Feature extraction

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With material from

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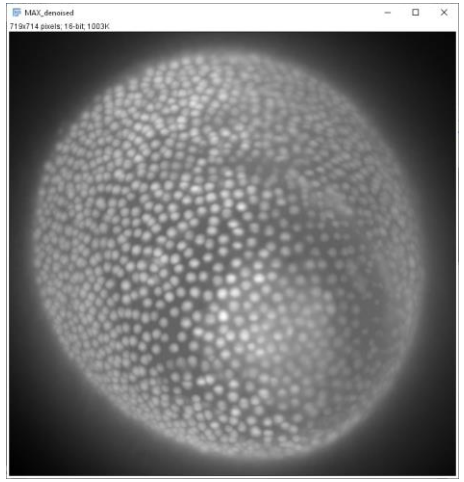
December 2022

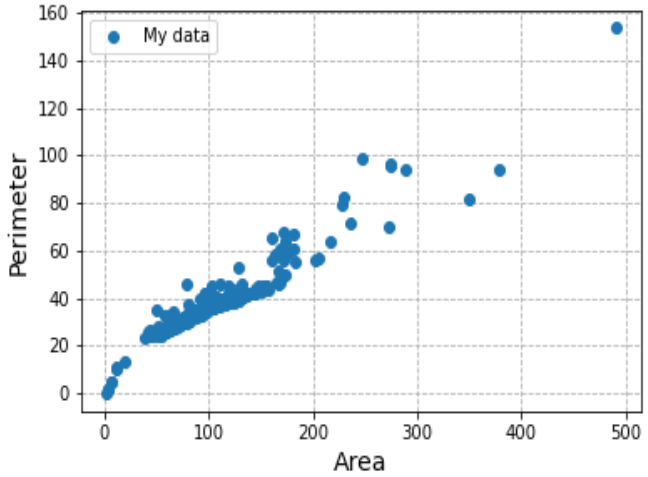
@jm_mightypirate

Feature extraction

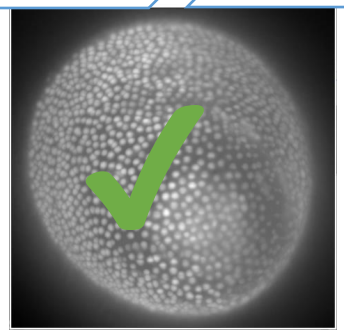
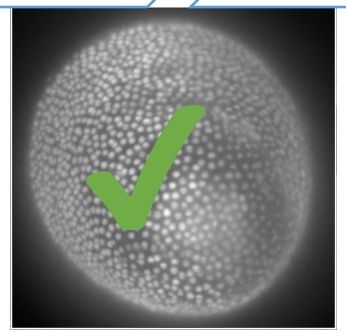
- Feature extraction is a *late* processing step in image analysis.
- It can be used for images, or segmented/labelled images

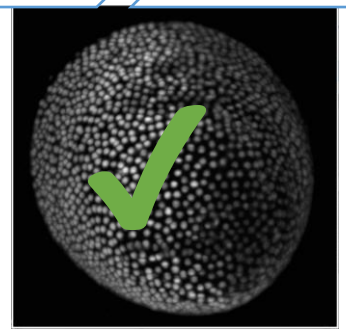


Feature Extraction



Acquisition → Denoising → Background subtraction → Segmentation → Labeling → Feature Extraction



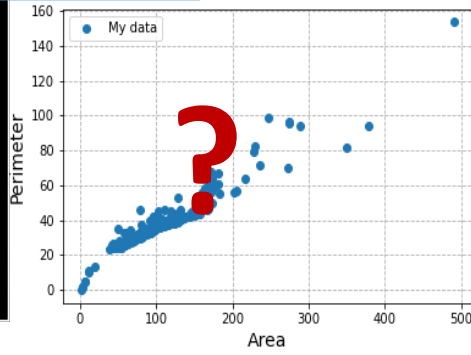



Image data source: Daniela Vorkel, Myers lab, MPI CBG

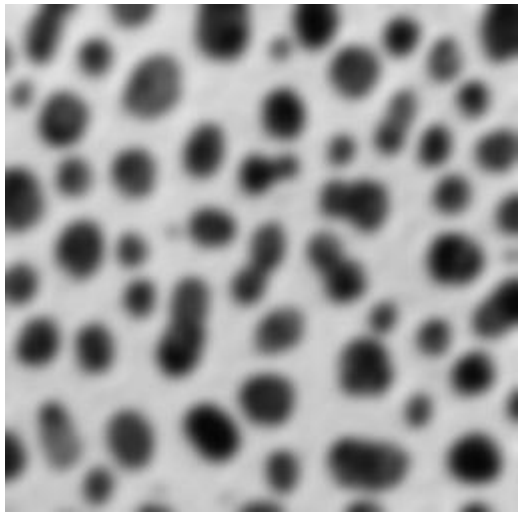
Feature extraction

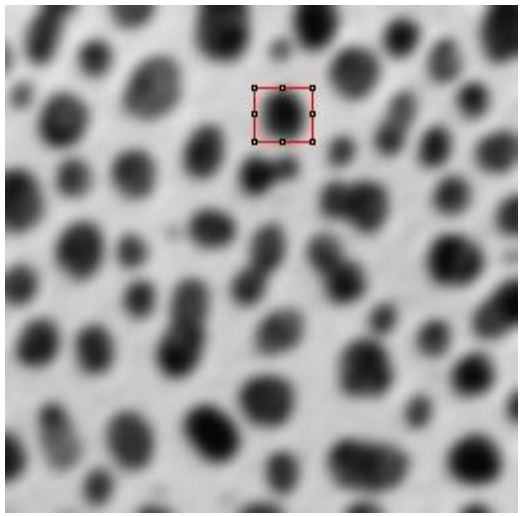
- A *feature* is a countable or measurable property of an image or object.
- Goal of feature extraction is finding a minimal set of features to describe an object well enough to differentiate it from other objects.

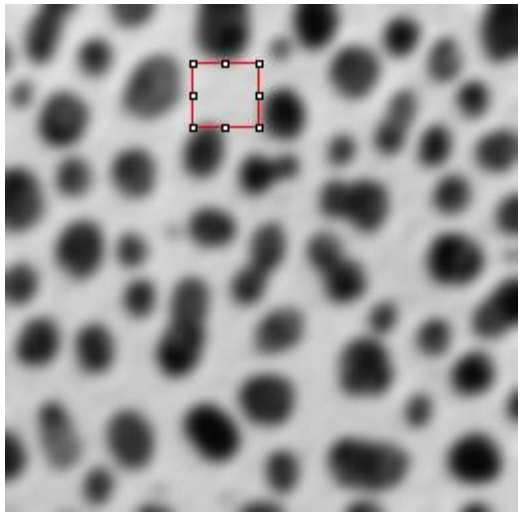
- **Intensity based**
  - Mean intensity
  - Standard deviation
  - Total intensity
  - Textures
- **Shape based /spatial**
  - Area / Volume
  - Roundness
  - Solidity
  - Circularity / Sphericity
  - Elongation
  - Centroid
  - Bounding box
- **Spatio-temporal**
  - Displacement,
  - Speed,
  - Acceleration
- **Others**
  - Overlap
  - Colocalization
  - Neighborhood
- **Mixed features**
  - Center of mass
  - Local minima / maxima

