Signal & image processing

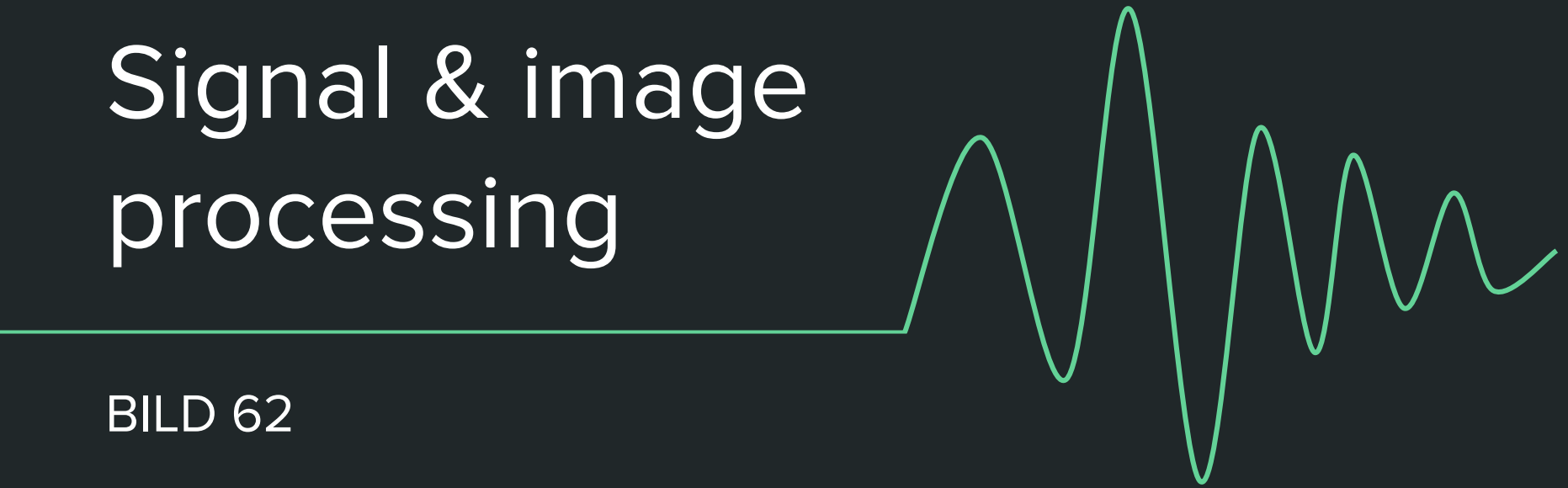

BILD 62

Objectives for today

- Identify the types of time series you may encounter in biology
- Implement common signal processing techniques for these time series
  - Filtering by convolution
- Describe how we work with images in Python & the types of image processing used in biology

Anything recorded continuously over time is a **time series**

(a set of data points generated from successive measurements over time)

Commonly encountered time series data in biology

- Gene expression data over time
- Neurophysiology recordings (e.g. electrophysiology, imaging) * **a6**
- Circadian rhythm data
- Medical observations over time
- Animal movement
- Physiology data (e.g. heart rate/ECG, pulse rate, respiration, etc.)
- Molecules/proteins/cells moving

