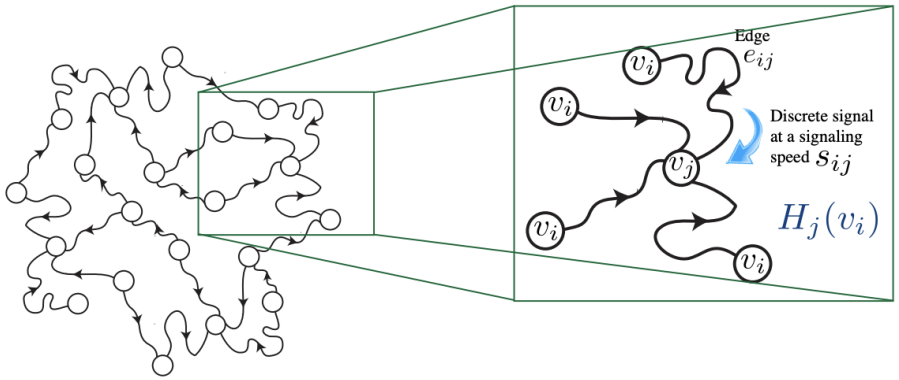
Signal and Image Processing

BILD 62

Dante Fisher

Mad World | Middlebury Dissipated Eight (2016)
The Dissipated Eight · 363 views · 8 years ago



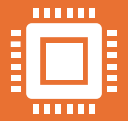
Who am I?

- Dante Fisher (He/Him/His)
- 3rd Year NGP student (Silva Lab)
- Use geometric models of the brain to study efficient signaling
- Originally from Pennsylvania
- Fun fact: I was in an a cappella group in college

Learning Objectives (Signals)

- **Identify different types of signals and how signal processing is used in the analysis of biological data**
- **Distinguish different types of signals and how the information they contain is structured**
- 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

What is a signal?



A **signal** is any data or information that can be measured and represented in a way that changes over time or space

Time-varying: sound waves, heart-rate

Spatially-varying: pixel intensity/ color

Both: temperature readings, fMRI data

What is signal processing?

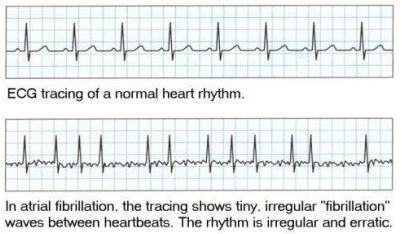
Signal processing is the method of analyzing and modifying signals—such as sounds, images, or biological data—to make them clearer, more useful, or easier to interpret.

It involves techniques to filter out noise, enhance important features, or extract meaningful information from raw data.

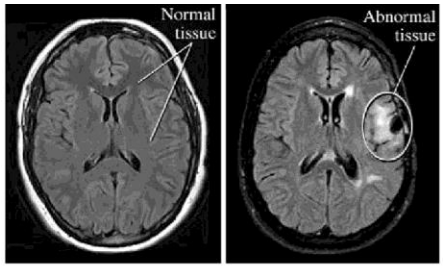
In biology, signal processing can be used to clean up ECG recordings, improve the quality of MRI images, or analyze DNA sequences.

Real-world signals have structure which contains meaningful information

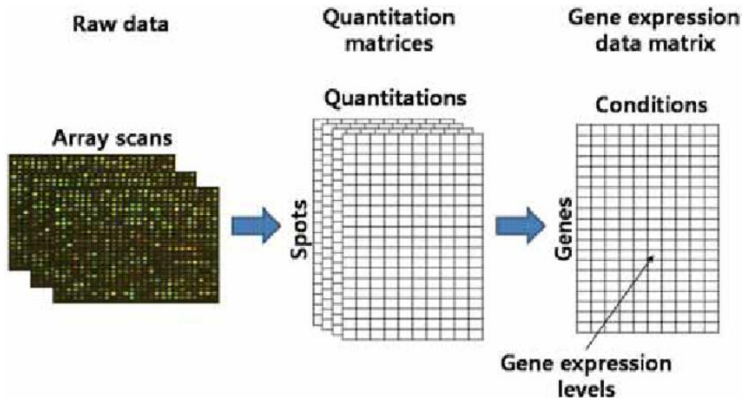
- Signal processing helps **preserve, enhance, or extract** this structure while reducing unwanted noise. If we ignore the structure, we might misinterpret the data or lose important biological insights.