Intensity based features

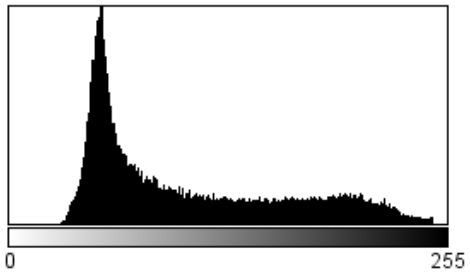
- Min / max
- Median
- Mean
- Mode
- Variance
- Standard deviation



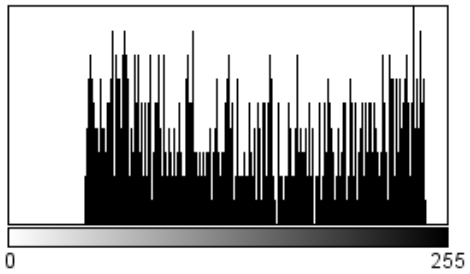




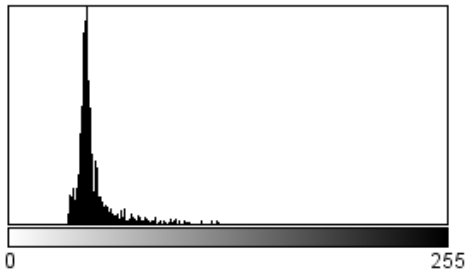
- Can be derived from pixel values
- Don’t take spatial relationship of pixels into account



Count: 65024
Mean: 103.301
StdDev: 57.991
Min: 29
Max: 248
Mode: 53 (1663)



Count: 783
Mean: 141.308
StdDev: 61.876
Min: 44
Max: 243
Mode: 236 (9)



Count: 1056
Mean: 49.016
StdDev: 12.685
Min: 34
Max: 122
Mode: 45 (120)

- See also:
  - descriptive statistics
  - histogram

Center of mass

- Relative position in an image weighted by pixel intensities

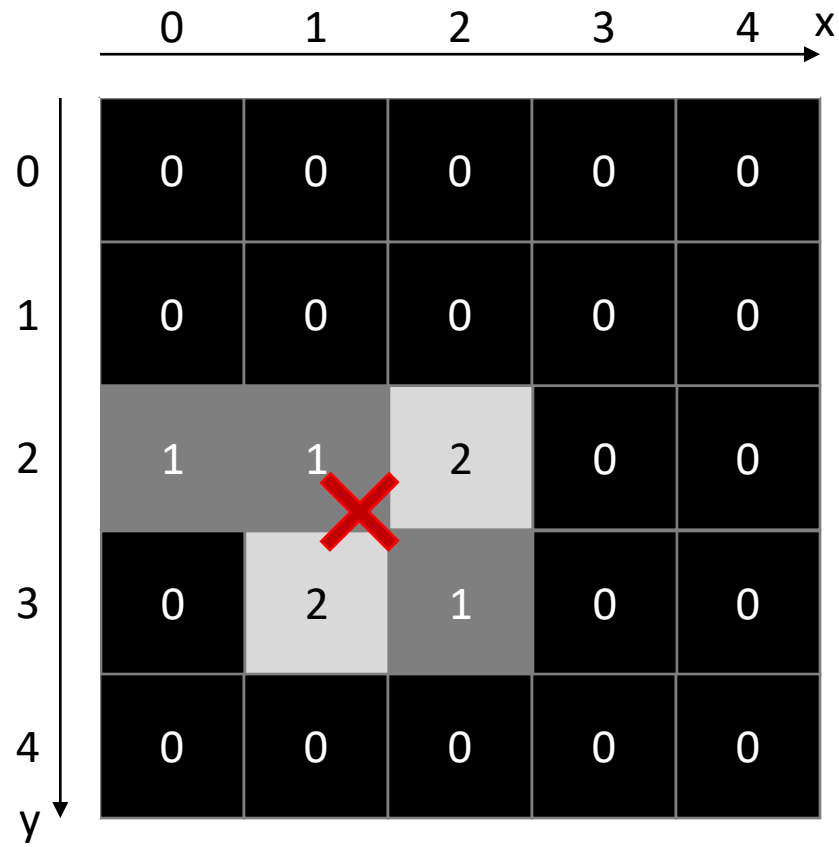
  - x, y … pixel coordinates
  - w … image width
  - h … image height
  - μ … mean intensity
  - $g_{x,y}$ … pixel grey value
  - x_m, y_m … center of mass coordinates

$$\mu = \frac{1}{wh} \sum_{y=0}^{h-1} \sum_{x=0}^{w-1} g_{x,y}$$

$$x_m = \frac{1}{wh\mu} \sum_{y=0}^{h-1} \sum_{x=0}^{w-1} x \, g_{x,y}$$

$$y_m = \frac{1}{wh\mu} \sum_{y=0}^{h-1} \sum_{x=0}^{w-1} y \, g_{x,y}$$

"sum intensity"
"total intensity"



x_m = 1/7 (1·0 + 1·1 + 2·2 + 2·1 + 1·2) = 1.3

y_m = 1/7 (1·2 + 1·2 + 2·3 + 2·2 + 1·3) = 2.4

Center of geometry / centroid

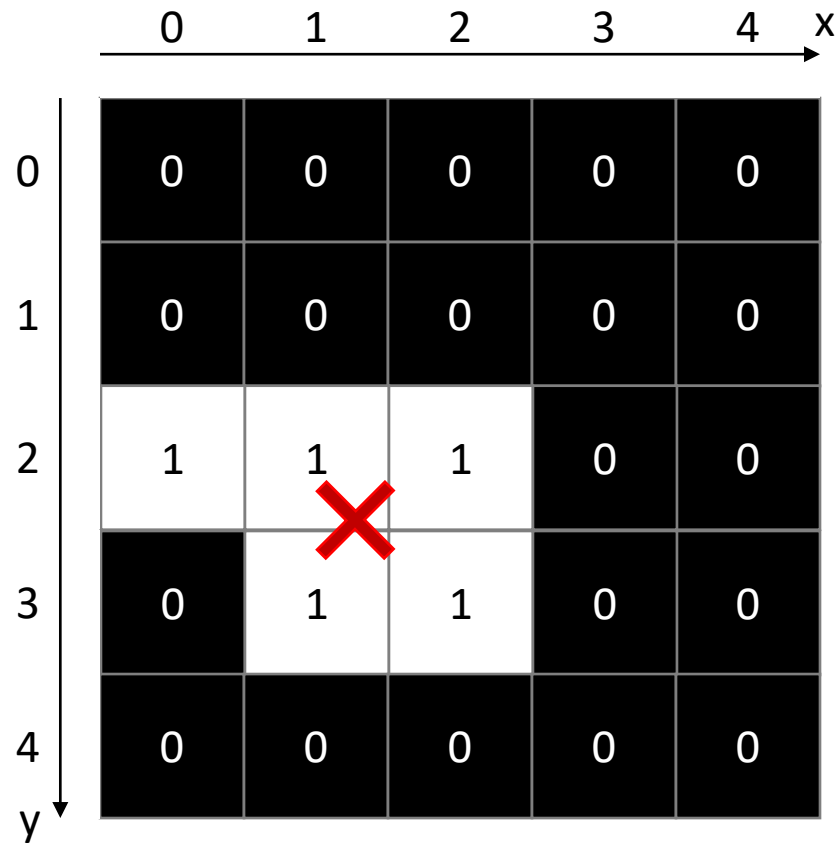
- Relative position in an image weighted by pixel intensities
- Special case of center of mass for binary images
  - x, y … pixel coordinates
  - w … image width
  - h … image height
  - μ … mean intensity
  - $g_{x,y}$ … pixel grey value, integer in range [0;1]
  - x_m, y_m … center of mass coordinates

