

Skúška

- Nezabudnite odovzdať svoje projekty **do 31.12.2021**
- Posledná domáca úloha **7.1.2022**
- **Písomná skúška:** príklad písomky v priebehu budúceho týždňa
40% známky, na úspešné absolvovanie aspoň polovicu bodov zo skúšky
riadny termín skúšky???
prihlasovanie najneskôr 2 dni pred skúškou
- Môžete si doniesť **t'ahák** – 2 listy A4 popísané čímkoľvek z oboch strán
- Ak bude potrebné robiť písomku on-line, bude nasledovať aj **ústna skúška**
- Opravné termíny – podľa potreby (po dohode s tými, čo to budú potrebovať)
- **Pred uzavretím známky vás môžeme požiadať o ústnu konzultáciu / demo vášho projektu!**

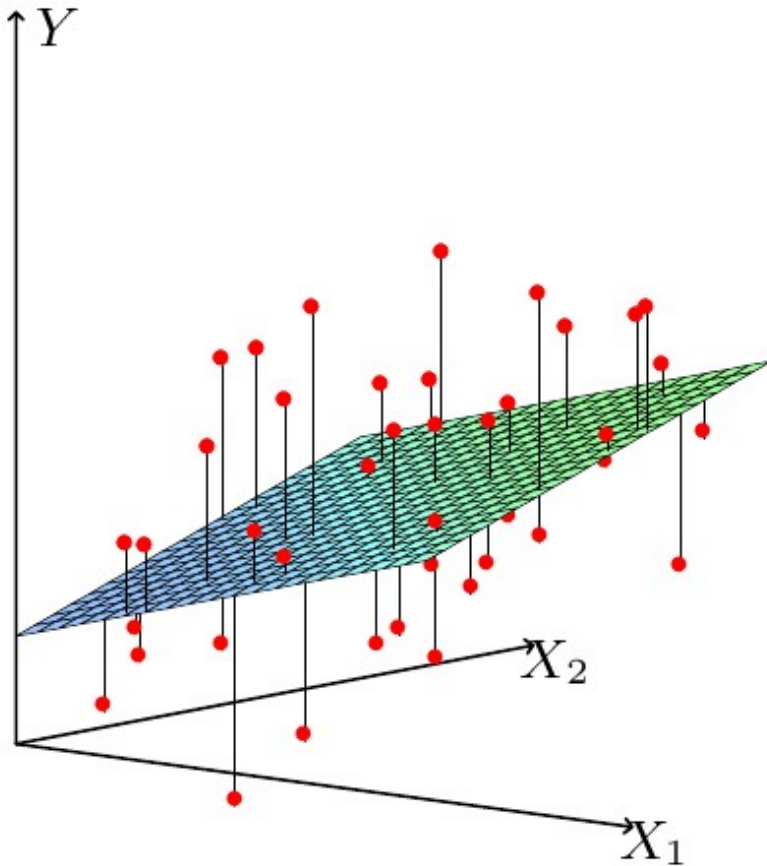


Tento rok
účast
120%!
anketa
[.fmph.uniba.sk](http://fmph.uniba.sk)

