Machine Learning for Bio-Image-Analysis

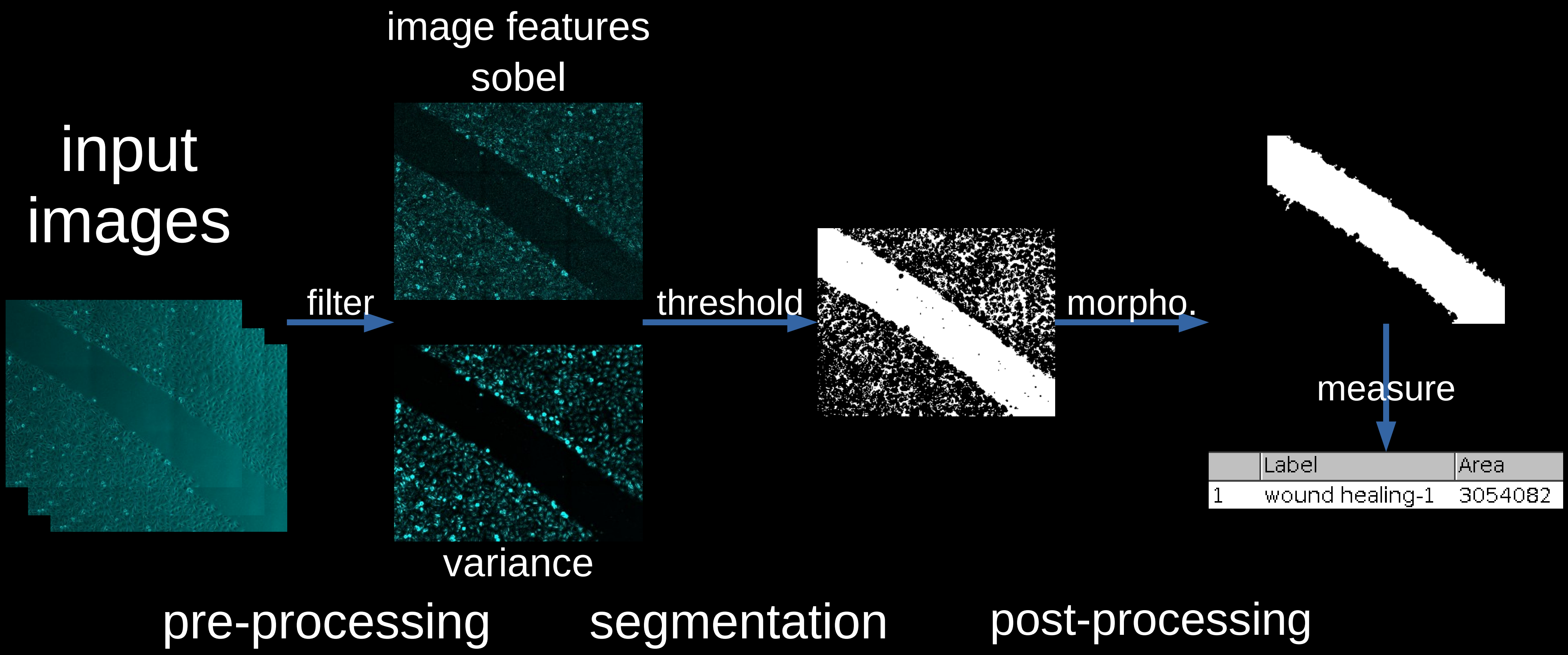
Introduction

- What is bio-image analysis?
- How is it done without machine learning?
- What is machine learning?
- How is it bio-image analysis done with machine learning?

Bio-Image-Analysis

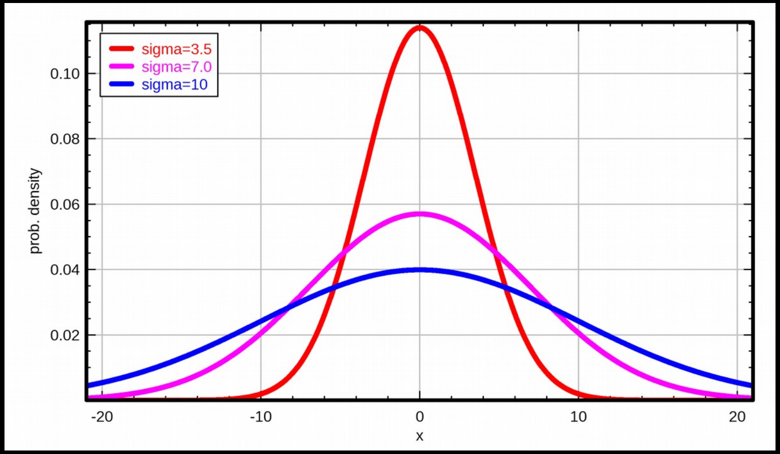
- “The extraction of information from digital images in the context of biological research”