$$\mu = \frac{1}{wh} \sum_{y=0}^{h-1} \sum_{x=0}^{w-1} g_{x,y}$$

$$x_m = \frac{1}{wh\mu} \sum_{y=0}^{h-1} \sum_{x=0}^{w-1} x \, g_{x,y}$$

$$y_m = \frac{1}{wh\mu} \sum_{y=0}^{h-1} \sum_{x=0}^{w-1} y \, g_{x,y}$$

Number of white pixels

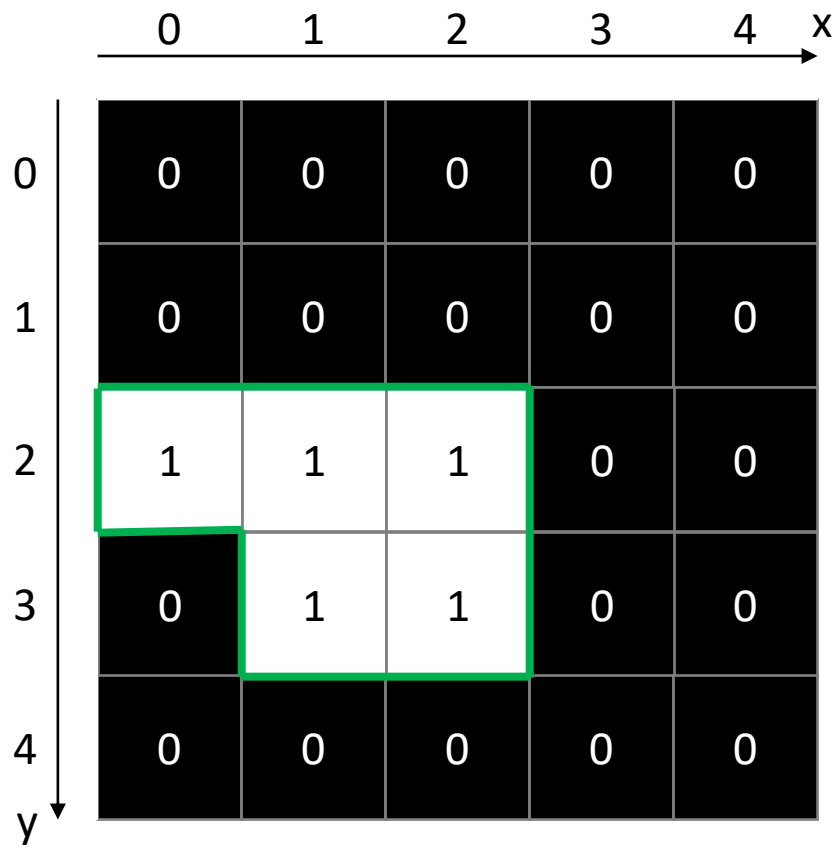


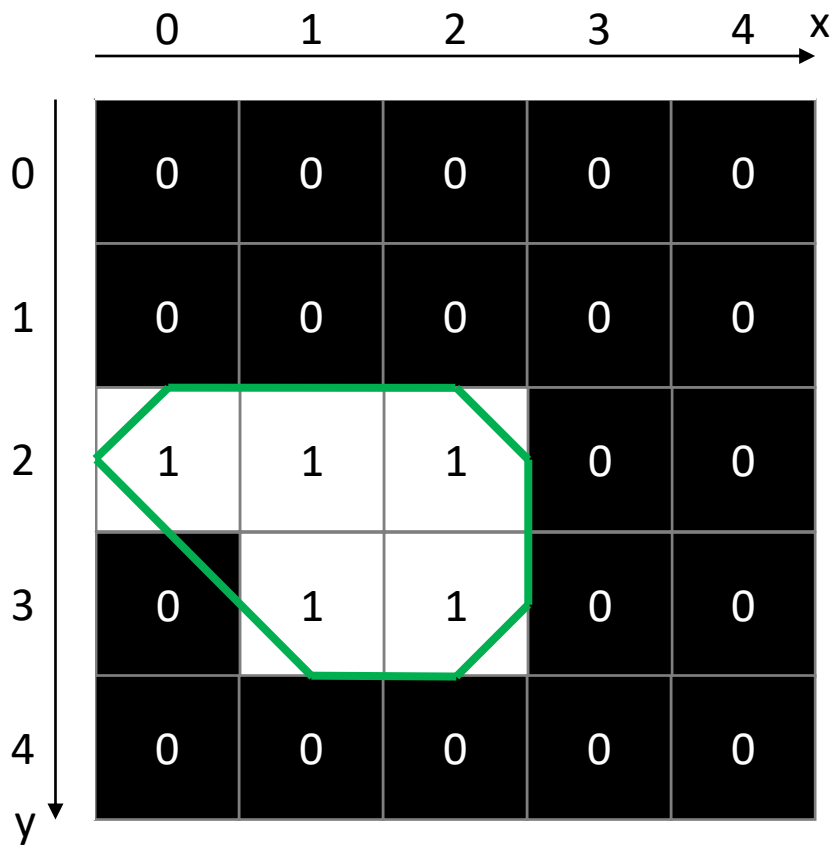
x_m = 1/5 (1·0 + 1·1 + 1·2 + 1·1 + 1·2) = 1.2