White blood cell tracking bacteria
Image info

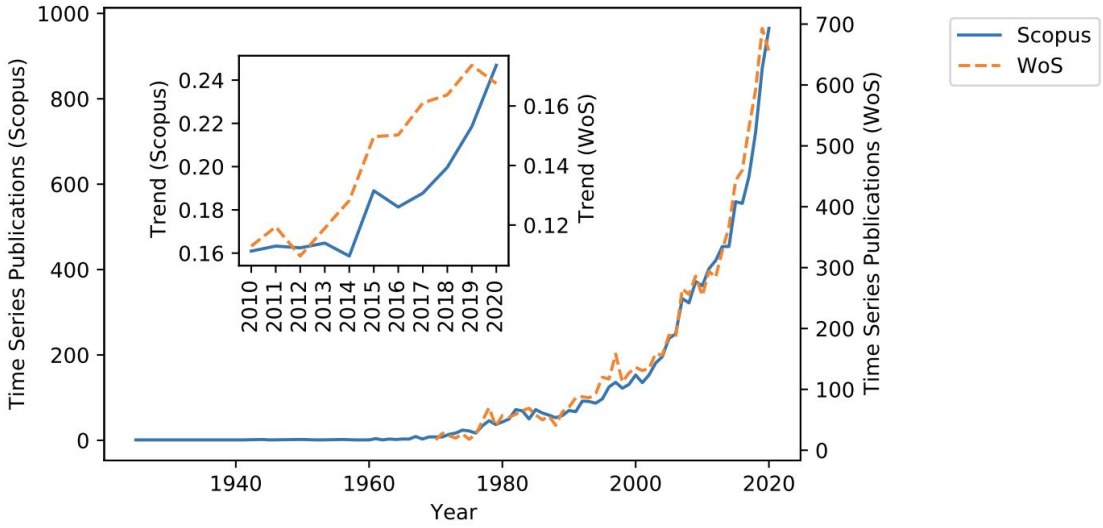

Fig. 1: Number of documents retrieved by Scopus (left axis) and Web Of Science (WoS, right axis) with the search string (restricted to documents titles): "time series" AND ("analysis" OR "data mining" OR "machine learning") over time. The inlet represents the trend (in %) over the last 20 years (the trend is normalized over the total publications in DBLP (the data is accessible in `https://dblp.org/statistics/publicationsperyear.html`).

More and more people developing time series analyses!
(Siebert et al., 2021)

Sample Python packages to work with time series

- BioSPPy
  https://github.com/PIA-Group/BioSPPy
- Obspy (seismology data)
  https://github.com/obspy/obspy
- yasa (sleep data)
  https://github.com/raphaelvallat/yasa
- pastas (groundwater)
  https://github.com/pastas/pastas
- exoplanet (astronomy)
  https://github.com/exoplanet-dev/exoplanet
- PyEMMA (molecular dynamics)
  https://github.com/markovmodel/PyEMMA

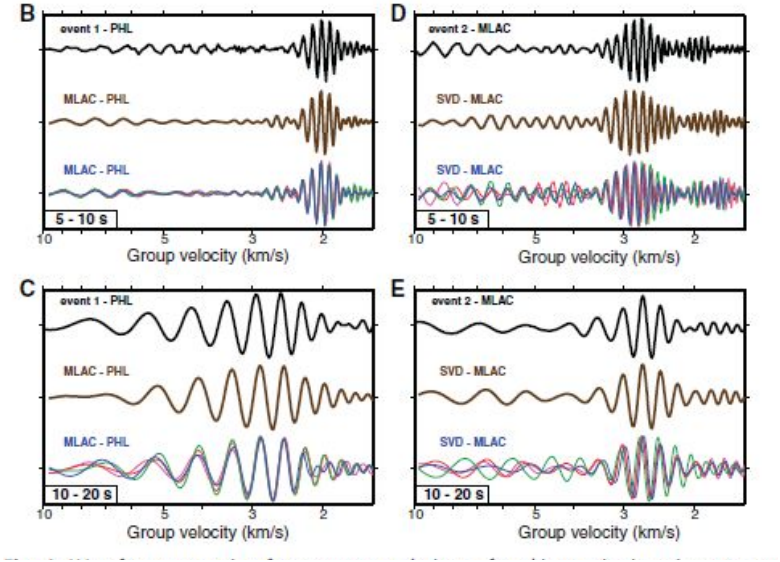

Image from obspy

Common signal processing approaches

- Preprocessing & data cleaning
  - Removing outliers and/or noise * **a6**
- **Filtering**
  - **Using convolution**
  - Using frequency
- Looking for correlations in time
- Clustering & classification
- Dimensionality reduction or segmentation
- Prediction
- Anomaly or peak detection * **a6**

