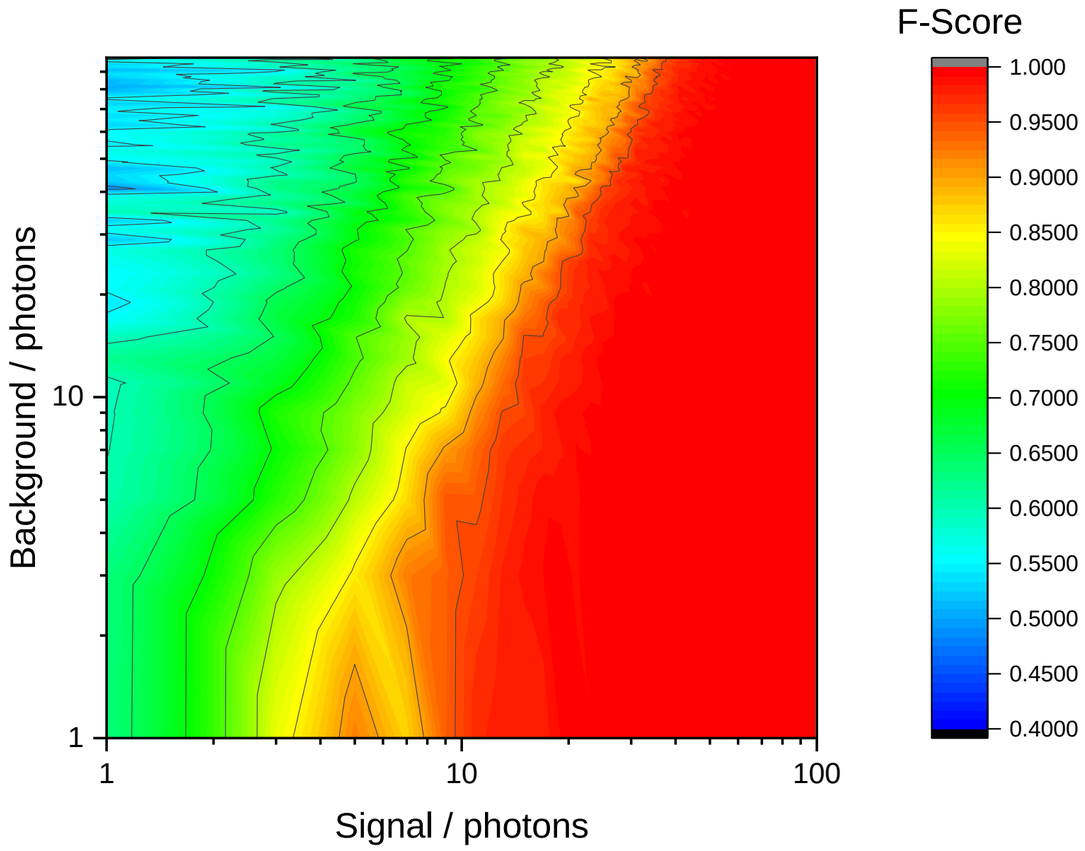
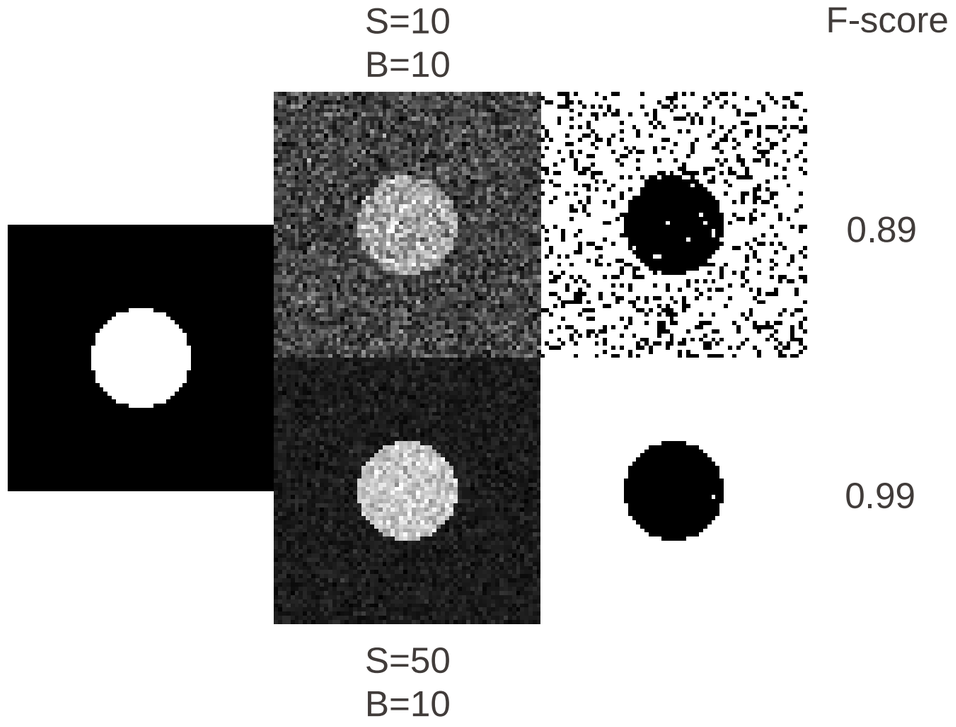
Signal, Noise and Background