EGC time series can distinguish between healthy and irregular heart function



2-D MRI slices are used to identify diseased tissue and hemorrhaging



Expression of genes depends on experimental conditions and produces high dimensional data

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- **Filtering by convolution**
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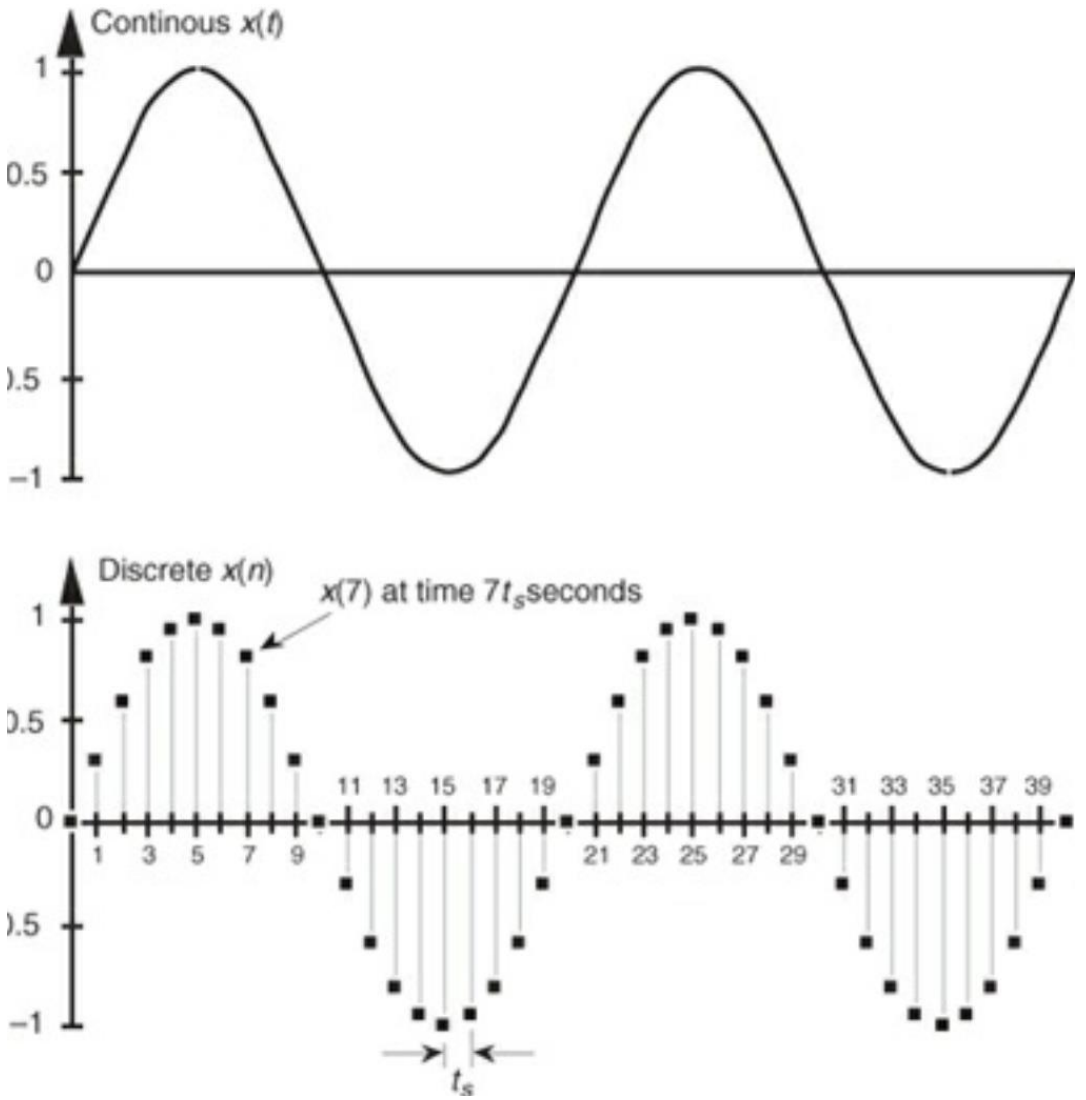
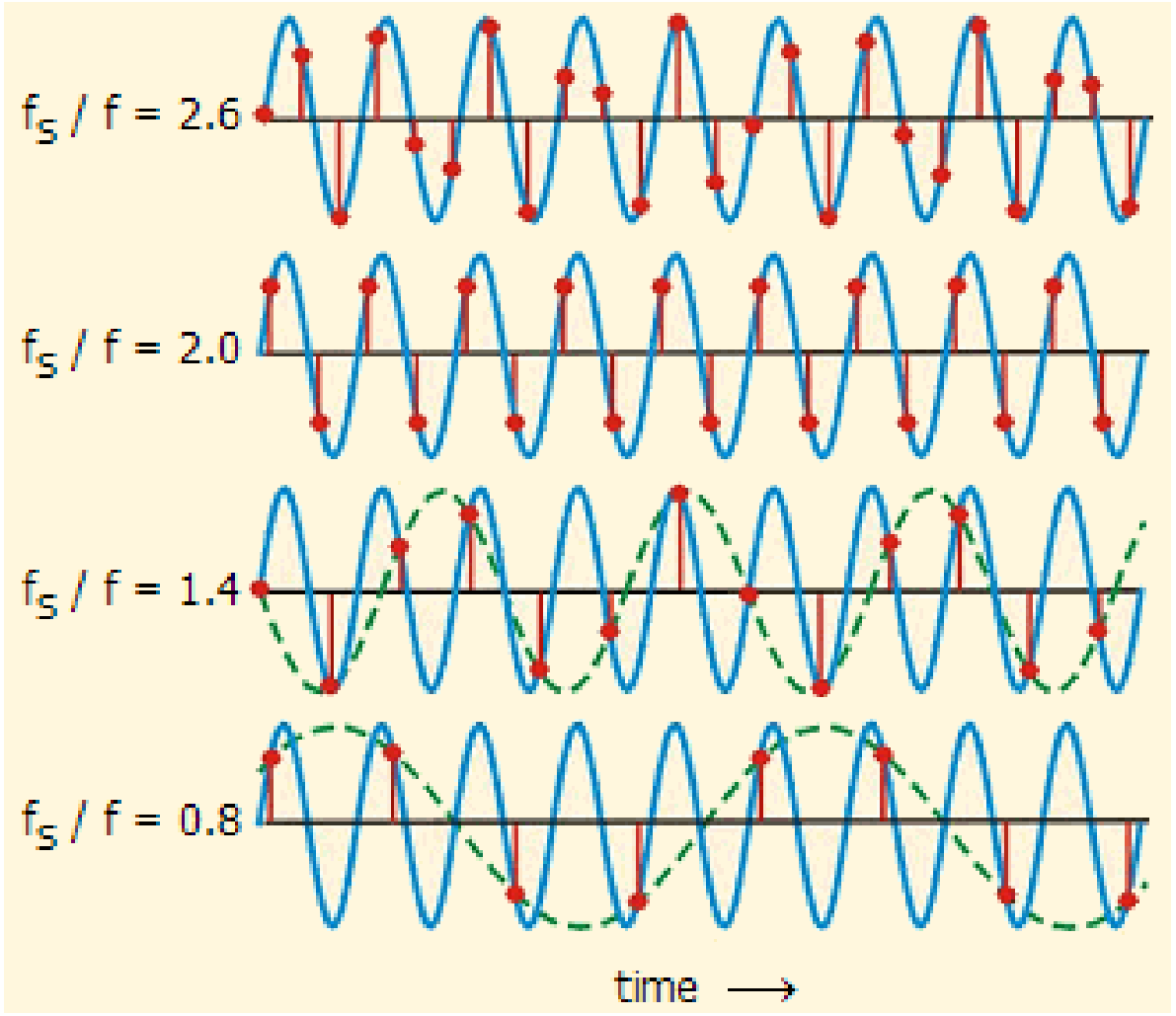
Time-Series