y_m = 1/5 (1·2 + 1·2 + 1·3 + 1·2 + 1·3) = 2.4

Perimeter

- Length of the outline around an object
- Depends on the actual implementation



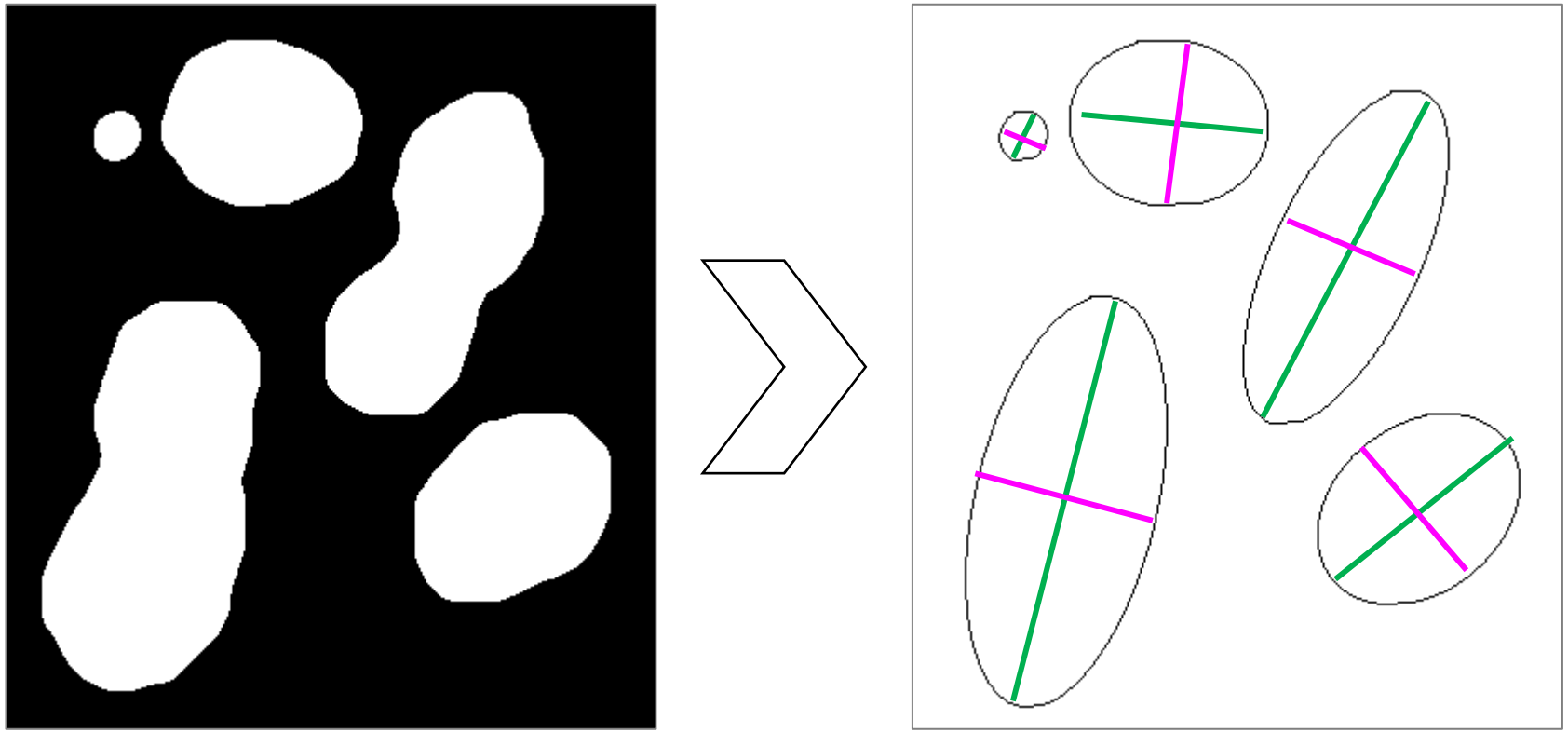


Fit ellipse

- For every object, find the optimal ellipse simplifying the object.

- Major axis … long diameter
- Minor axis … short diameter

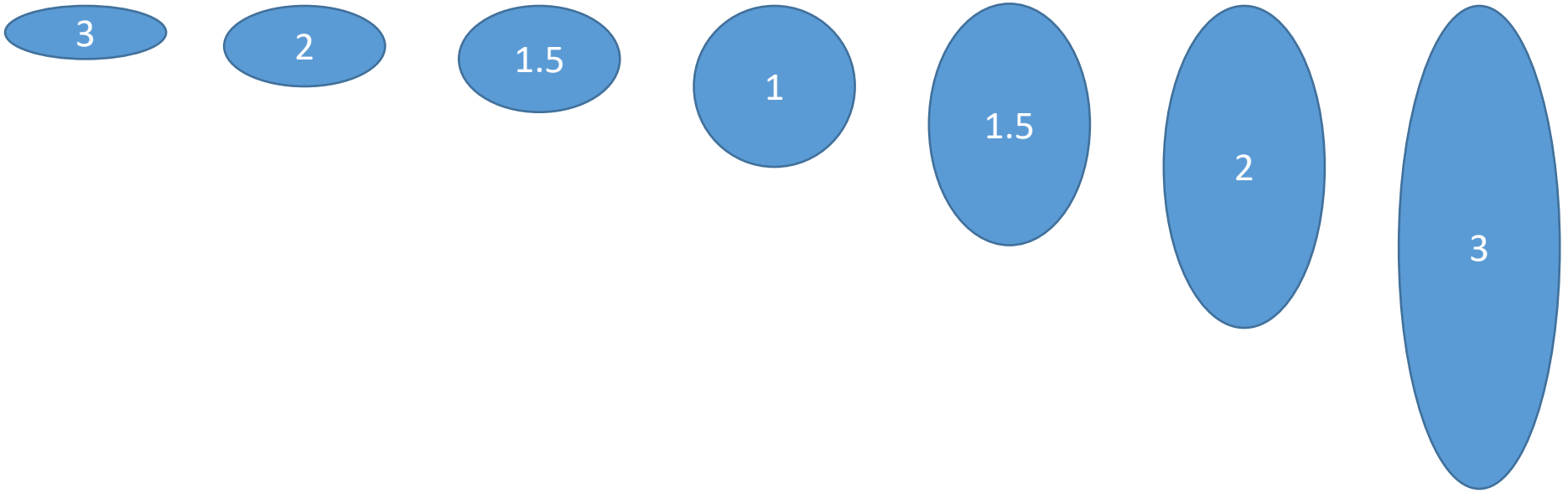
- Major and minor axis are perpendicular to each other



Aspect ratio

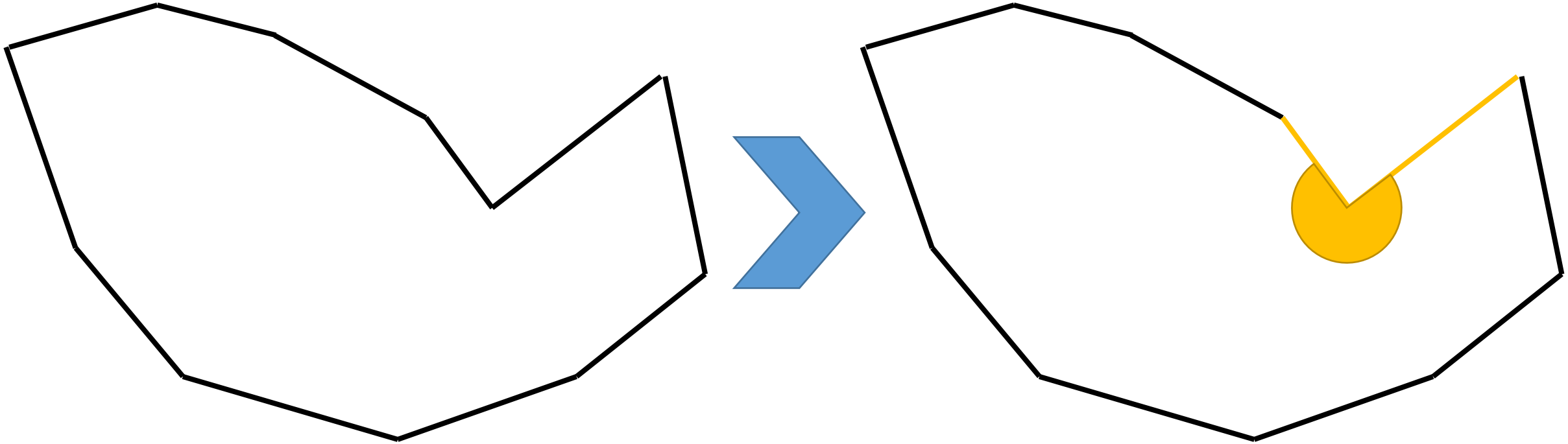
- The aspect ratio describes the elongation of an object.