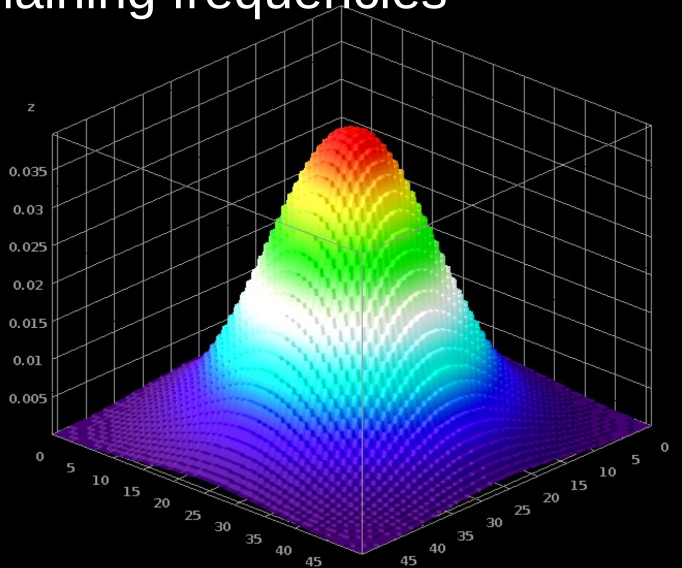
The Image-Analysis Workflow



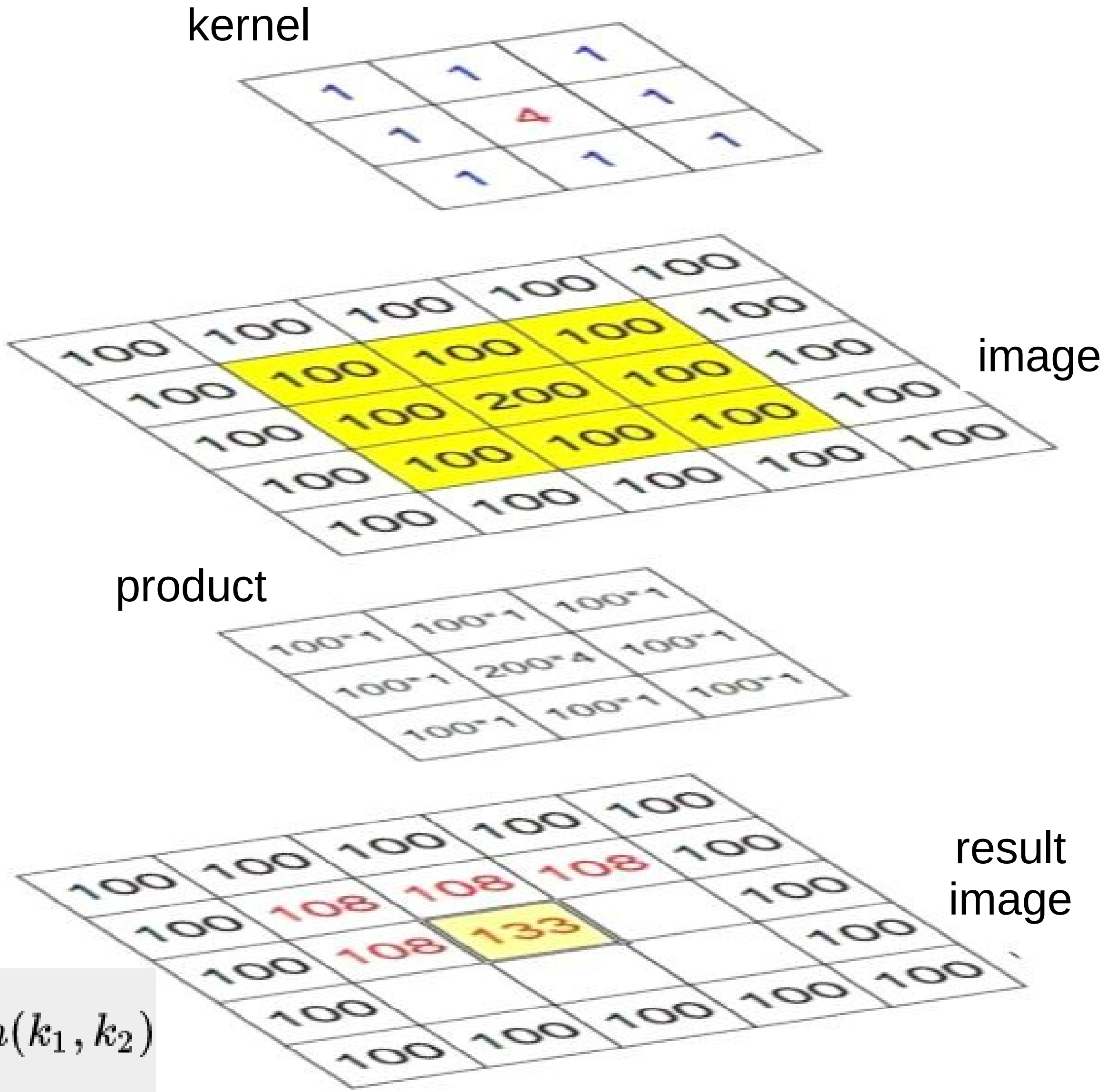
Select a scale

- Use “Gaussian blur”-filter to select a scale
  - Low-pass filter
  - Removes high frequencies from the images
    - The higher sigma the lower the remaining frequencies