Objectives for today

- Identify the types of time series you may encounter in biology
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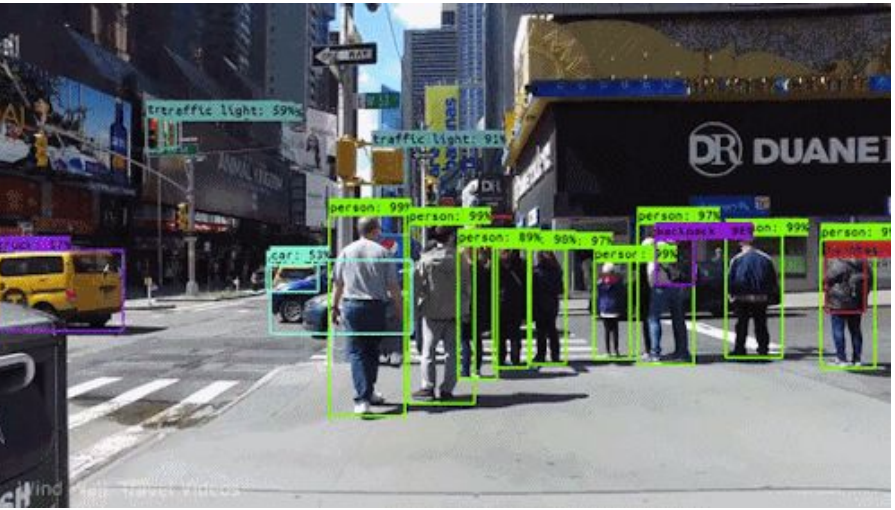
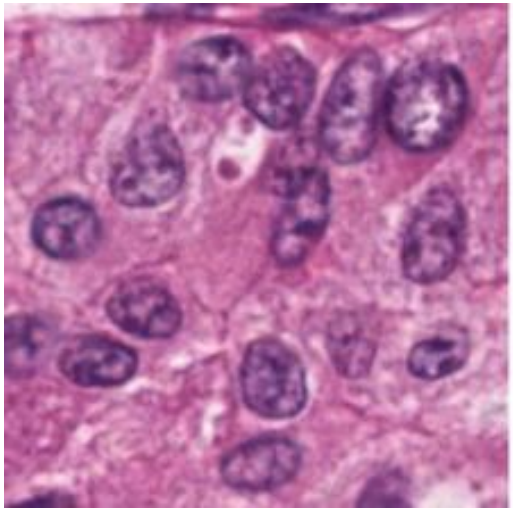
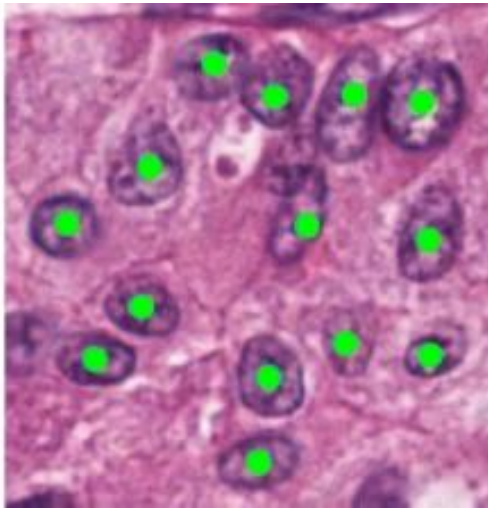
- **Describe how we work with images in Python & the types of image processing used in biology**

From self driving cars to segmenting nuclei, image processing is important!







From [this article]

From [this paper]