Course Summary

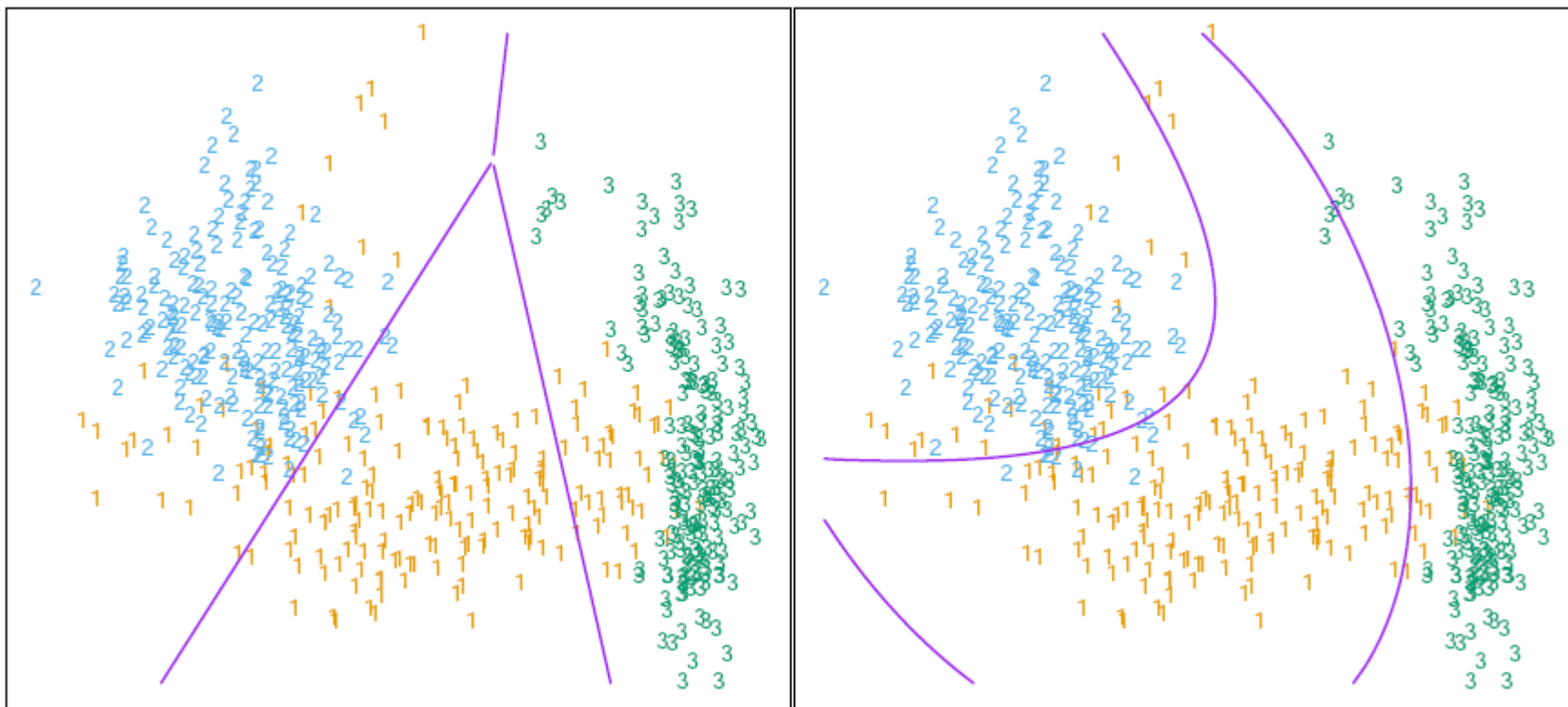
- **Supervised learning**
 - regression, classification
- **Unsupervised learning**
 - clustering, dimensionality reduction
- **Machine learning theory**
 - bias and variance, PAC learning, VC dimension
- **On-line learning and reinforcement learning**

Regression



- Linear regression
- Solving normal equations in $O(n^3)$
- Gradient descent
- Expansion of underlying vector space through non-linear transformation => generalized linear regression