Convolution



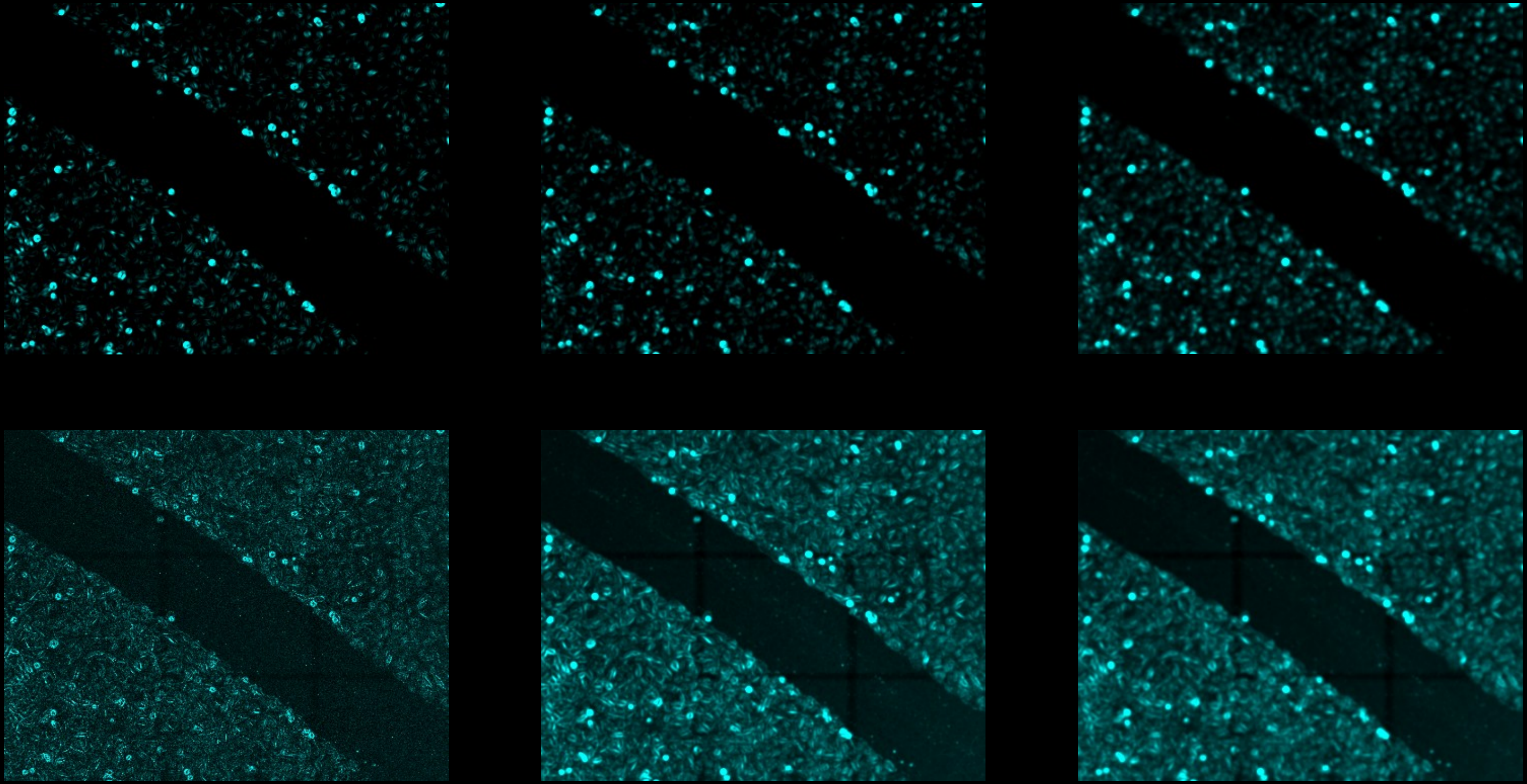
$$y(n_1, n_2) = \sum_{k_1=-\infty}^{\infty} \sum_{k_2=-\infty}^{\infty} x(n_1 - k_1, n_2 - k_2) h(k_1, k_2)$$

Image features at different scales

scale feature | $\sigma=3.5$ | $\sigma=7$ | $\sigma=10$

variance

sobel



Machine Learning

Machine learning algorithms build a mathematical model of sample data, known as ”training data”, in order to make predictions or decisions without being explicitly programmed to perform the task.

Machine Learning

- Training
  a model is learned from training data
- Validation
  the trained model is validated against test data
- Application
  use the trained model to make predictions on new data

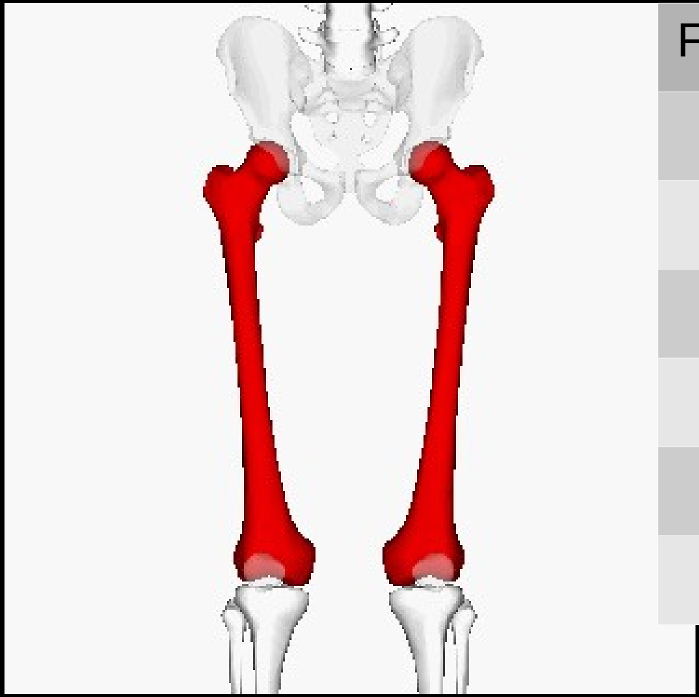
Machine Learning vocabulary

- Supervised
  - a model is learned from pairs of input and output data
- Unsupervised
  - a model is learned from the inherent structure of the input data alone
- Classification
  - the result is a category
- Regression
  - the result is a real number

Machine Learning
How is that even possible?