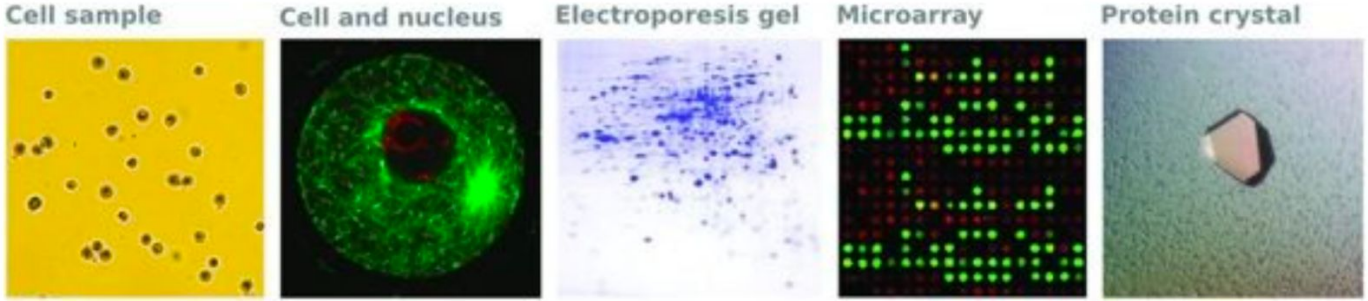


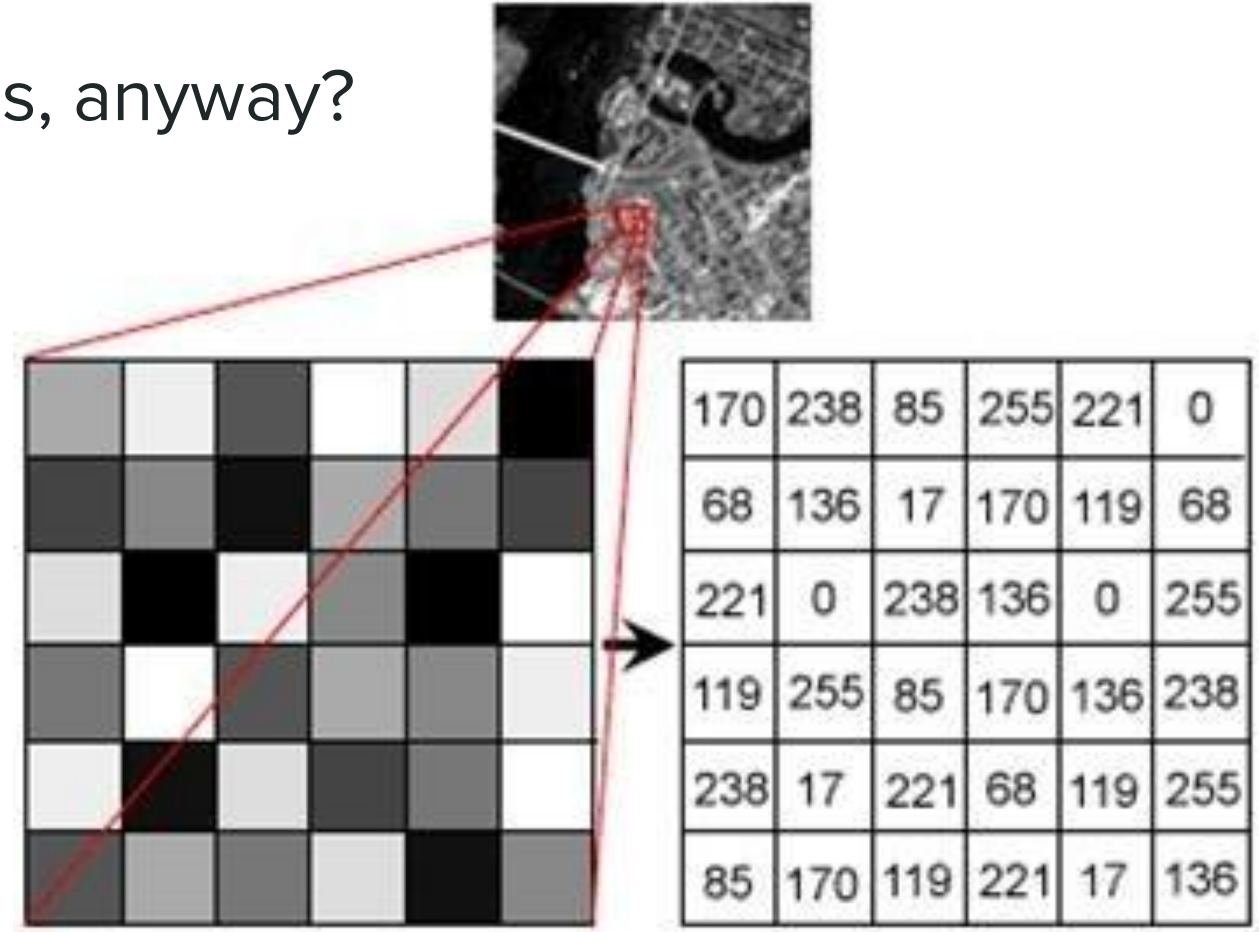
Figure 18.1 (Plate 5). Examples of a variety of different kinds of images used in biology. Shown from left to right are: a microscope image of a mammalian cell culture (courtesy Dr. Anja Winter, University of Leicester); a red-green fluorescence microscope image of an oocyte and its nucleus (courtesy Dr. Melina Schuh, MRC Laboratory of Molecular Biology); a two-dimensional electrophoresis gel of a plant proteome (courtesy Prof. Paul Dupree, University of Cambridge); an image of a DNA microarray (courtesy Karen Howarth, University of Cambridge); a protein crystal that has been grown for structure determination by X-ray crystallography (courtesy Dr. Aleksandra Watson, University of Cambridge).

We use lots of images in biology

Figure from Python Programming for Biology

What are images, anyway?