AR = major / minor



Convex hull

- By removing all concave corners of an object, we retrieve its convex hull.



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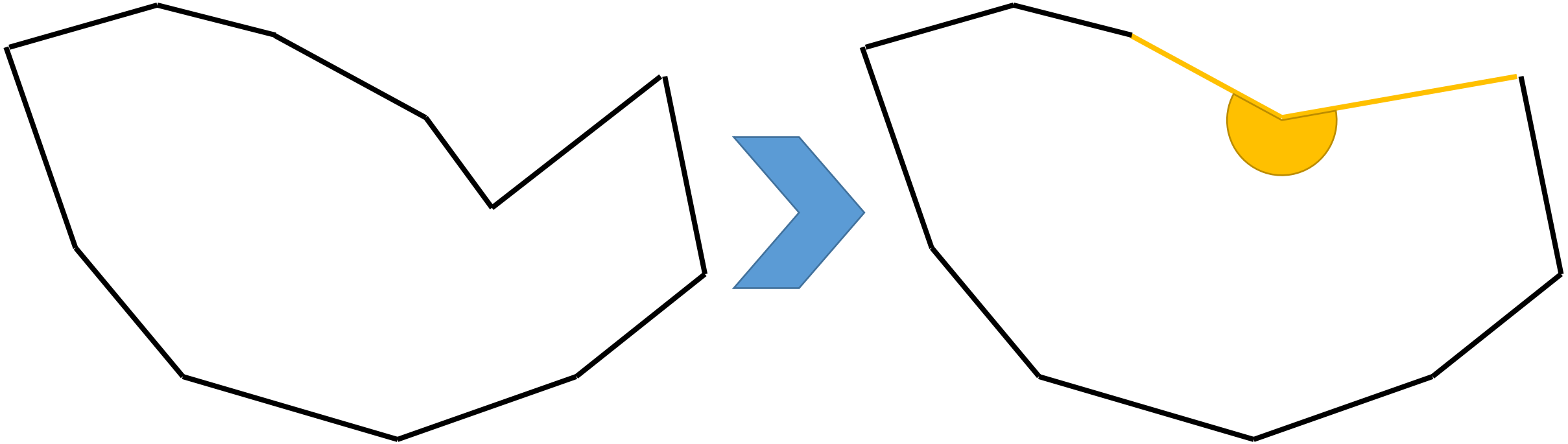

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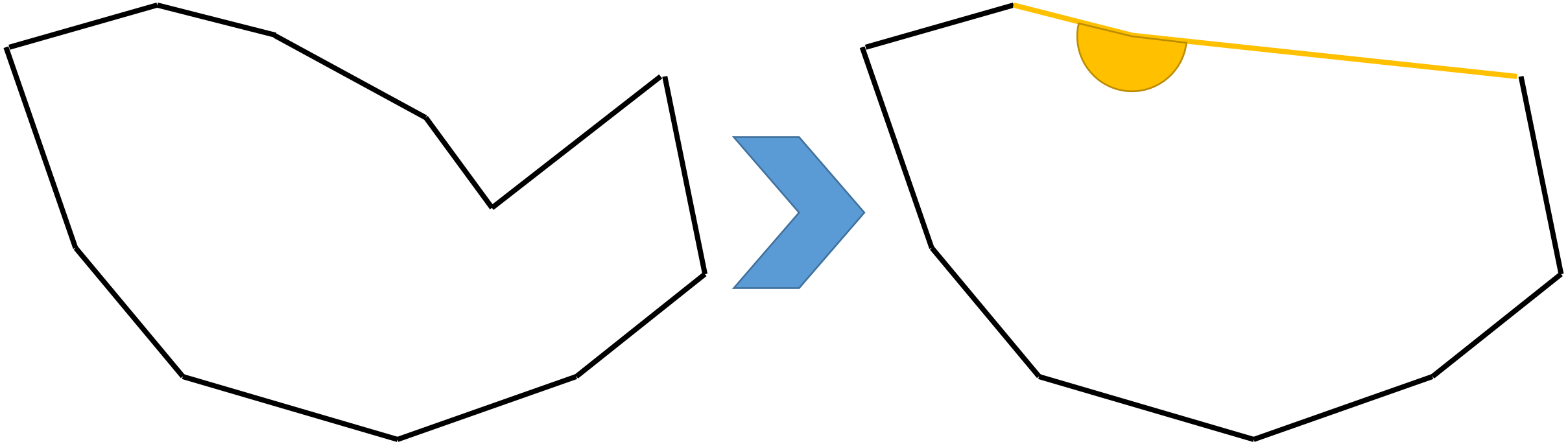

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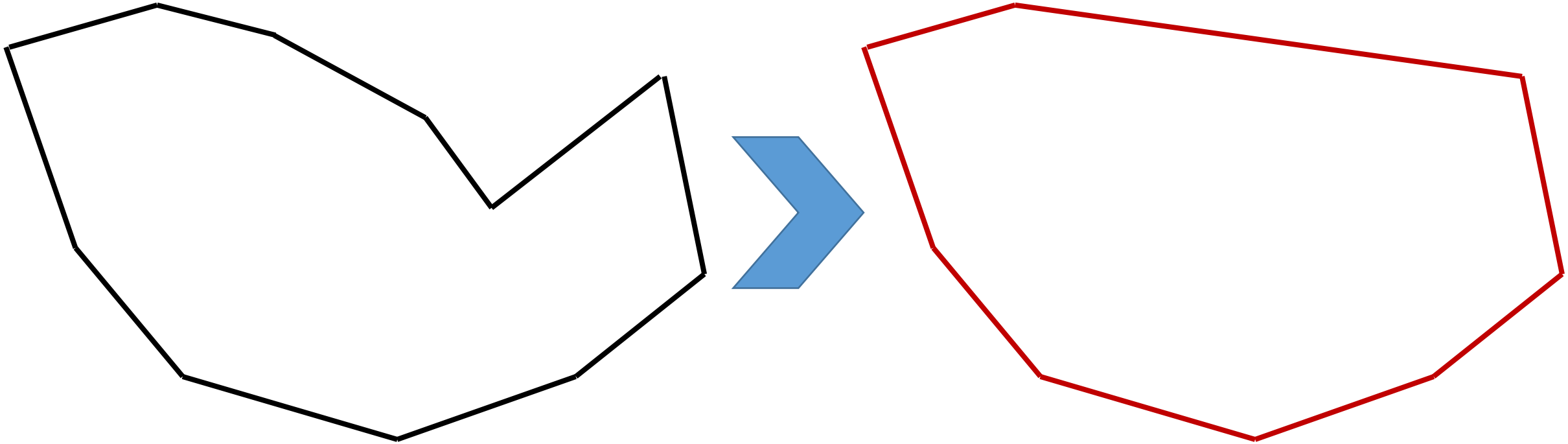


$$solidity = \frac{A}{A_{convexHull}}$$

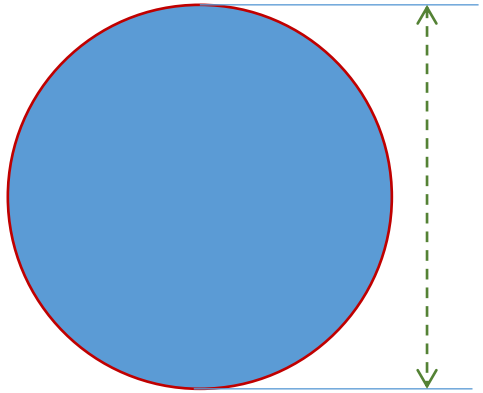
Roundness and circularity

- The definition of a circle leads us to measurements of circularity and roundness.
- In case you use these measures, define them correctly. They are not standardized!