- ML algorithm implements a mathematical model with a number of model parameters
- Given the training data, find parameter values that minimize the prediction error

Machine Learning
Example 1 - linear regression



Femur length (cm)	Height (cm)
45	153
44	168
44	177
47	180
44	171
50	168

- Estimate body height f(x) given the femur length x.

- model

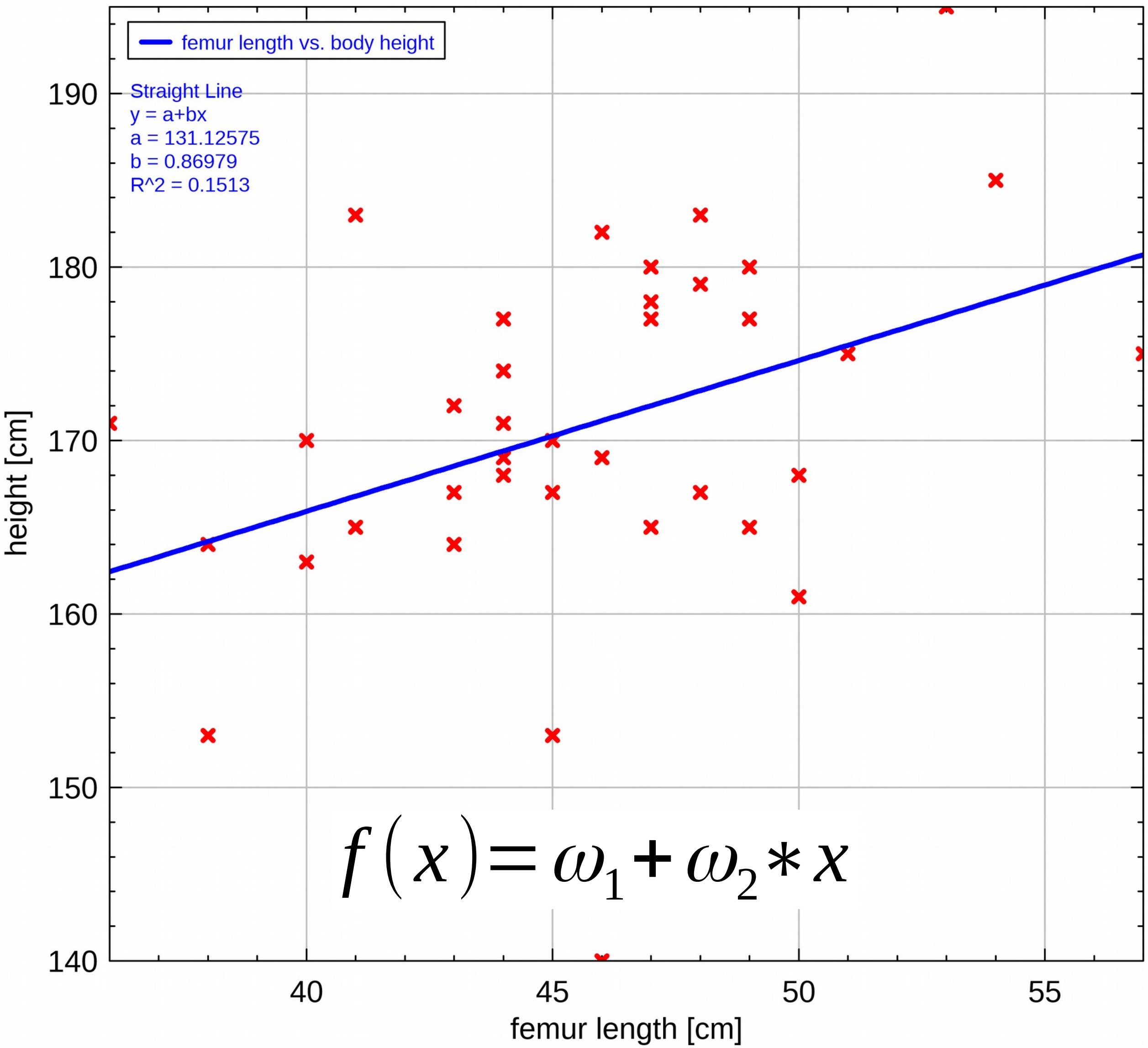
$$f(x) = \omega_1 + \omega_2 * x$$

training data

- ω_1, ω_2 model parameter

Example 1 - Linear regression

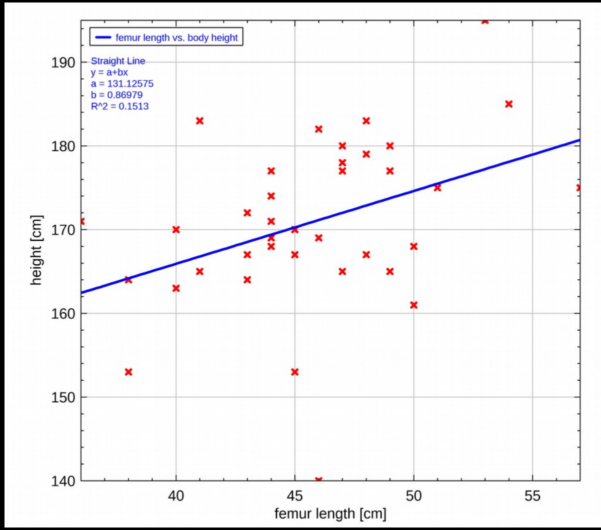
- Find parameters ω_1, ω_2,
- so that error between training data and model is minimal