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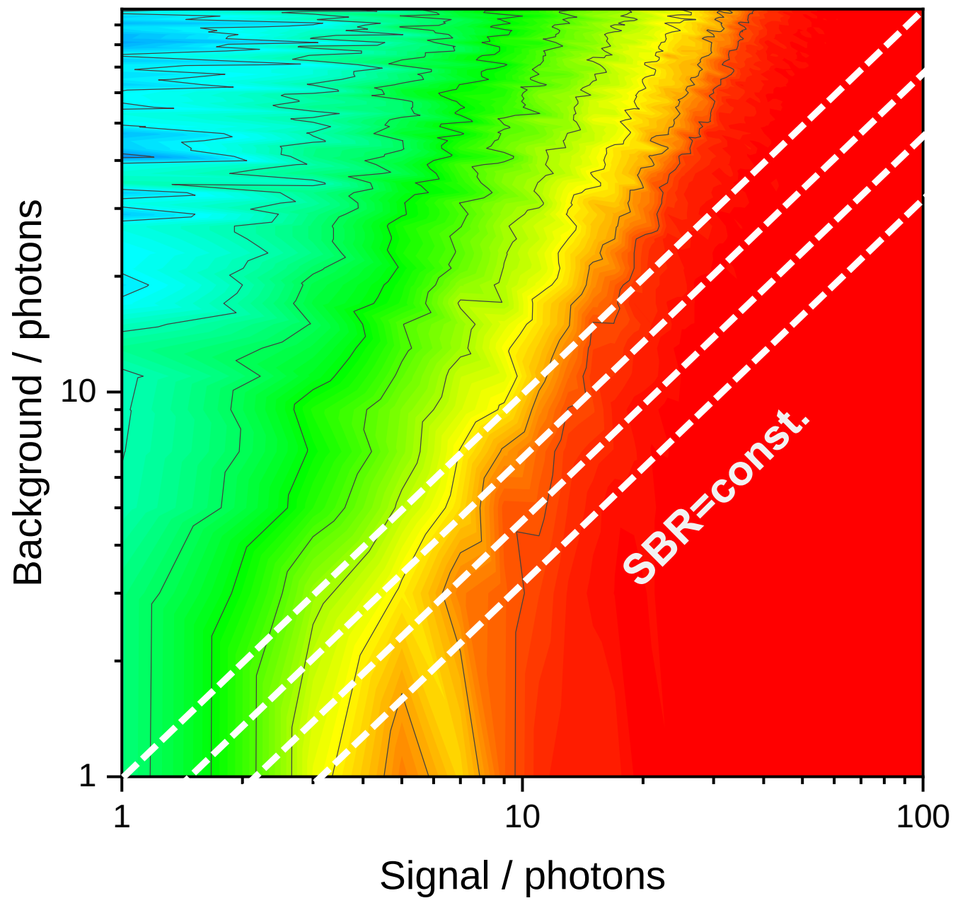
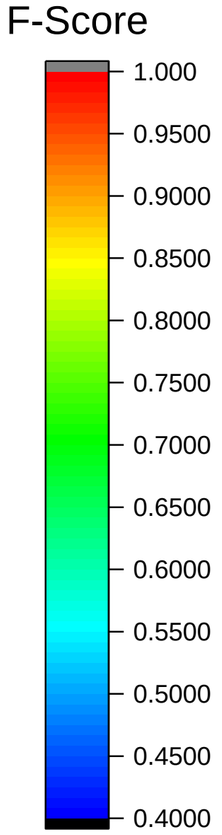
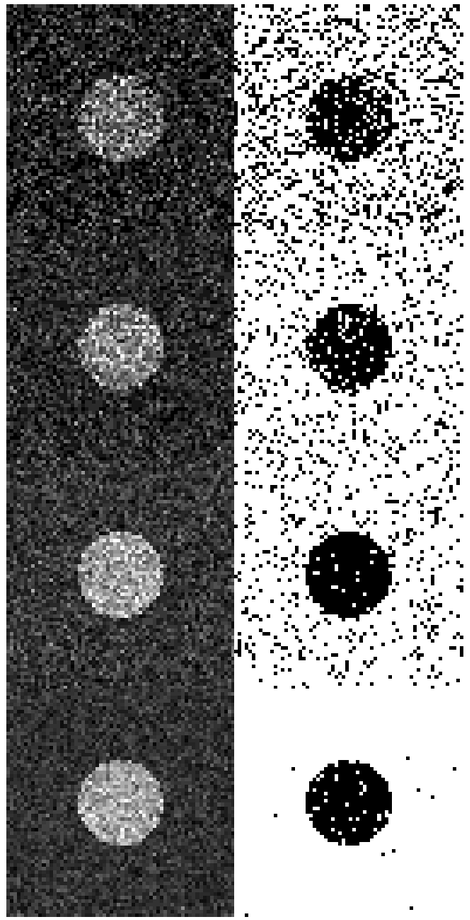
Signal, Noise and Background