Diameter d

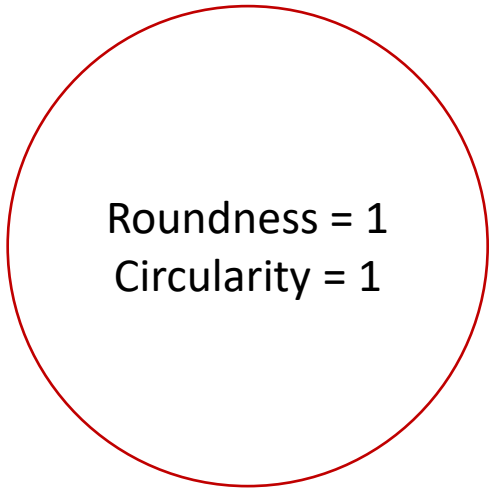
Circumference $C = \pi d$

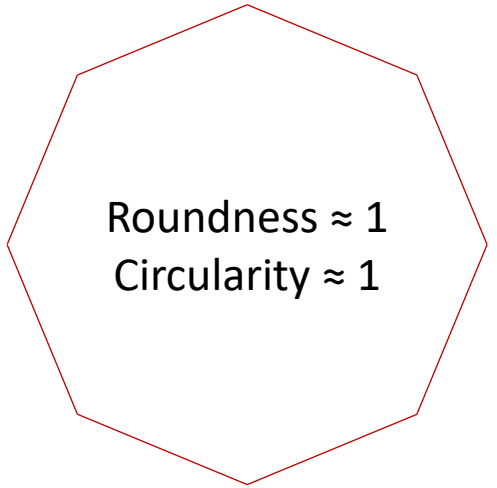
Area $A = \frac{\pi d^2}{4}$

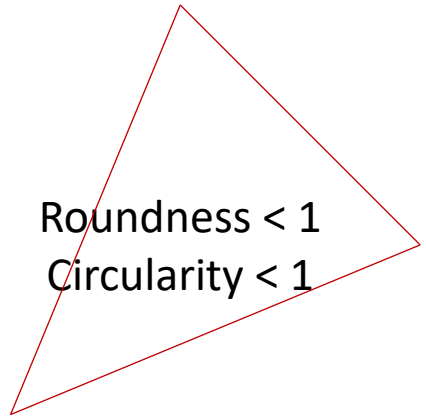


$$roundness = \frac{4 * A}{\pi\, major^2}$$

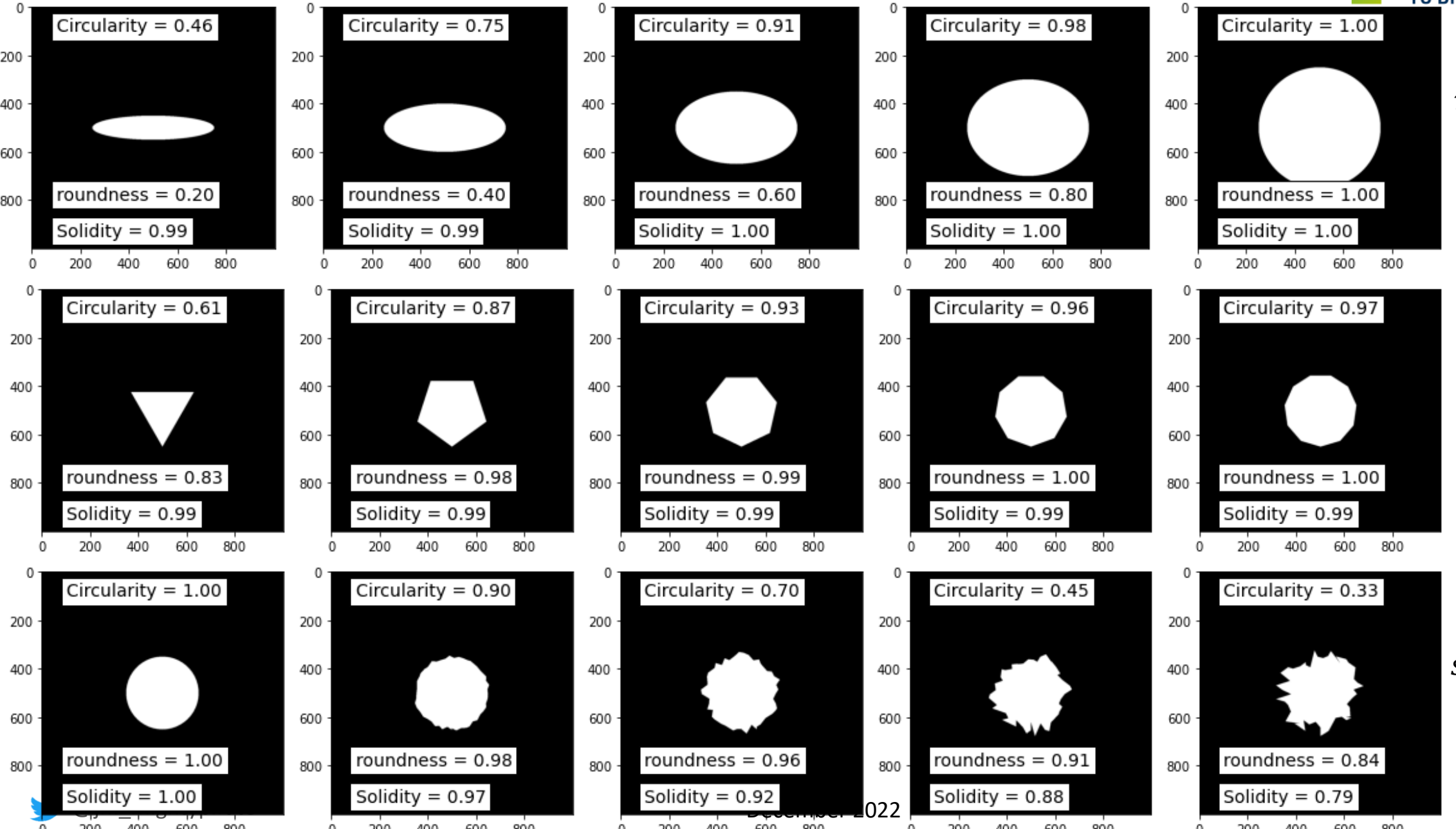
$$circularity = \frac{4\pi * A}{perimeter^2}$$