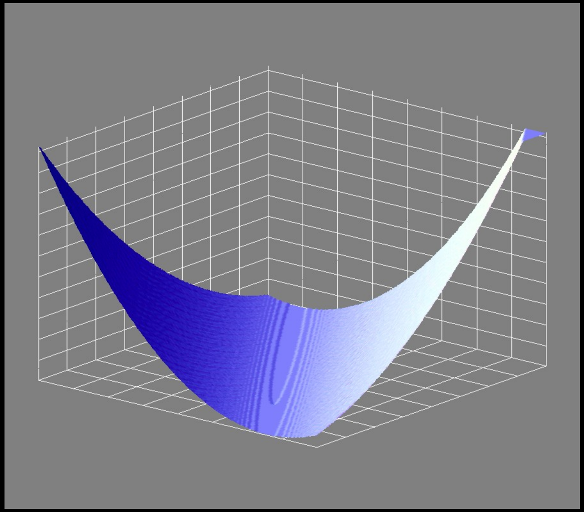
$$f(x) = \omega_1 + \omega_2 * x$$

Example 1 - Squared Loss function

$$f(x) = \omega_1 + \omega_2 * x$$

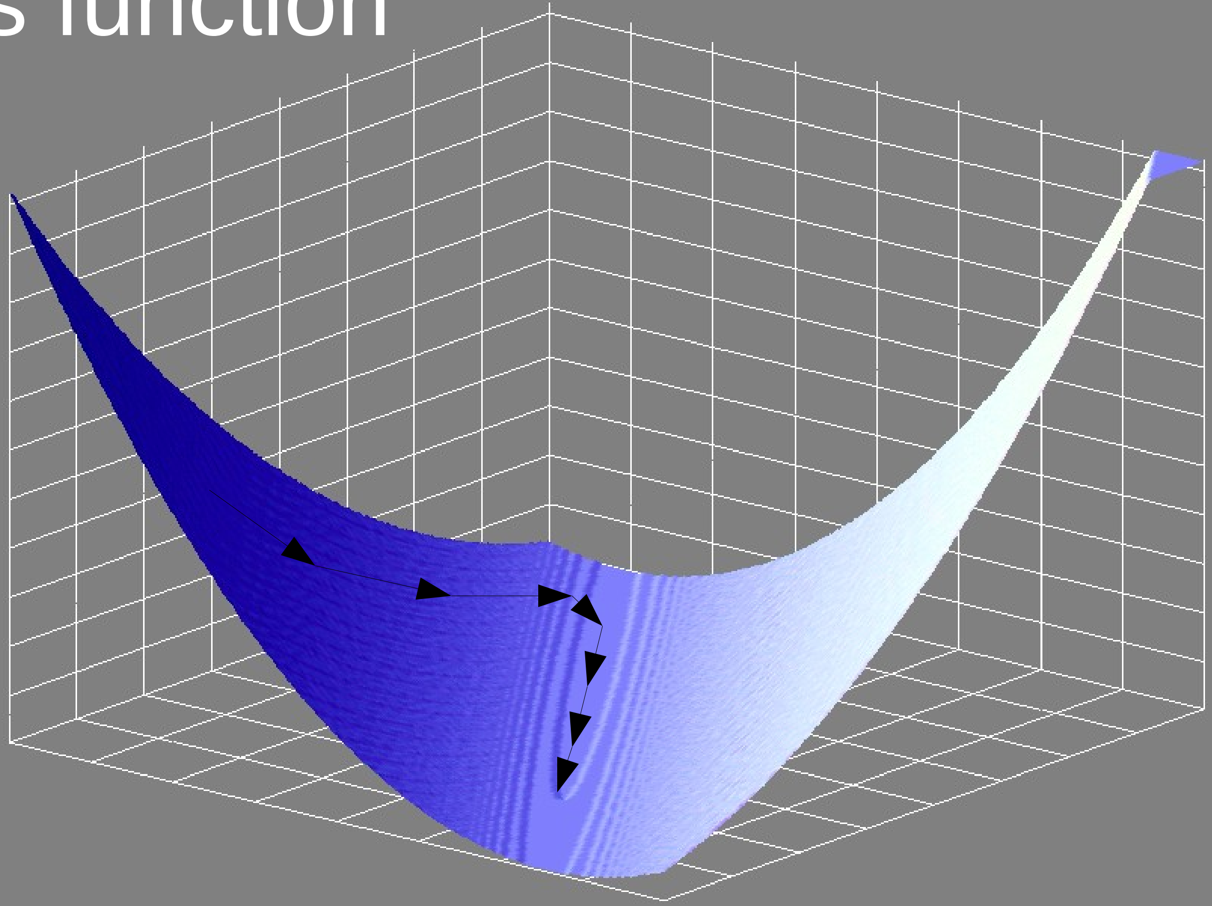


$$L(\omega_{1,}\omega_2) = \frac{1}{N} * \sum_{n=1}^{N} (t_n - f(x_n; \omega_{1,}\omega_2))^2$$