- Time-series are signals that change over time
- Many real-world signals are continuous (e.g. neuron membrane potential, heart rate, expression level)
- To analyze continuous signals with a computer, we have to discretize them by sampling at specific time points



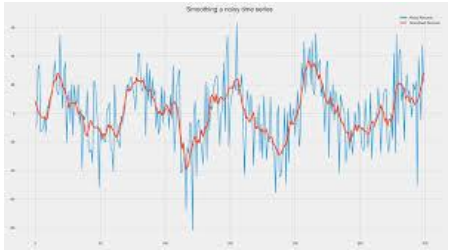
Nyquist Sampling Criterion

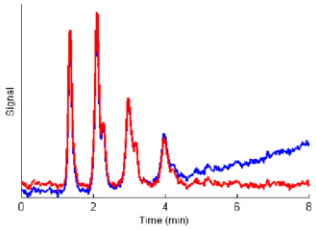
- Since sampling results in a loss of information, choosing an appropriate sampling rate to accurately reproduce our original signal
- The **Nyquist Sampling Criterion** tells us that we must sample our signal at least twice as fast as the highest frequency in our data
- Visual example on Youtube

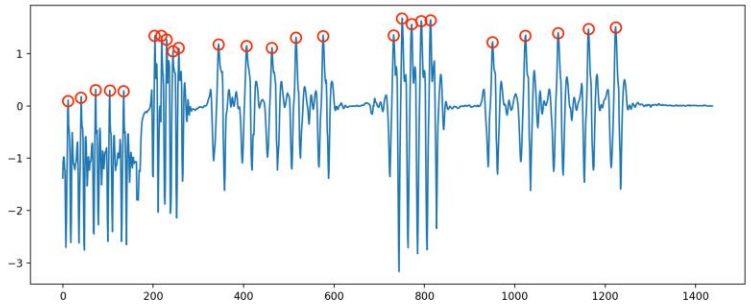


Time-Series Signal Processing

- Common techniques include:
  - Smoothing – removes fluctuations due to noise; makes trends in data clearer
  - Baseline Correction – removes a shift in data caused by external interference (e.g. recording equipment); improves biological interpretability
  - Peak Detection – Finds maxima/ minima in signal corresponding to biological events (e.g. heart beat, action potential)







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

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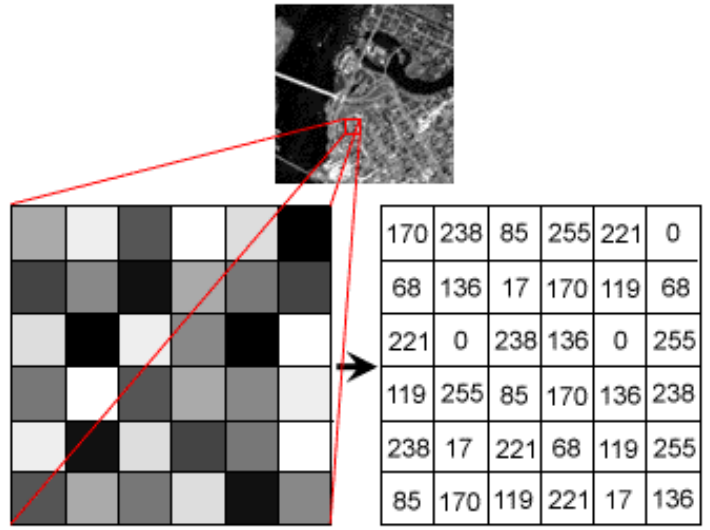
What is an image?

- An image is a 2D collection of signals that vary spatially
- Signals are contained within pixels and can be a single value (gray-scale) or a vector (RGB)



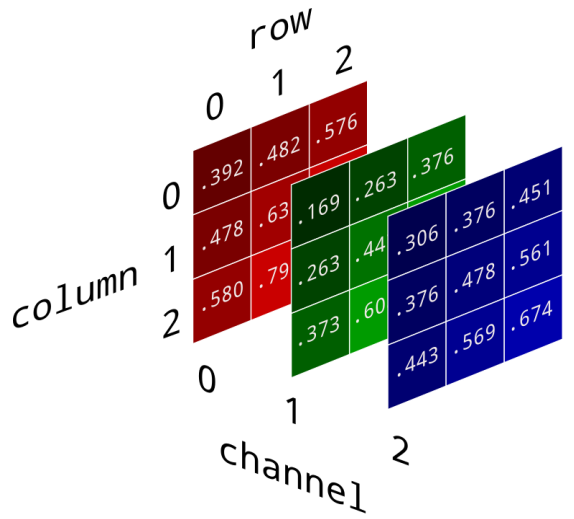


Image Structure

- Pixels are indexed with an ordered pair (x,y)
- By convention we number left to right and top to bottom
- The top left corner is (0,0)