Gray scale images mean each pixel has just one value

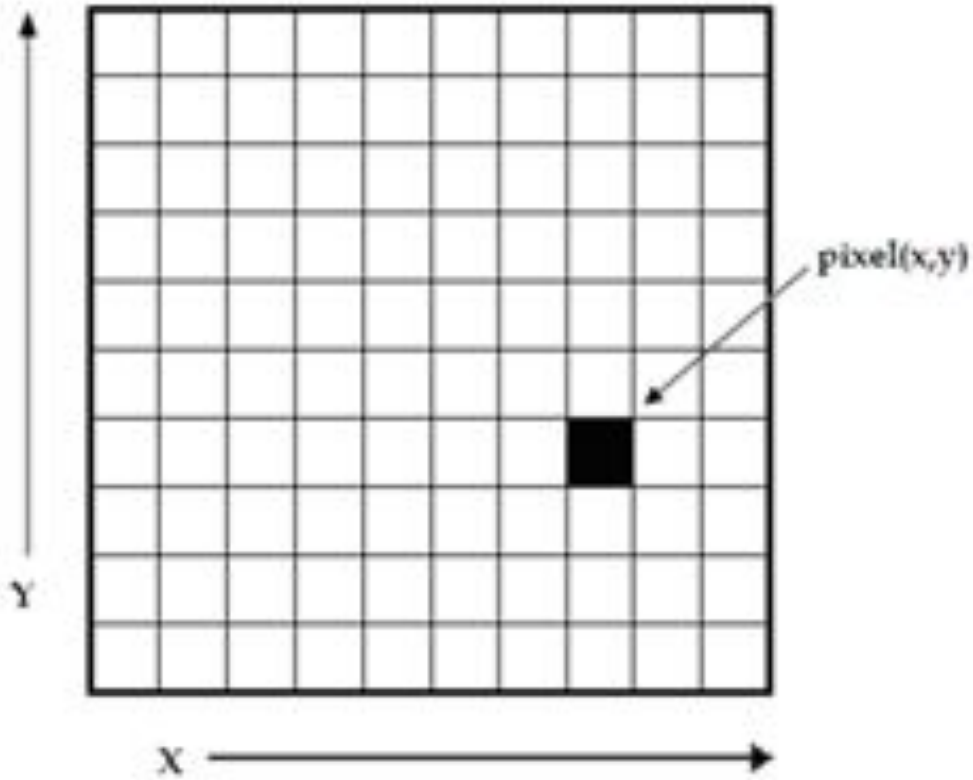


170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

What are images, anyway?

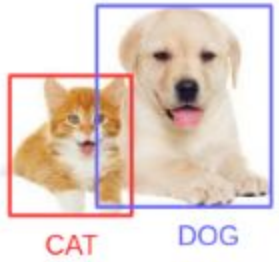
Images can be represented as 2D arrays

By convention [0,0] is the top left corner



Often, we want to perform different types of image segmentation: localization or object detection