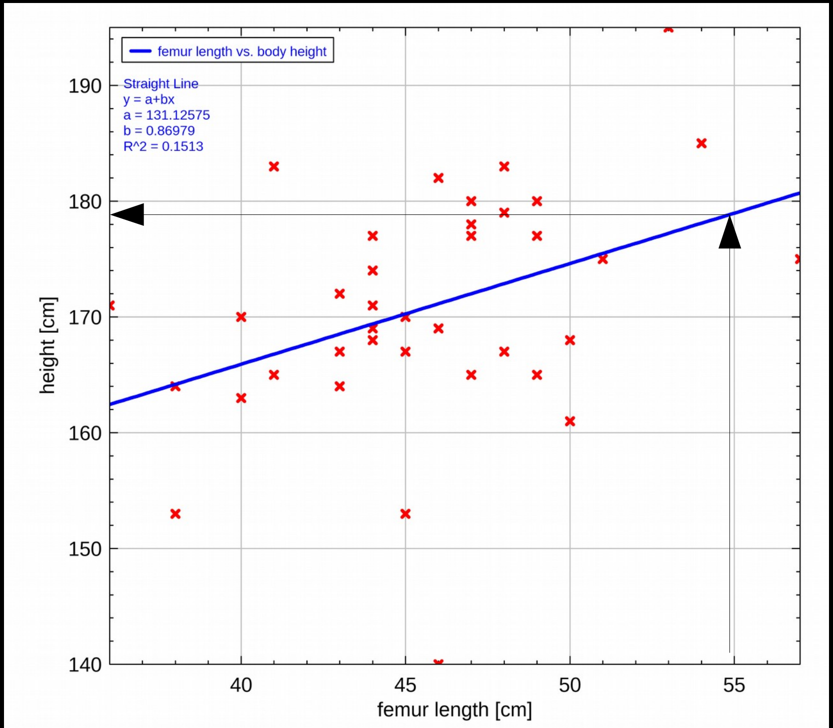


Example 1 - Loss function

- Find the minimum of the loss function
- By using gradient descent



Example 1 - Predictions



$$f(x) = \omega_1 + \omega_2 * x$$

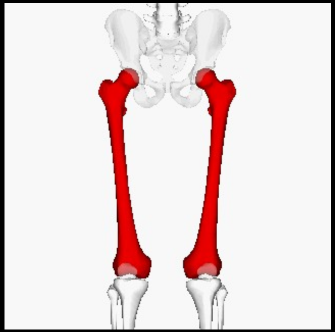
$$\omega_1 = 131.13\,cm$$

$$\omega_2 = 0.87$$

$$f(55\,cm) = 131.13\,cm + 0.878 * 55\,cm$$

$$f(55\,cm) = 179.42\,cm$$

Femur example



- Supervised or Unsupervised?
- Classification or Regression?

- Supervised
  - a model is learned from pairs of input and output data
- Unsupervised
  - a model is learned from the inherent structure of the input data alone
- Classification
  - the result is a category
- Regression
  - the result is a real number

The programs

- ImageJ/FIJI
- Weka
- Ilastik
- Cellprofiler / Cellprofiler Analyst
- Orbit

ImageJ/FIJI

- Demo ImageJ 01
  - Open image
  - Threshold
  - Binary Watershed
  - Compare to GT

ImageJ/FIJI

- Demo ImageJ 02
  - Revert Image
  - Laplacian of Gaussian (scale 3)
  - Threshold (Yen)
  - Binary Watershed
  - Compare to GT

Ilastik

- Demo Ilastik 01
  - import image(s)
  - select features and scales
  - name classes
  - select training data
  - export result
  - batch

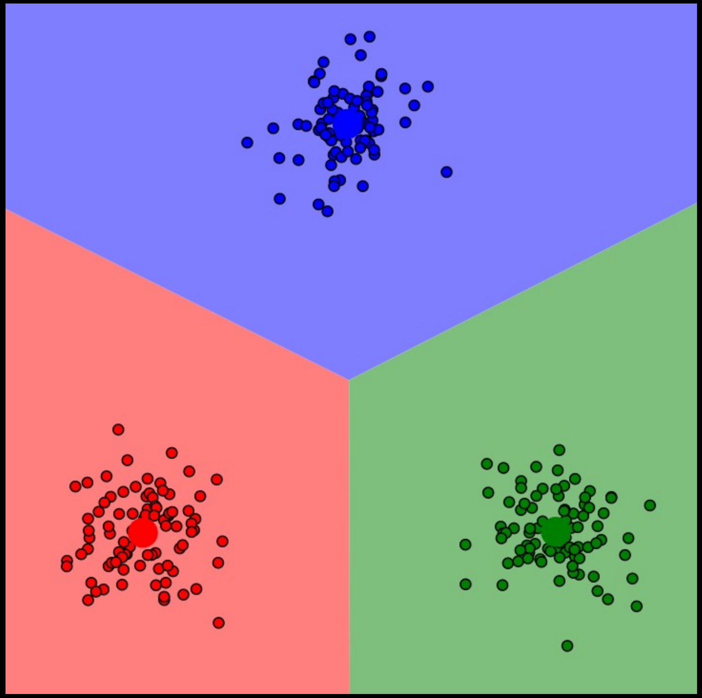
Exercises 01

Clustering

- A machine learning method
  - Unsupervised
  - Classification

Clustering

- Clustering
  - Group objects in a way that
    - objects in the same cluster are more similar to each other
    - than to objects in other clusters