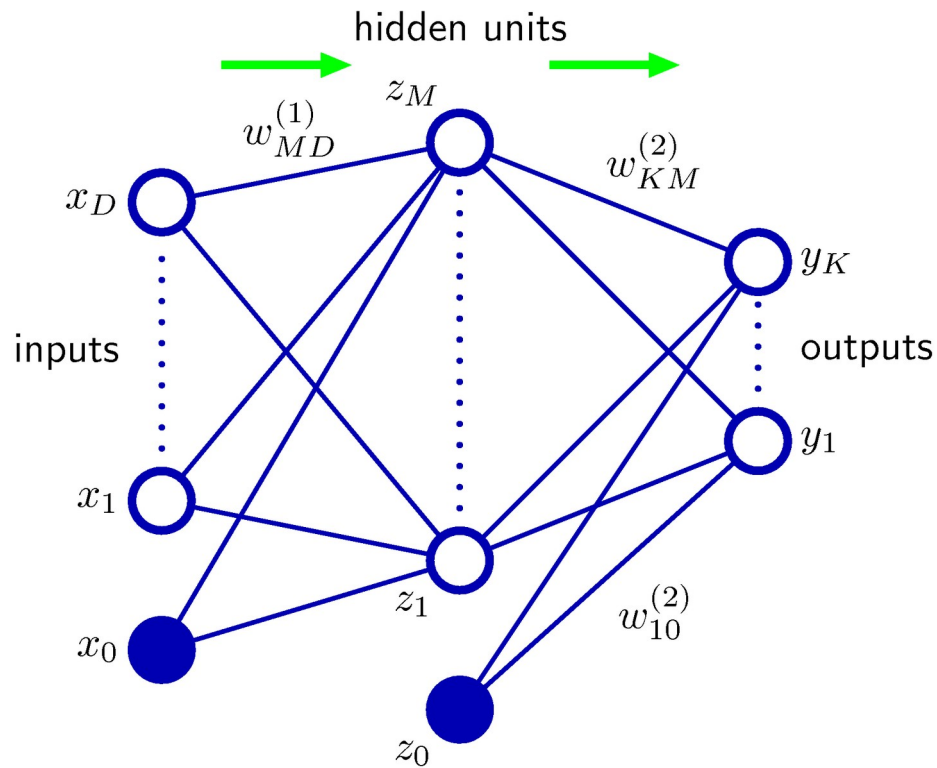
Classification



Linear classification

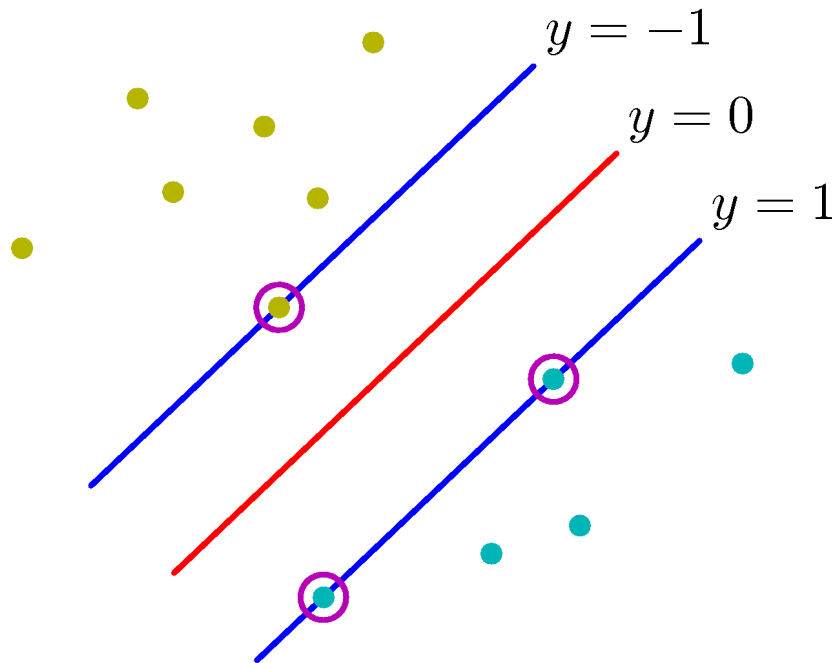
Using non-linear expansions

Neural Networks