Image Localization

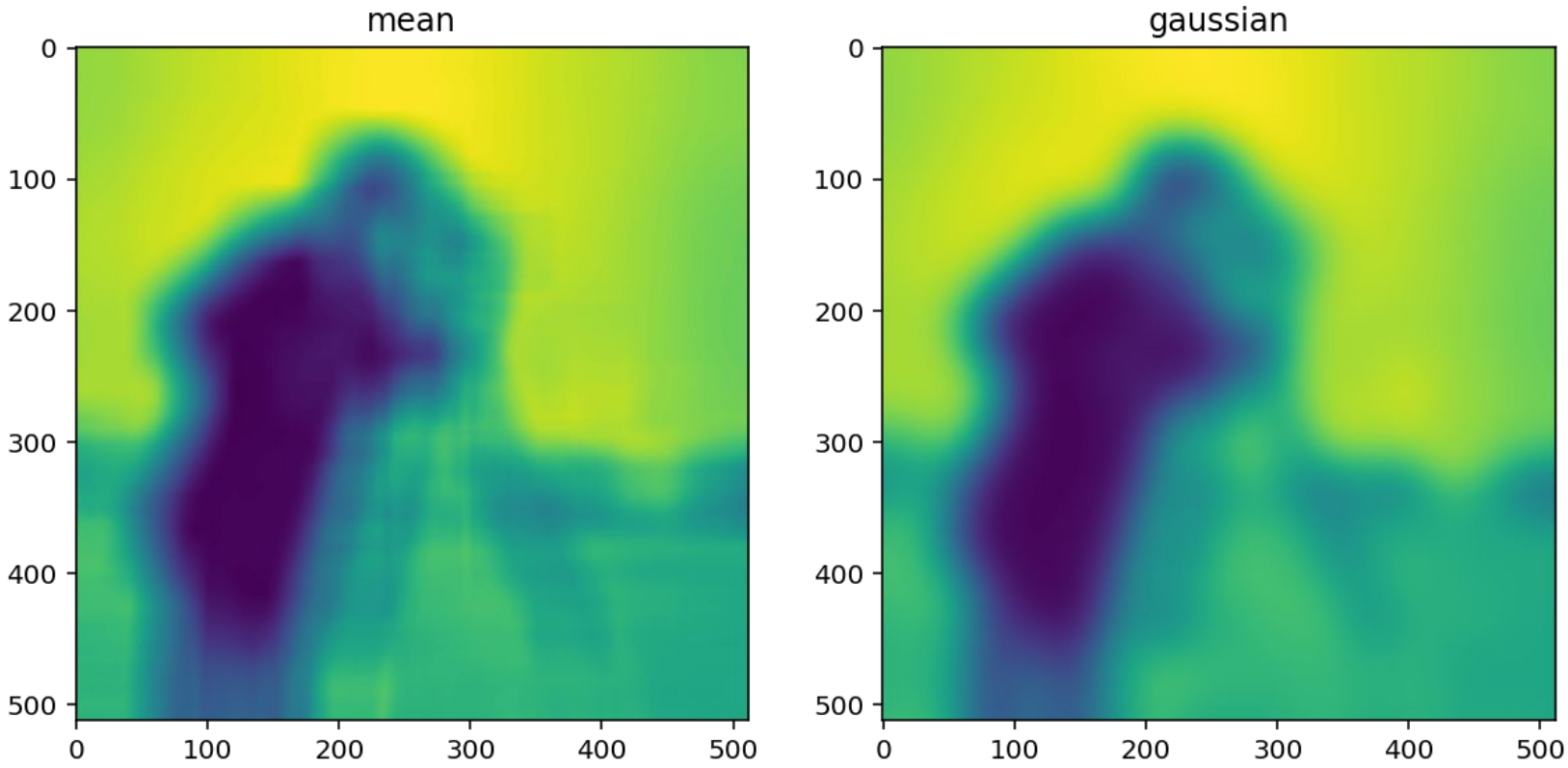


Object Detection

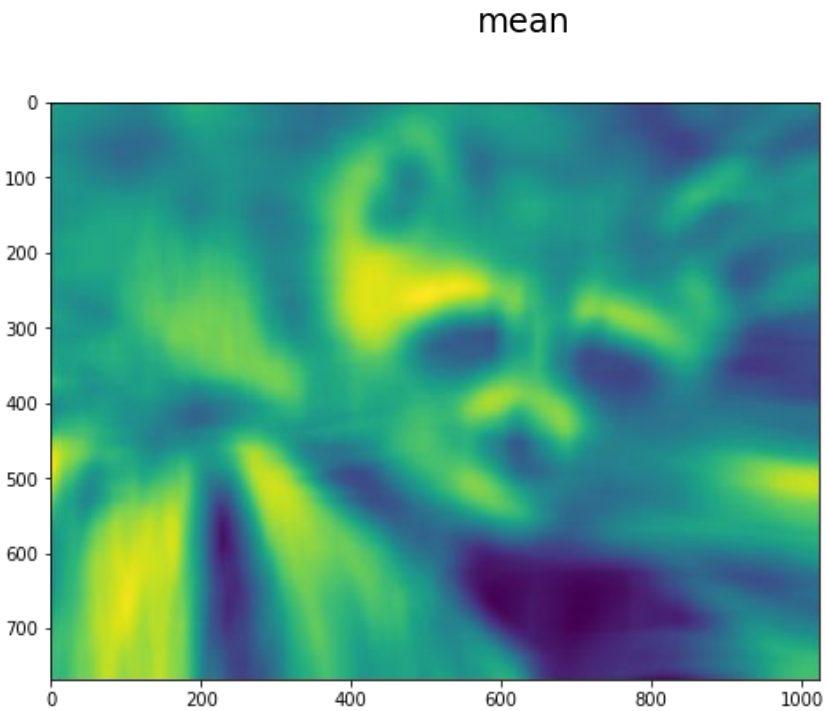
https://www.analyticsvidhya.com/blog/2019/04/introduction-image-segmentation-techniques-python/