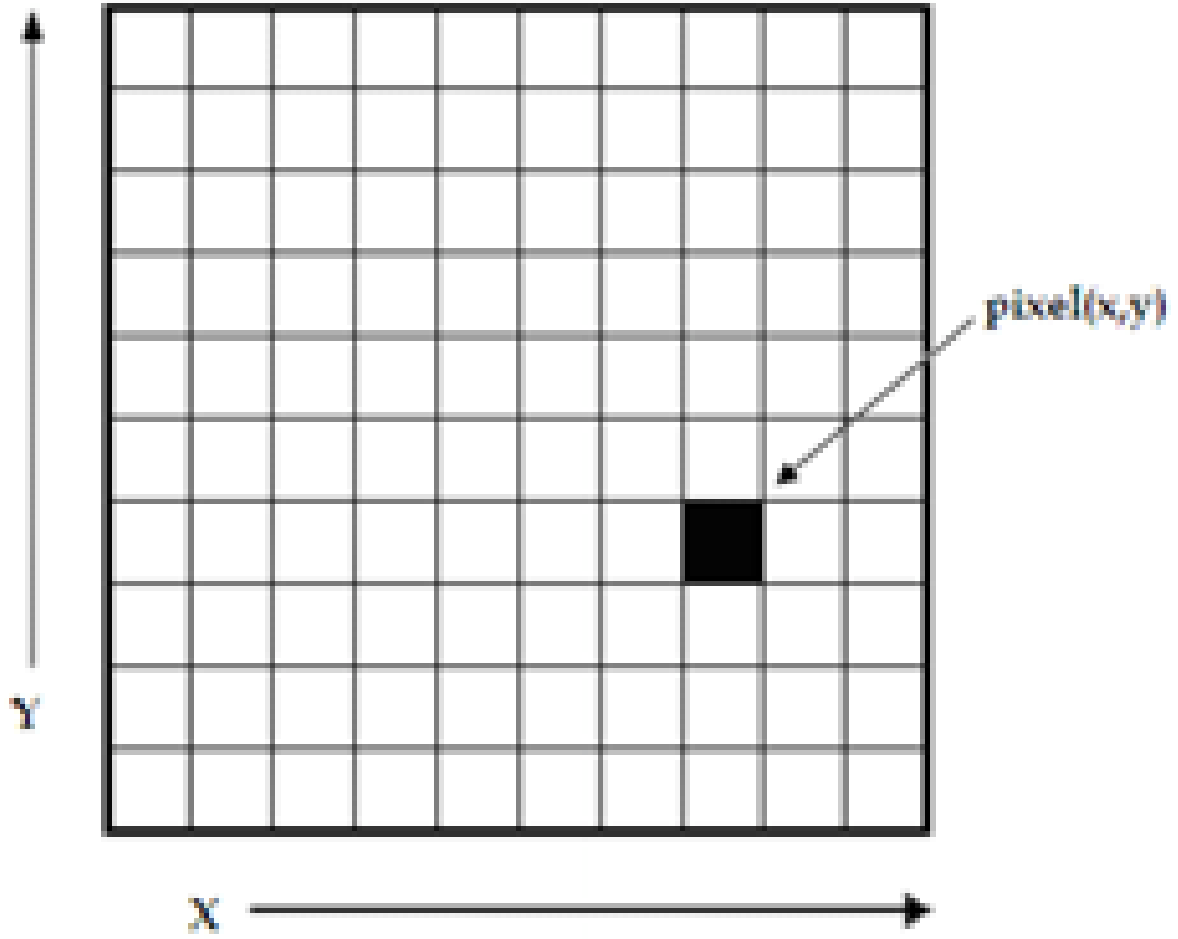
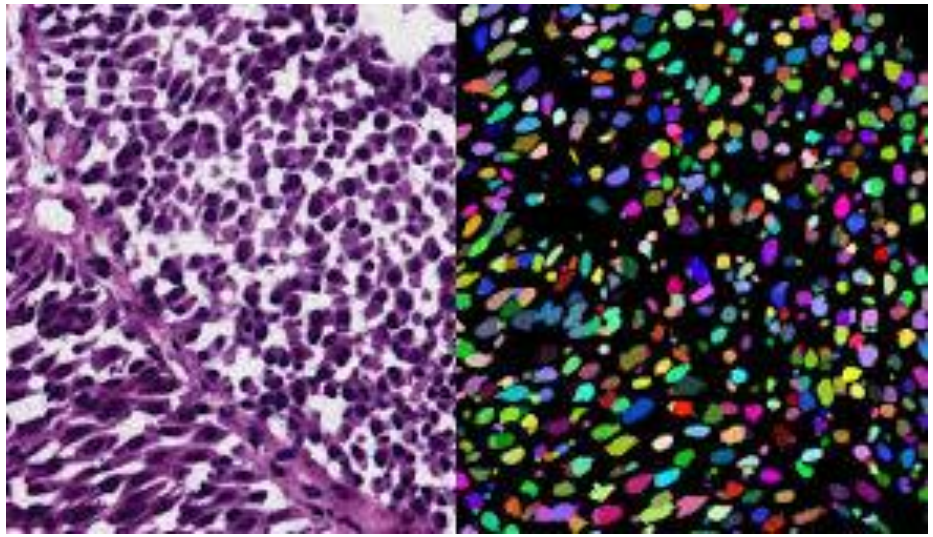