Clustering algorithms

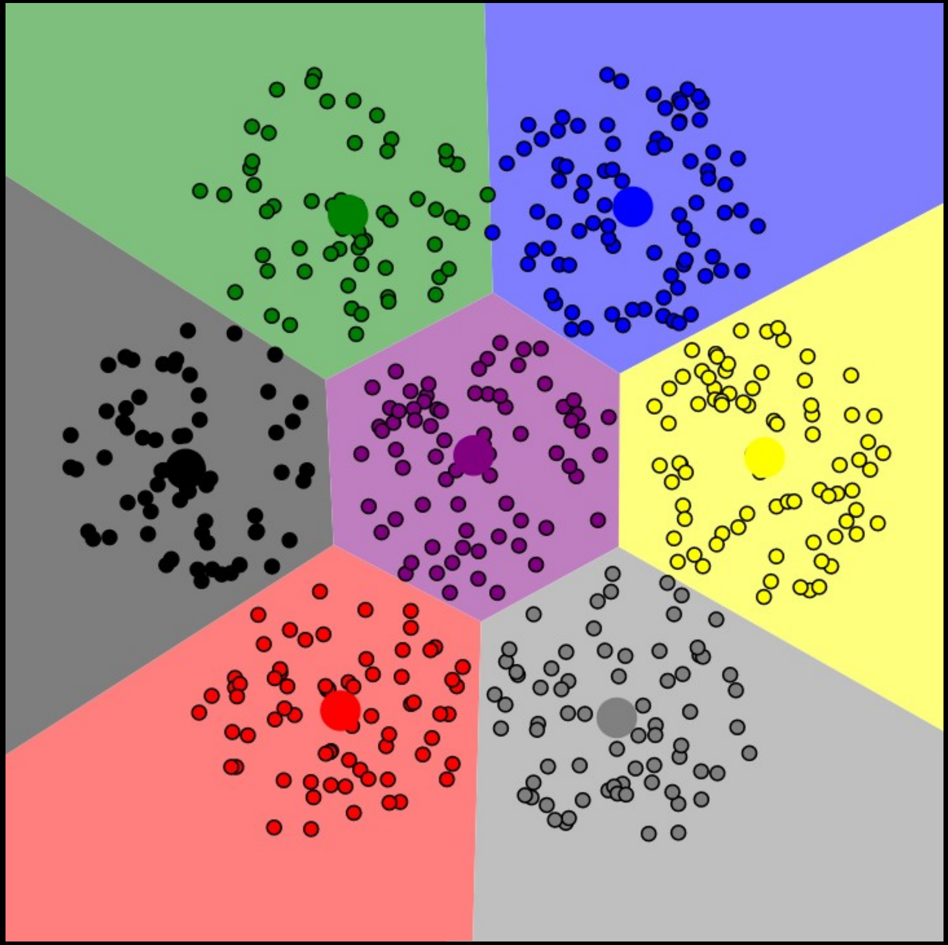
- K-means
- DBScan
- hierarchical clustering
- expectation-maximization
- ...

k-means clustering

- Partition the feature-space into k-clusters
- Each feature-vector belongs to the cluster with nearest mean

- Algorithm:
  - Start with k initial means
  - Repeat until convergence
    - Assign feature-vectors to clusters
    - Recalculate the means of the clusters

K-means example



K-means clustering in machine learning

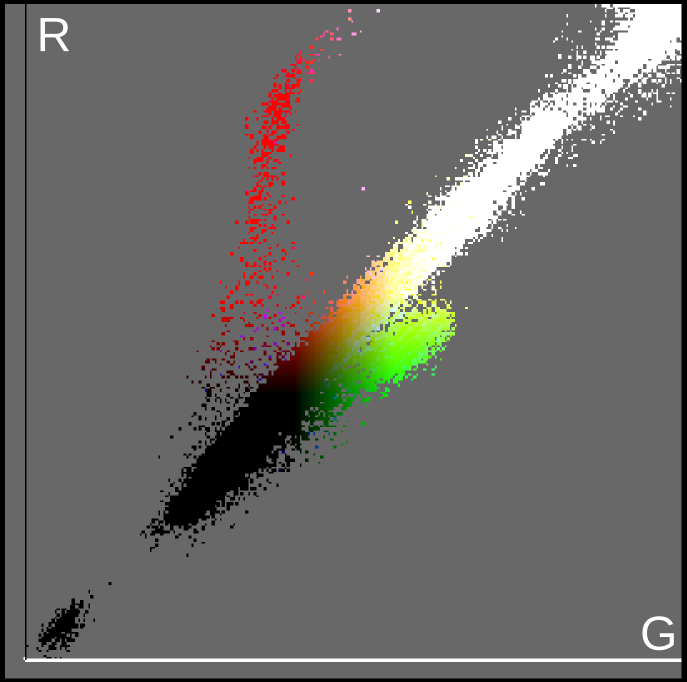
- Training phase:
  - randomly select a number of feature vectors
    - for example 5% of the data
  - run the k-means clustering on the selected feature vectors
  - the resulting means are the classifier

- Classification of unknown data:
  - Calculate the feature vector
  - Assign it to the cluster with the nearest mean