Roundness and circularity



$$roundness = \frac{4 * A}{\pi\, major^2}$$

$$circularity = \frac{4\pi * A}{perimeter^2}$$

$$solidity = \frac{A}{A_{convexHull}}$$

Feature extraction in Python

PoL Physics of Life TU Dresden

- **In Python:** `from skimage import measure`

https://scikit-image.org/docs/stable/api/skimage.measure.html

`skimage.measure.blur_effect` (image[, h_size, …])	Compute a metric that indicates the strength of blur in an image (0 for no blur, 1 for maximal blur).
`skimage.measure.euler_number` (image[, …])	Calculate the Euler characteristic in binary image.
`skimage.measure.find_contours` (image[, …])	Find iso-valued contours in a 2D array for a given level value.
`skimage.measure.grid_points_in_poly` (shape, verts)	Test whether points on a specified grid are inside a polygon.
`skimage.measure.inertia_tensor` (image[, mu])	Compute the inertia tensor of the input image.
`skimage.measure.inertia_tensor_eigvals` (image)	Compute the eigenvalues of the inertia tensor of the image.
`skimage.measure.label` (label_image[, …])	Label connected regions of an integer array.
`skimage.measure.regionprops` (label_image[, …])	Measure properties of labeled image regions.
`skimage.measure.regionprops_table` (label_image)	Compute image properties and return them as a pandas-compatible table.

area : int

Number of pixels of the region.

area_bbox : int

Number of pixels of bounding box.

area_convex : int

Number of pixels of convex hull image, which is the smallest convex polygon that e

area_filled : int

Number of pixels of the region will all the holes filled in. Describes the area of the i

axis_major_length : float

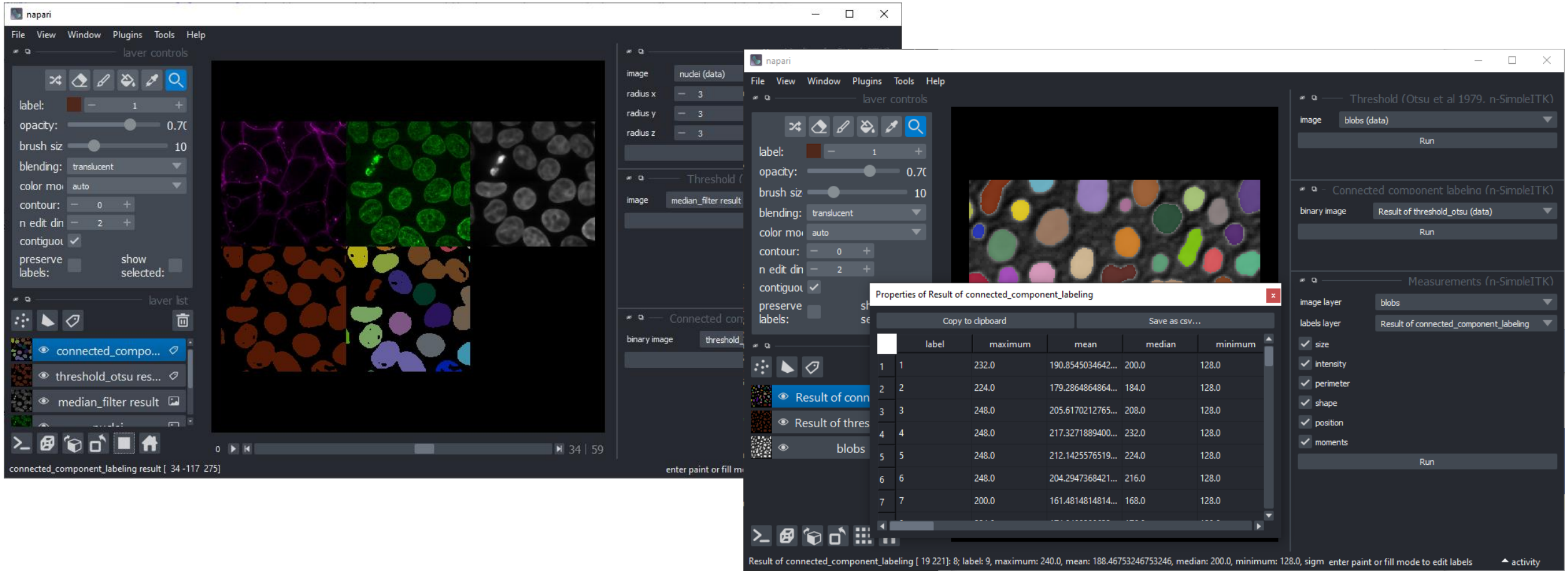
The length of the major axis of the ellipse that has the same normalized second ce
the region.

axis_minor_length : float

The length of the minor axis of the ellipse that has the same normalized second ce
the region.

SimpleITK

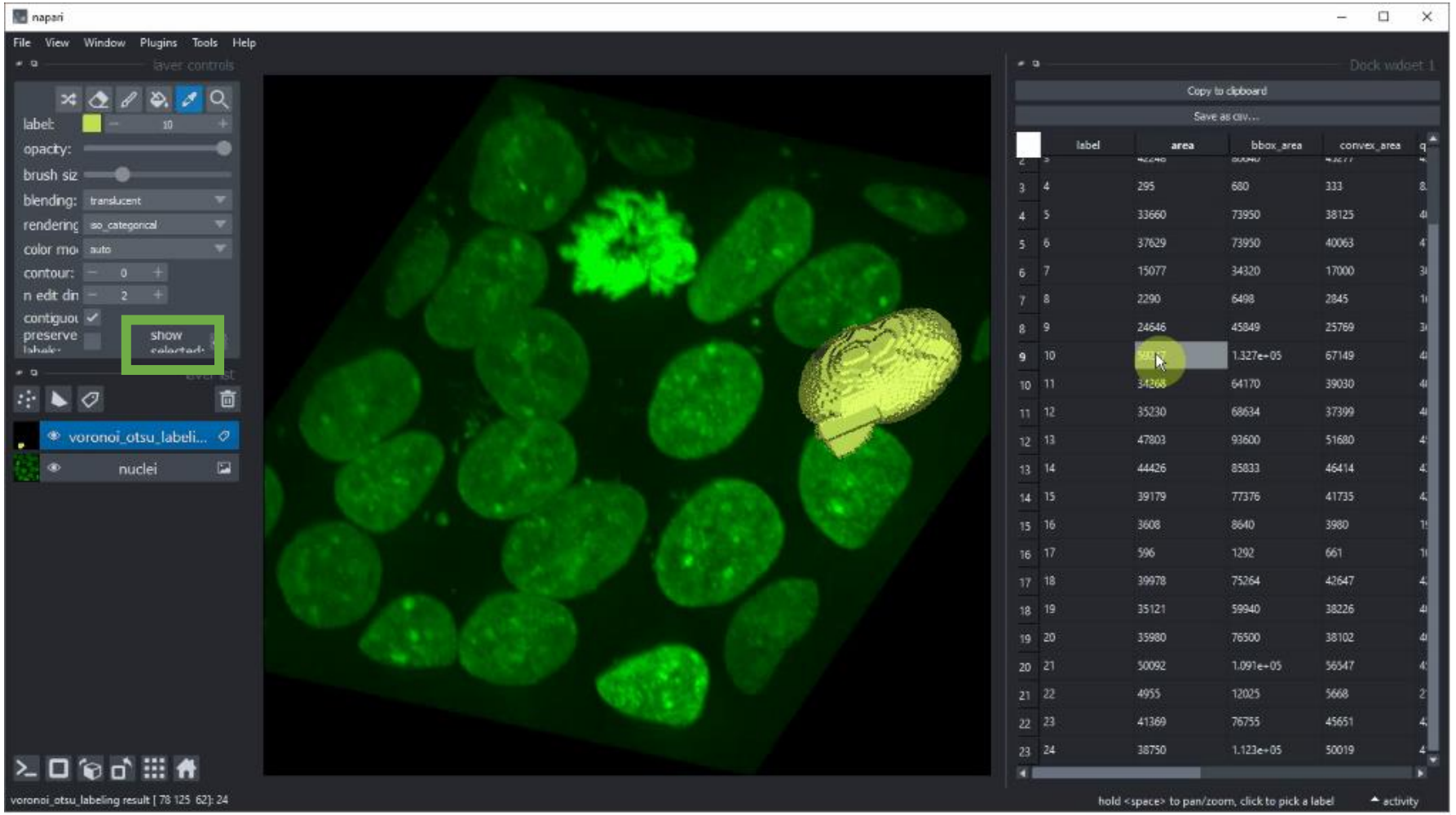
- Recommended for 3D-measurements, based on the SimpleITK-project