S=2: F=0.786

S=4: F=0.859

S=8: F=0.925

S=16: F=0.959

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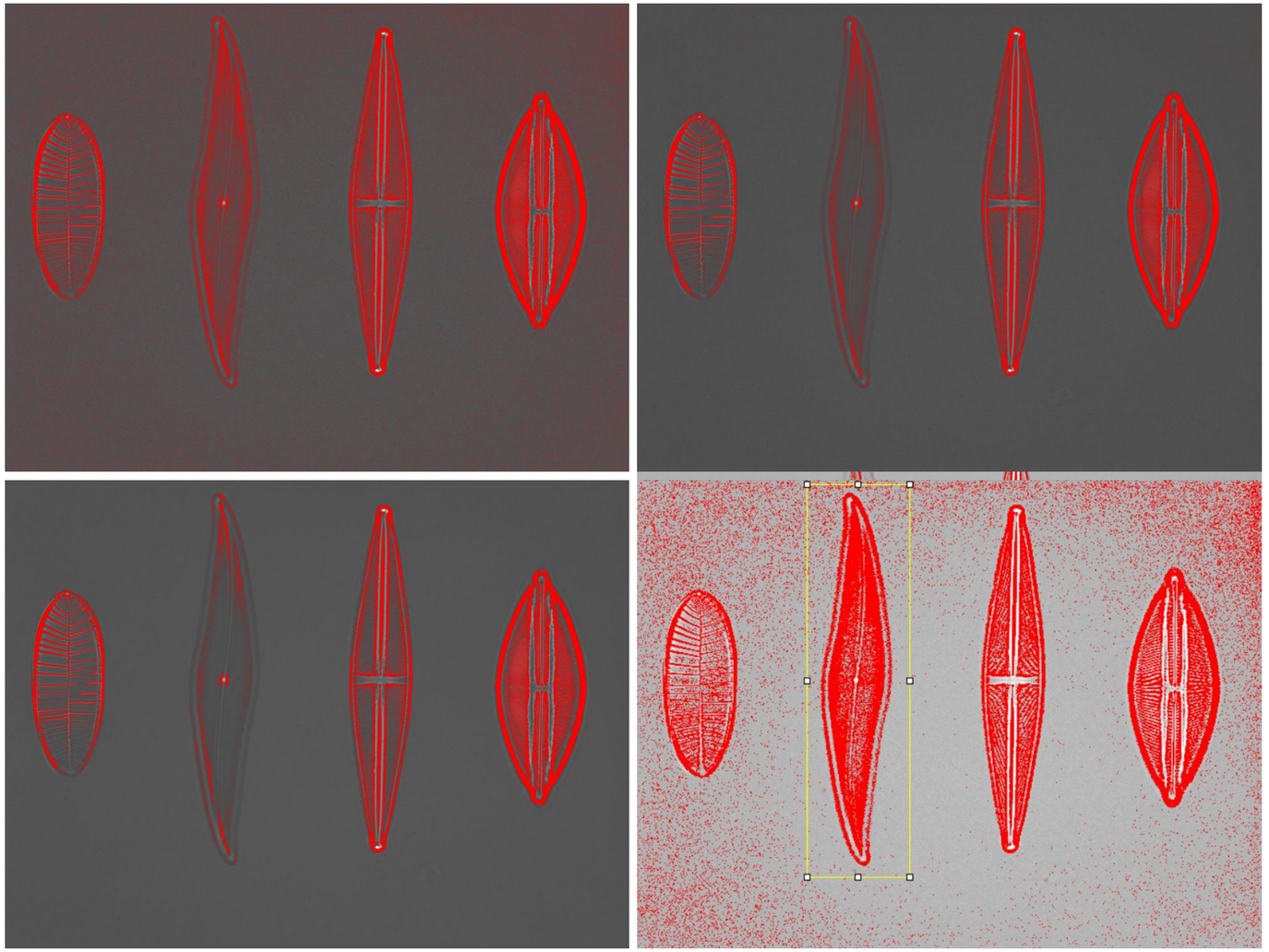
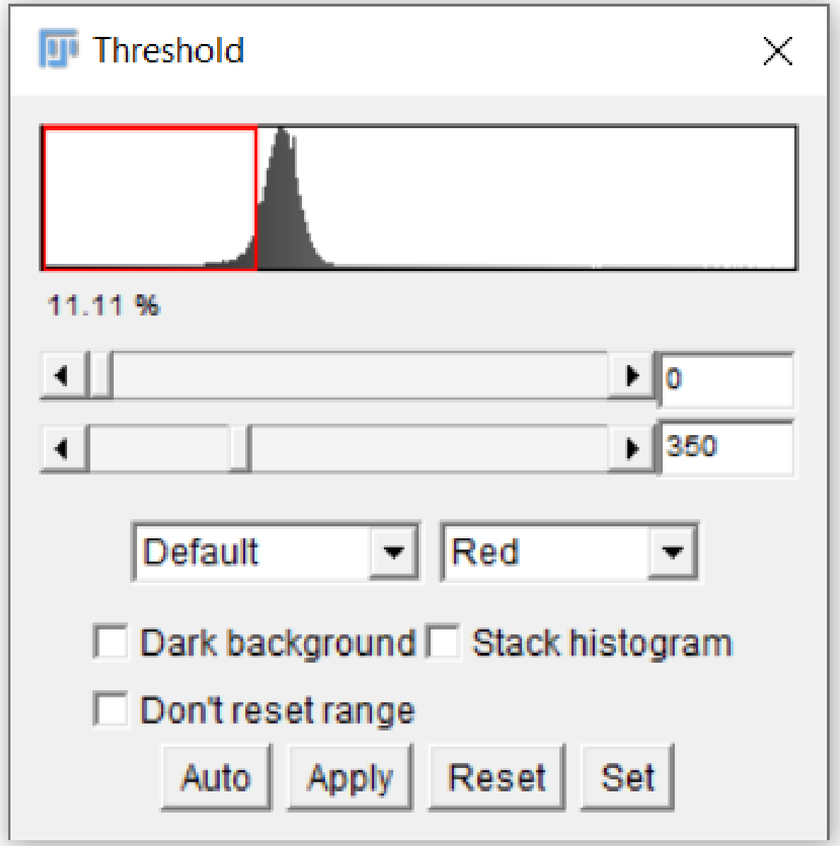
Segmentation algorithms
Context dependency