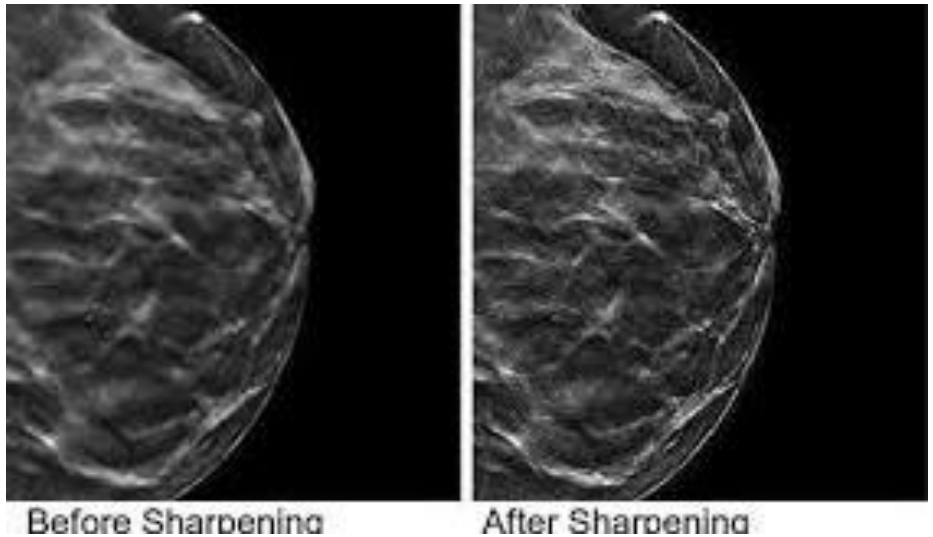