Classify pixels by color

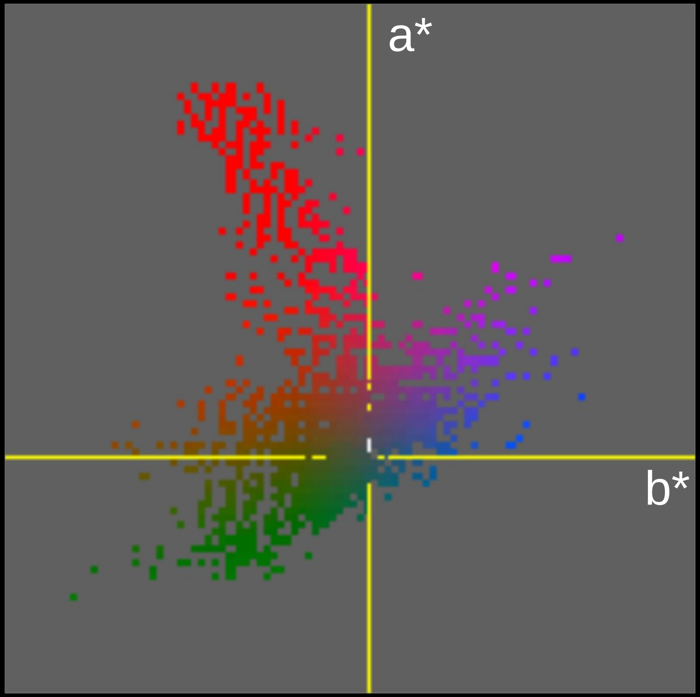
- Input Image

- RGB



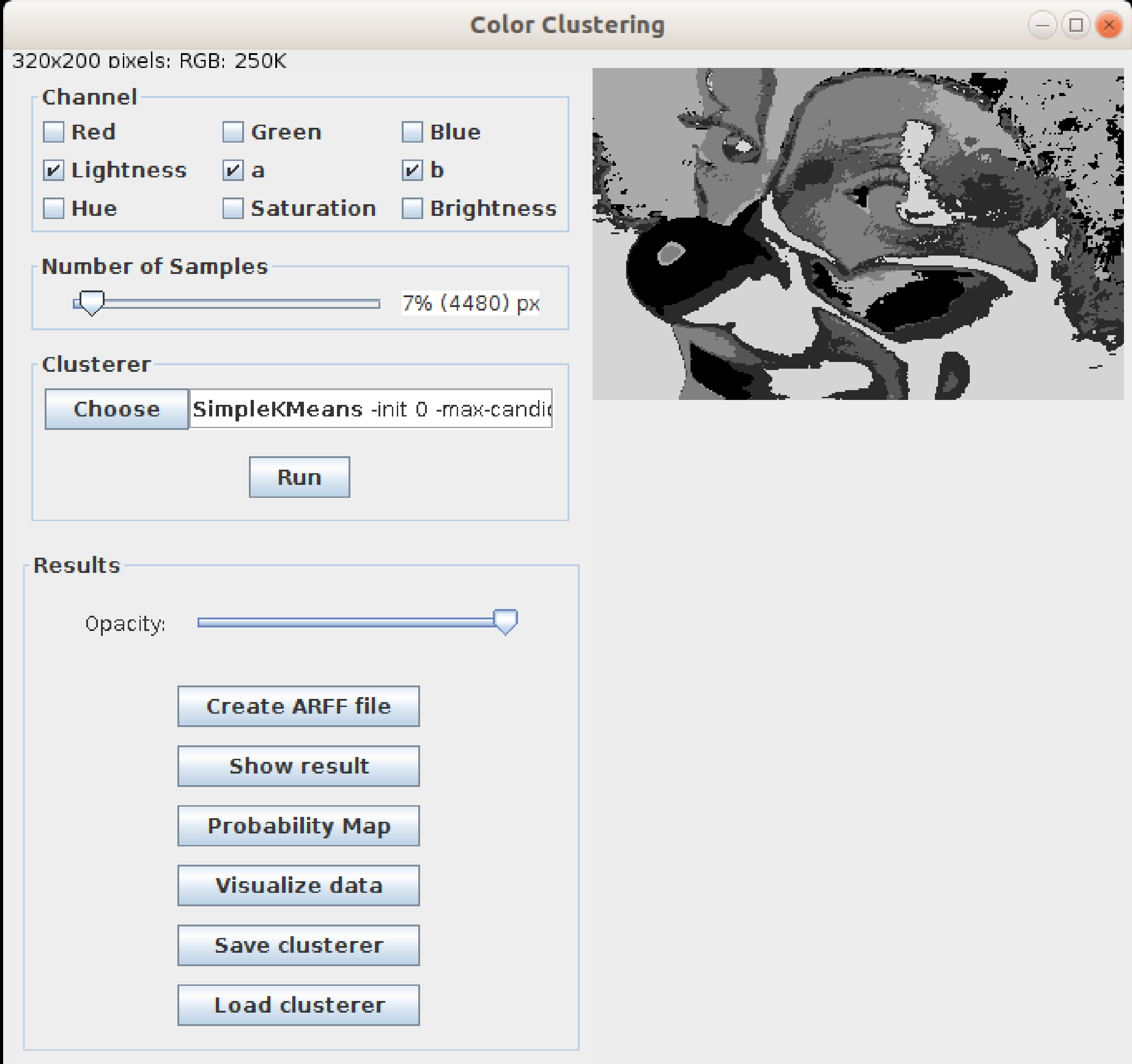
CIEL*a*b* color-space

- CIEL*a*b* color-space
  - L = lightness
  - a = green (-) to red (+)
  - b = yellow (-) to blue (+)
- Designed, so that
  - distances correspond to perceived distances between colors.



Software

- color clustering in FIJI
- comes with WEKA
- Plugins> Segmentation> Color Clustering



Exercises 02