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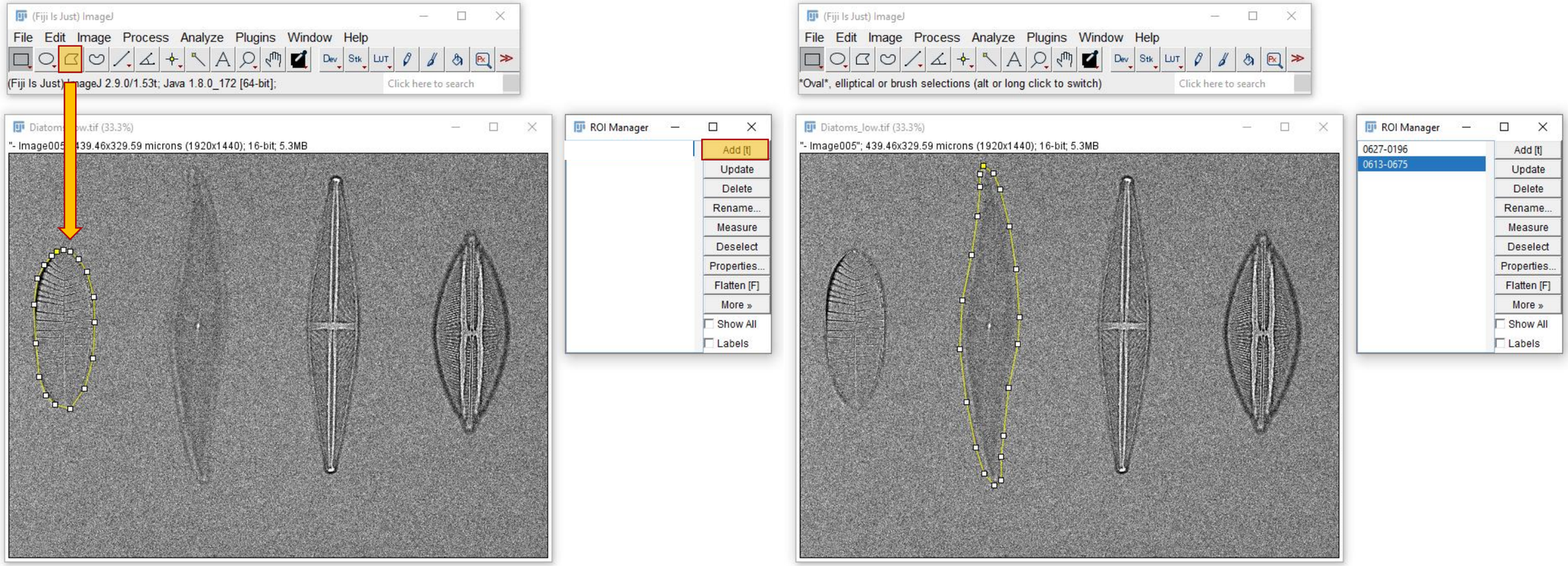
Exercise Segmentation qualitiy