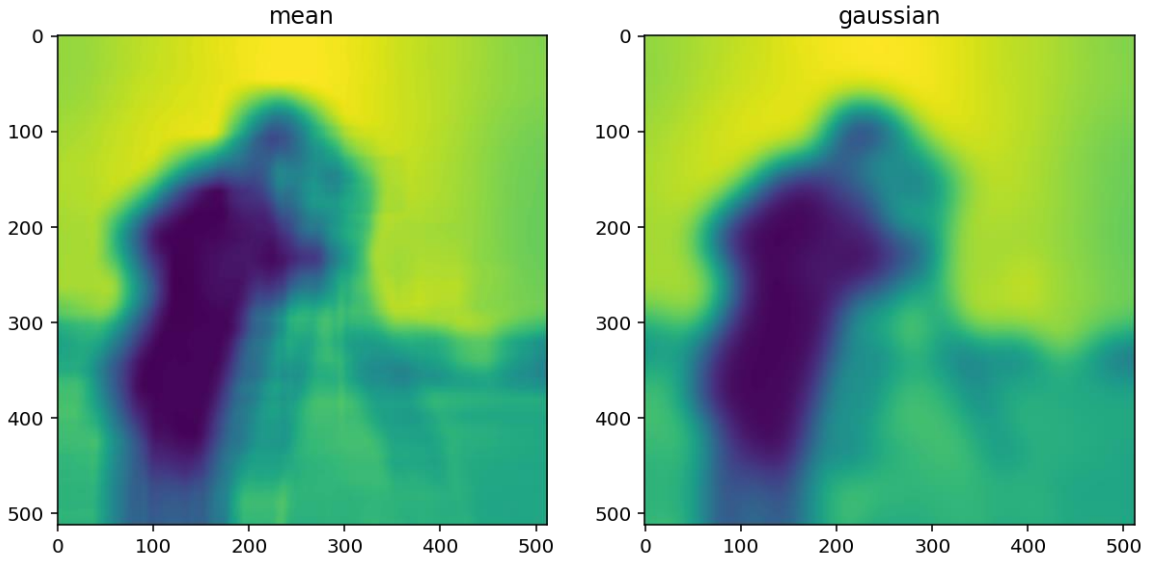
Image Processing

- Image processing is useful for dividing images into useful regions (segmentation) and enhancing/ removing features (filtering)
- Image segmentation can be used to isolate individual cells within a microscope image
- Applying a blur filter to a noisy image can reduce noise
- A sharpening filter can help highlight object boundaries



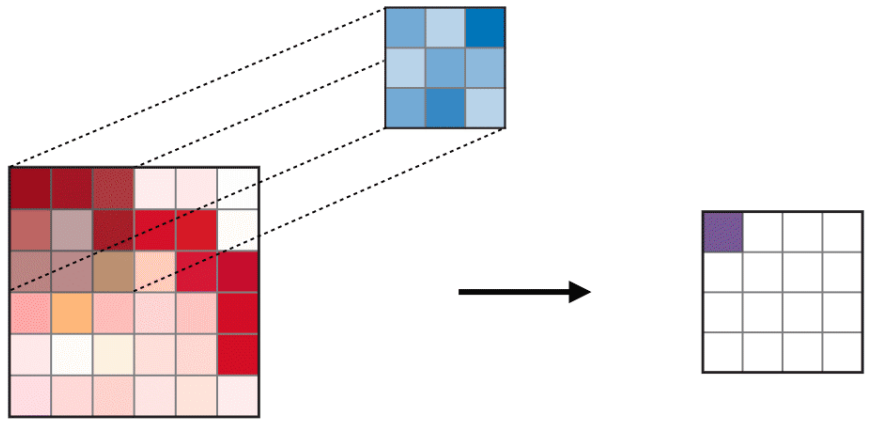


Mean VS Gaussian Smoothing



Convolutions

- Convolution is a common technique in image processing technique used to detect patterns, blur images, and detect edges
- They form a basic building block for more advanced image processing and computer vision
  - A small matrix (kernel) applied to part of the image
  - Kernel and pixel values are multiplied and summed to get a new pixel value
  - The kernel slides across the image, and the process repeats