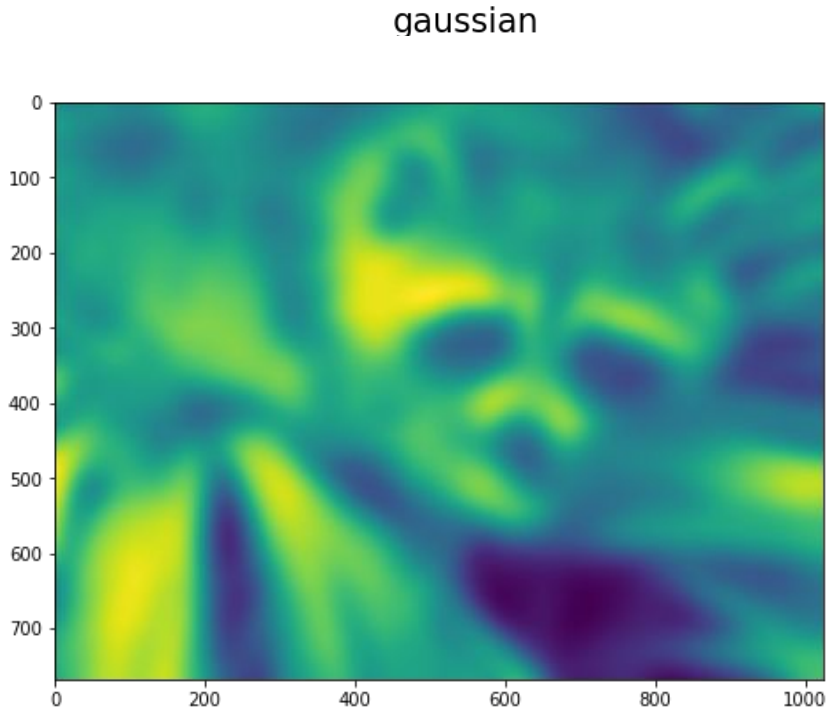
Commonly used filters for biological images

- Gaussian filter — to smooth and remove irregularities
- Edge filters — to detect edges
  - Sobel filter