1. Segment the four different diatoms in two different images (Diatom_low.tif, Diatom_high.tif). Please do the segmentation from left to right.
2. Use the polygon selection.
3. Store each segmentation in the Roi manager.



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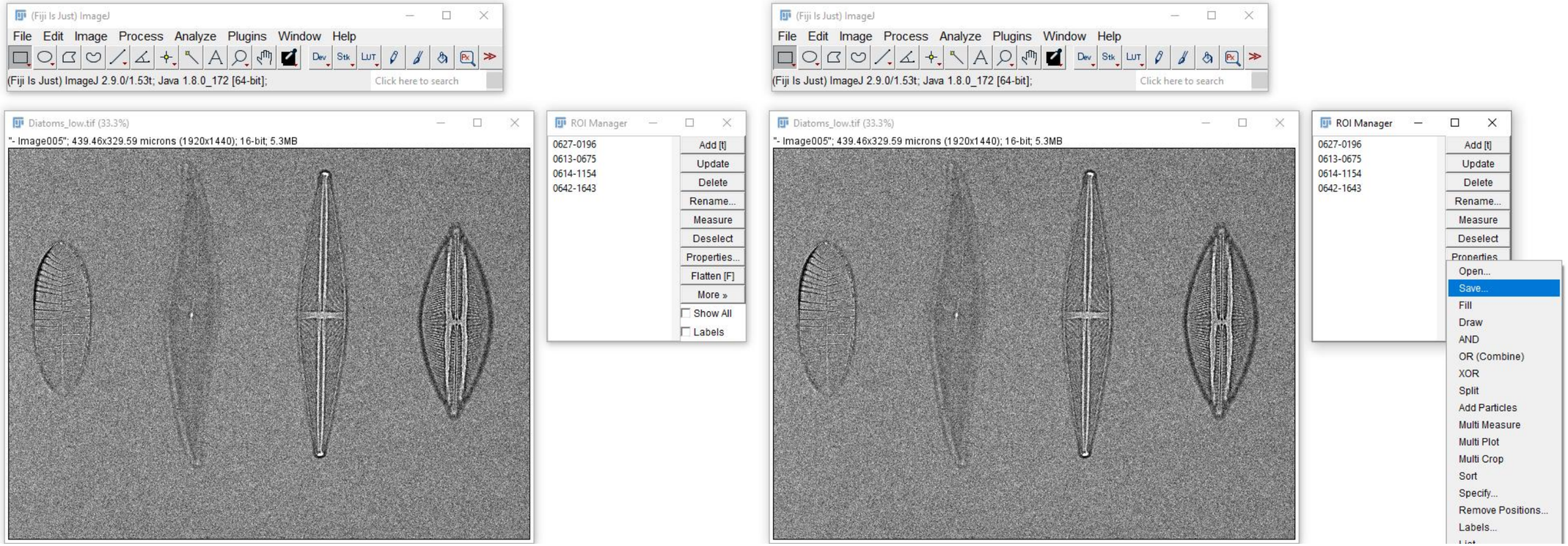
Exercise

4. Save the four regions of interest (e.g “Dia_low_ArneSeitz.zip”).
5. Repeat the segmentation for the second image (Diatoms_high.tif). Do not forget to delete the Rois from the previous segmentation.
6. Save the four regions of interest (e.g “Dia_high_ArneSeitz.zip”).
7. Upload the two files to Moodle.



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