Great 3Blue1Brown Video on Convolutions

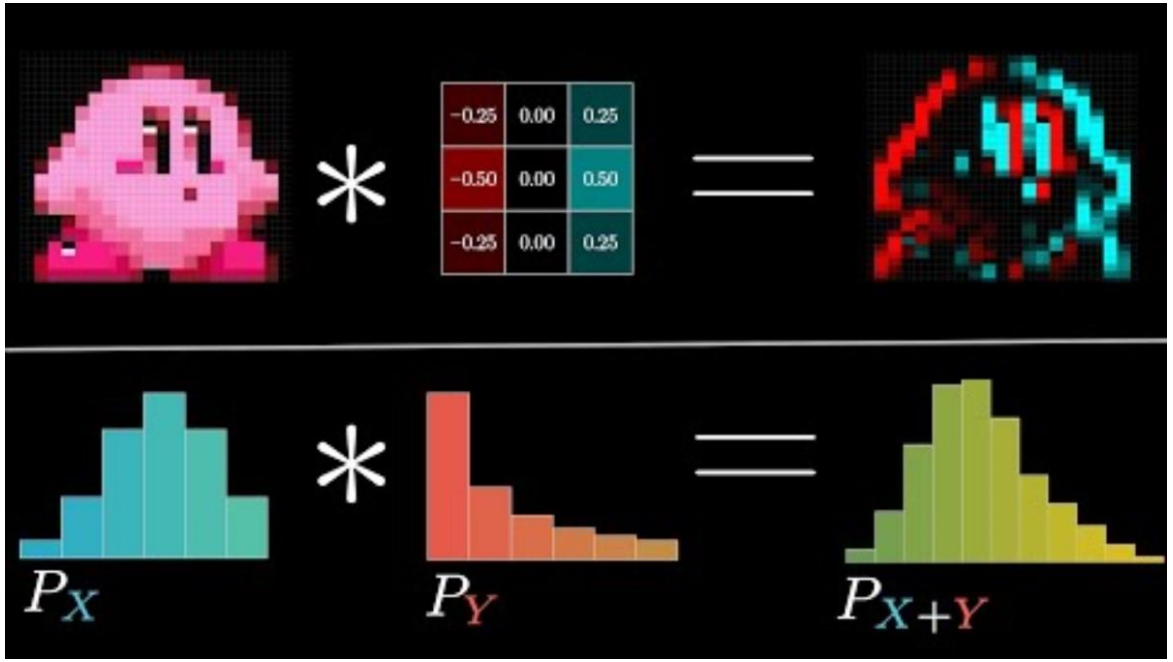
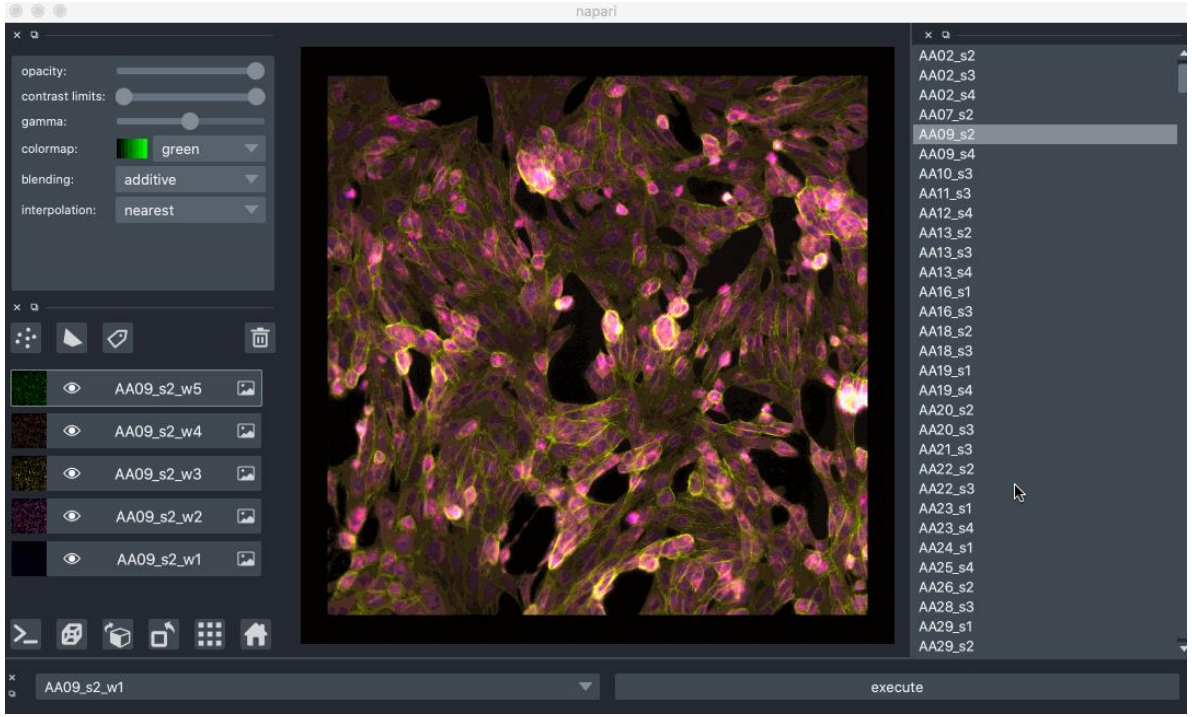


Image processing tools based in Python

- 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

Sources

- 1)
- https://heart-sense.org/atrial-fibrillation
- https://maelfabien.github.io/machinelearning/Speech6/#