https://simpleitk.readthedocs.io/en/master/
https://github.com/haesleinhuepf/napari-simpleitk-image-processing

Exploring features in Napari

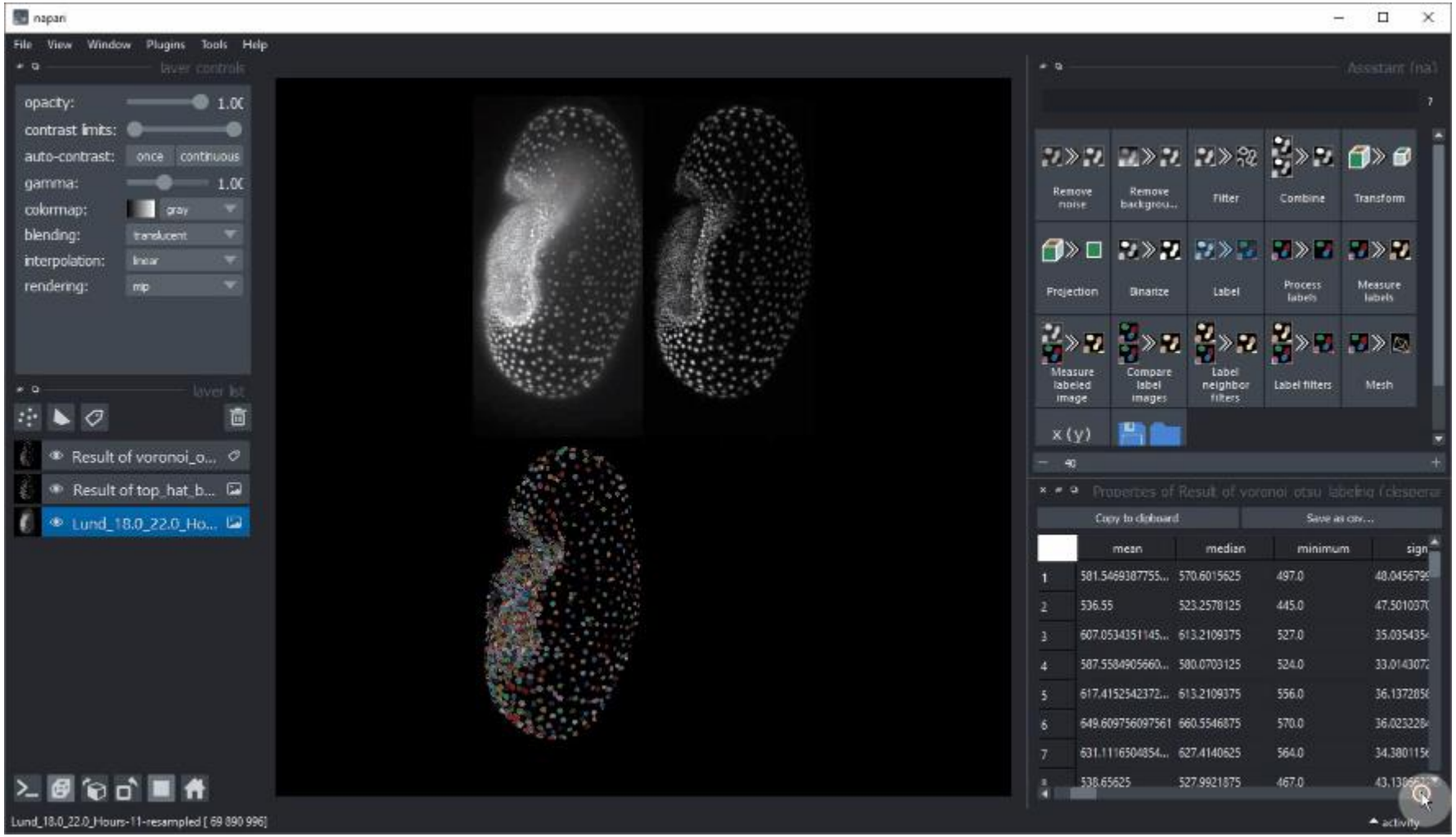
- Select table rows and view corresponding object in 2D/3D space



https://www.napari-hub.org/plugins/napari-skimage-regionprops

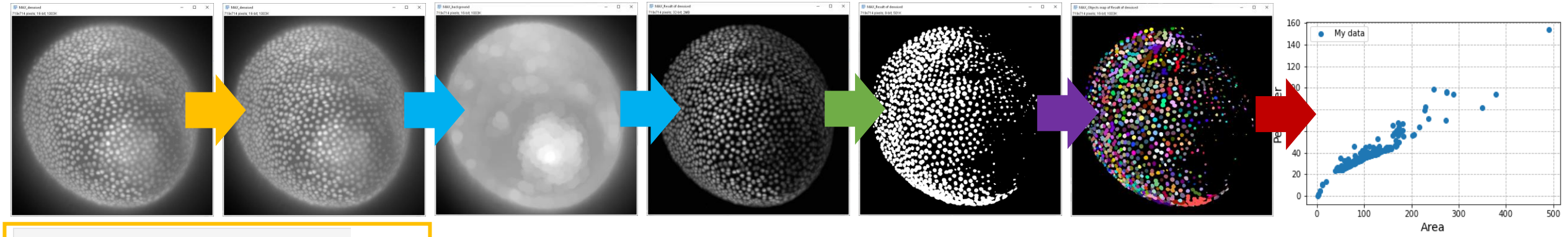
Exploring features in Napari

- Double-click on table column to retrieve a parametric map image



https://www.napari-hub.org/plugins/napari-skimage-regionprops

Summary




```
filtered = filters.median(image)
```

```
filtered = filters.gaussian(image, sigma=5)
```

Filtering the image reduces pixel noise

```
bg_subtracted = morphology.white_tophat(image, footprint=footprint)
```

Top-hat filtering removes the background

Thresholding binarizes the image

```
threshold = filters.threshold_otsu(image)
```

Connected-components analysis groups pixels to objects

```
labels = measure.label(binary)
```

Feature extraction allows descriptive statistics

```
measurements = measure.regionprops_table(labels, properties=properties)
```