Image Processing Math with Images

- Image Compression
- Changing the Size
- Utilizing the Colors Channels of an Image
- Image Filters

- Discrete Cosine Transform
  (.jpeg, .heif (, video, sound, ...)
  - 2<sup>n</sup> x 2<sup>n</sup> tiles approximates by 2D cosines





8x8



+ 6.192 🗶

https://en.wikipedia.org/wiki/Image\_compression

- Discrete Cosine Transform
- Wavelet Transform (JPEG 2000)

https://en.wikipedia.org/wiki/Image\_compression



- Discrete Cosine Transform
- Wavelet Transform
- Reducing the color space
  - Reducing bit depth/color space vs. reduction to or summarizing occuring colors



https://en.wikipedia.org/wiki/Color\_space https://en.wikipedia.org/wiki/Image\_compression

- Discrete Cosine Transform
- Wavelet Transform
- Reducing the color space
  - Reducing bit depth/color space vs. reduction to or summarizing occuring colors
  - (Dithering)







#### https://en.wikipedia.org/wiki/Color\_quantization https://en.wikipedia.org/wiki/Image\_compression

- Discrete Cosine Transform
- Wavelet Transform
- Reducing the color space
  - Reducing bit depth/color space vs. reduction to or summarizing occuring colors
  - (Dithering)





16 colors + dithering



**Noise Dither** 

https://de.wikipedia.org/wiki/Dithering\_(Bildbearbeitung) https://en.wikipedia.org/wiki/Image\_compression

- Discrete Cosine Transform
- Wavelet Transform
- Reducing the color space
- Chroma subsampling (JPEG)
  - Stronger reduction of color information over a reduction intensity information

- Discrete Cosine Transform
- Wavelet Transform
- Reducing the color space
- Chroma subsampling
- Fractal compression
  - Compressed self-similar (reoccuring) parts saved once

- Run-length encoding (GIF)
  - Repeated lines saved once

https://en.wikipedia.org/wiki/Image\_compression

- Run-length encoding
- Differential Pulse Code Modulation
  - Calculating and saving the difference of one part of the signal with another part

https://en.wikipedia.org/wiki/Image\_compression

- Run-length encoding
- Differential Pulse Code Modulation
- Entropy encoding
  - Prefix code for each "unique symbol" in signal, saving prefix code sequence
  - Basis for arithmetic coding and Huffman coding

- Run-length encoding
- Differential Pulse Code Modulation
- Entropy encoding
- Lempel–Ziv–Welch (GIF, TIFF)
  - Assemble Dictionary of signal sequences in input and where to find them

- Run-length encoding
- Differential Pulse Code Modulation
- Entropy encoding
- Lempel–Ziv–Welch
- DEFLATE (.png, .mng, .tiff)
  - Lempel–Ziv–Storer–Szymanski + Hoffmann encoding
  - Dictionary method + entropy encoding

- Run-length encoding
- Differential Pulse Code Modulation
- Entropy encoding
- Lempel–Ziv–Welch
- DEFLATE
- Chain code
  - Saves outline of area with same greyvalue

#### https://en.wikipedia.org/wiki/Image\_compression

- Several typical algorithms available
  - Bilinear and Bicubic
  - Nearest Neighbor



Functions in FIJI/ImageJ to resize images

- Image  $\rightarrow$  Adjust  $\rightarrow$  Size...
- Image  $\rightarrow$  Scale...

https://en.wikipedia.org/wiki/Bicubic\_interpolation https://en.wikipedia.org/wiki/Image\_scaling

- Several typical algorithms available
  - Bilinear and Bicubic
    - Extrapolates local image intensities
    - Can extrapolate curved lines
    - May introduce artifacts



- Several typical algorithms available
  - Bilinear and Bicubic
  - Nearest Neighbor
    - Preserves image intensities and edges if image enlarged by n
    - Can otherwise also create artifacts
      - Bad edge preservation when reducing size
      - Lower pixel intensities due to rounding down



#### 3dmix.com https://en.wikipedia.org/wiki/Image\_scaling

- Several typical algorithms available
  - Bilinear and Bicubic
  - Nearest Neighbor
  - Choose according to purpose/image
  - Always check for artifacts (at the pixel scale)!



# Changing the Image Size - Vector based Images

- All Image information strored as primitives such as lines, circles, splines, etc. (essentially functions)
- Supported by .svg, .eps, .wmf, .ai, .pdf
- Infinitely scalable
- Concept also available in 3D renderings



# Changing the Image Size - Best practices

- Ideally record images of carefully chosen areas and with enough pixels (min 4M pixels!)
- Avoid small changes in image size
- Change image size as few times as possible
- Use Corel Draw, since pixelated images intensities are only extrapolated once when image is saved in pixelated format
- Or save as vector file

# Utilizing the Color Channels of an Image

- Up to 3 greyscale maps/images remain rather interpretable
- Illustration of change between two points in time between two greyscale images



Development of [111] texture in Pt thin film due to heating

# Utilizing the Color Channels of an Image

- Up to 3 greyscale maps/images remain rather interpretable
- Illustration of change between two points in time between two greyscale images
- RGB channels (e.g. for three overlapping images/EDX maps)
  - Maximize contrast vs quantified contrast?
  - Apparent intesity of different colors?



Functions in FIJI/ImageJ to separate/combine images

- Image → Color → Merge/Split Channels
- Image  $\rightarrow$  Stacks...  $\rightarrow$  Z Project
- Process → Image Calculator

Up to 7 color channels available Channel operations also possible with stacks

- Easiest to stick with greyscale images
- Adjustments have to be stated!

# Image Filters - Convolutions for Noise Reduction

• At each pixel a new value is calculated based on the surrounding pixels



Original noisy image

	1	4	7	4	1
	4	16	26	16	4
<u>1</u> 273	7	26	41	26	7
	4	16	26	16	4
	1	4	7	4	1

Median of intensities in 5x5 matrix

median filter

stackexchange.com

scipy-lectures.org/intro/scipy/auto\_examples/plot\_image\_filters.html



# Image Filters - Convolution for Edge Detection (Sobel Filter)

• Convolution with matrices for x and y direction





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



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

Gy

medium.com

# Image Filters – Threshold based Segmentation

- Theshold selcted visually or based on histogram
- Several automatic methods availble in FIJI/ImageJ
- Automatic particle anaylsis available as well

😝 🖯 🔿 Threshold				
	↓      124        ↓      255			
Default 🛟	Red			
Dark background				



imagej.nih.gov



medium.com







 $f(x) = sin(x) + sin(8^*x)$ 



bonedo.de





Just Spots

Wedge Shaped Filter

applied in GMS3

B. Mei, ACS Catal. 3 2013 3041–3049.









# The World of Scripting – Python ftw!

- All the things above!
- Summing up images after aligning them via cross-correlation!
- Zoom videos consisting of extrapolated images based on images recorded at fixed magnifications!
- Dynamic scale bars!
- Create your own noise removal techniques!
- Extracting data from *in situ* image series!
- Data visualization!
- Combining image series into single images in creative ways!
- There are no limits!



# Thank you for your attention!