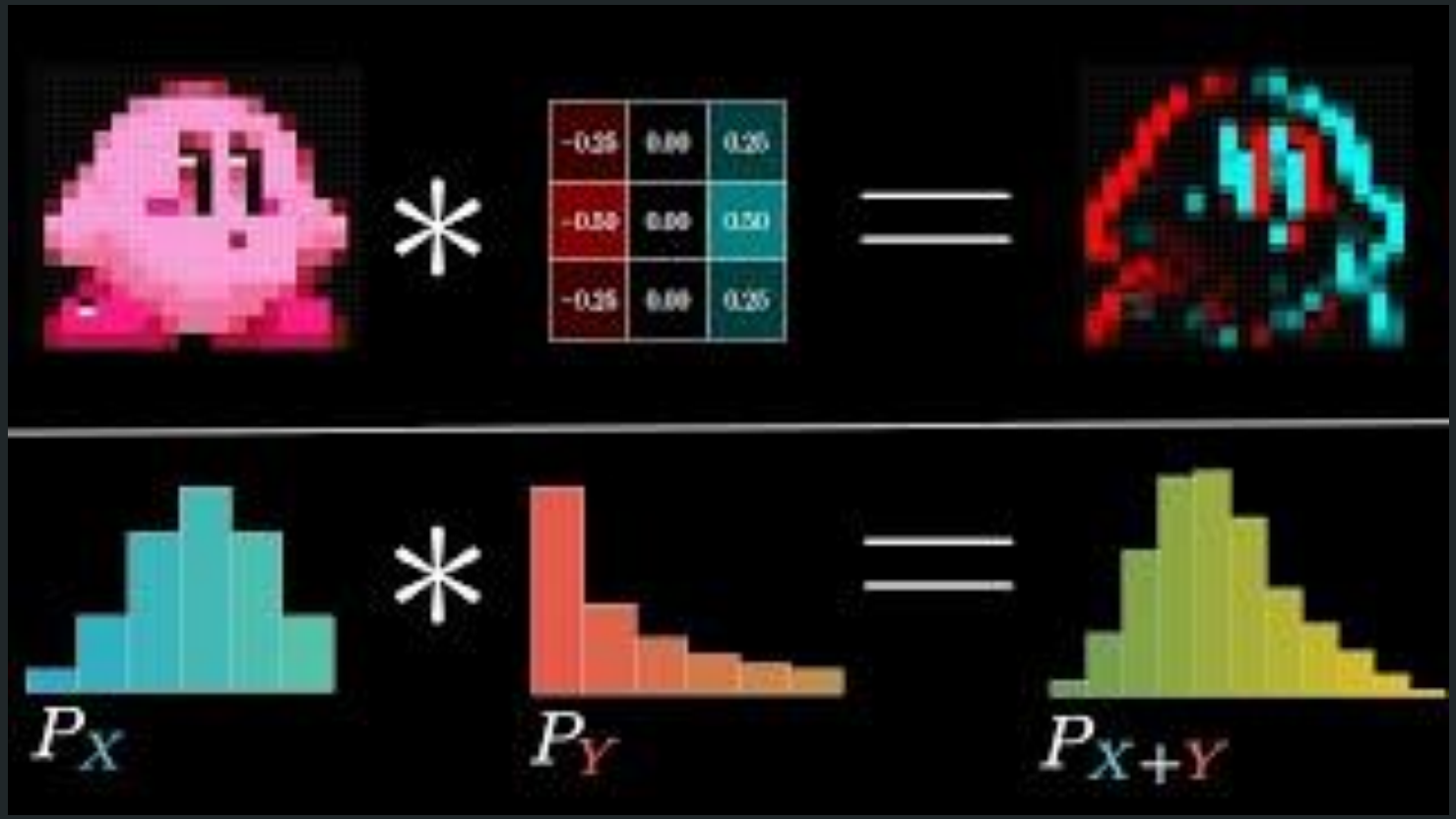


Mean vs. Gaussian smoothing





Mean vs. Gaussian smoothing

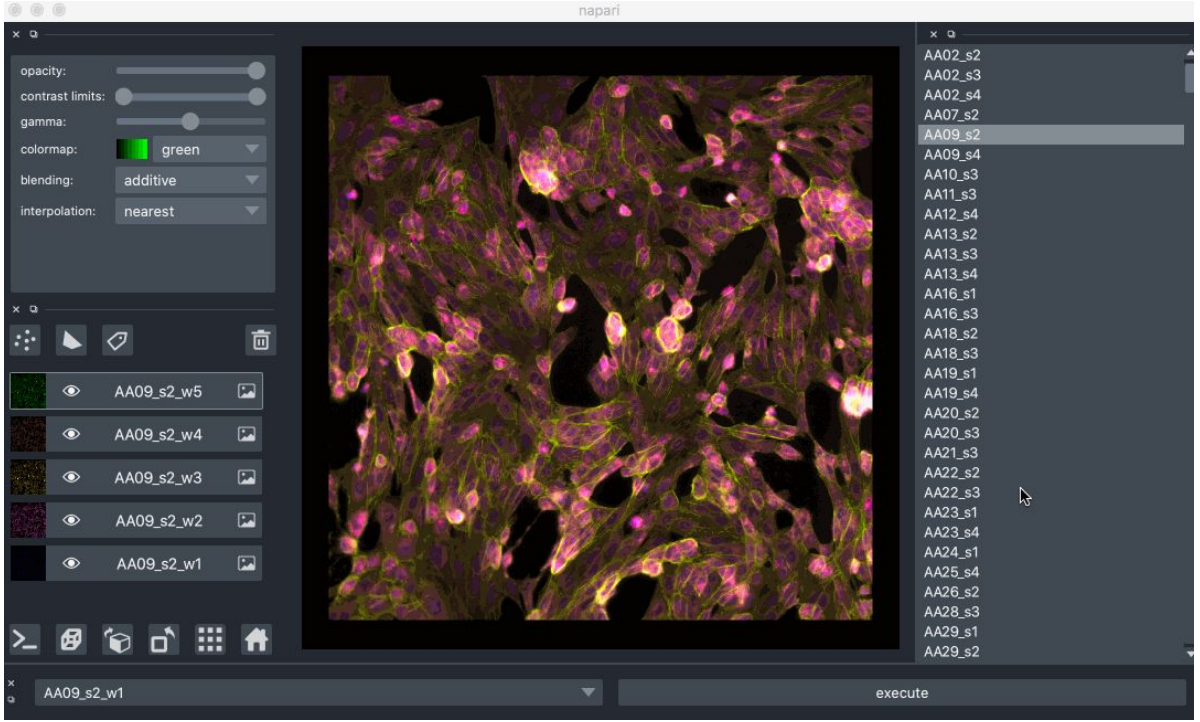


How do we implement these different filters? **Convolution**!

Image processing tools based in Python

cellpose
https://github.com/MouseLand/cellpose

Napari
https://github.com/napari/napari



Additional Resources (Signal processing)

https://mark-kramer.github.io/Case-Studies-Python/03.html

https://voyteklab.com/oscillations/publications/interpreting-spectrum/

Related UCSD classes:

COGS 118C. Neural Signal Processing

DSC 120. Signal Processing for Data Analysis

Additional resources (Image processing)

95 - What is digital image filtering and image convolution?

Finding the Edges (Sobel Operator) - Computerphile

Computer Vision Tutorial: A Step-by-Step Introduction to Image Segmentation Techniques (Part 1)

I2K 2020: Bioimage analysis fundamentals

2018 Data Science Bowl: Image Segmentation
https://www.nature.com/articles/s41592-019-0612-7