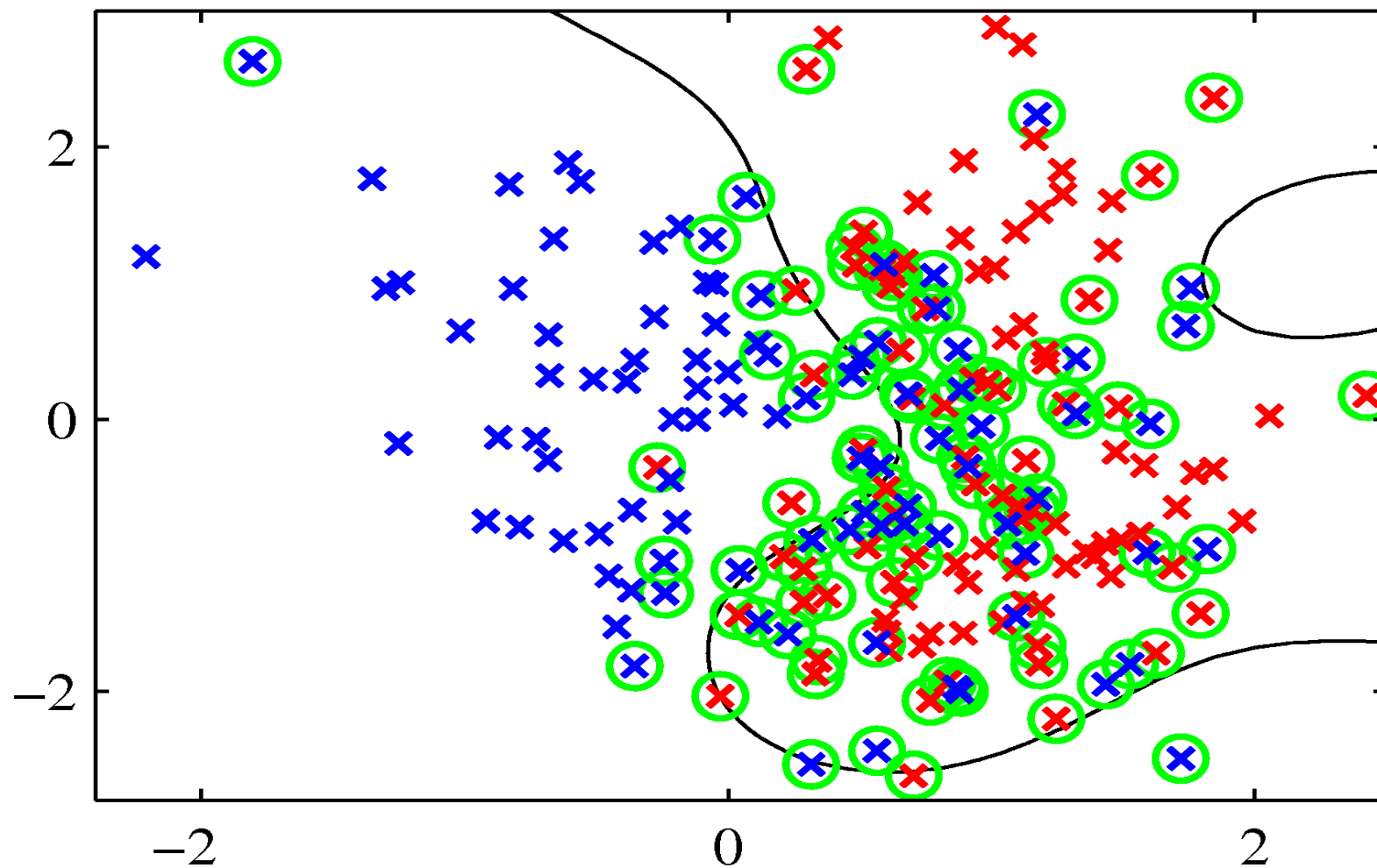
- Each unit (“neuron”) - linear combination followed by non-linear transformation
- Gradient descent (so called “back propagation”)

Support Vector Machines

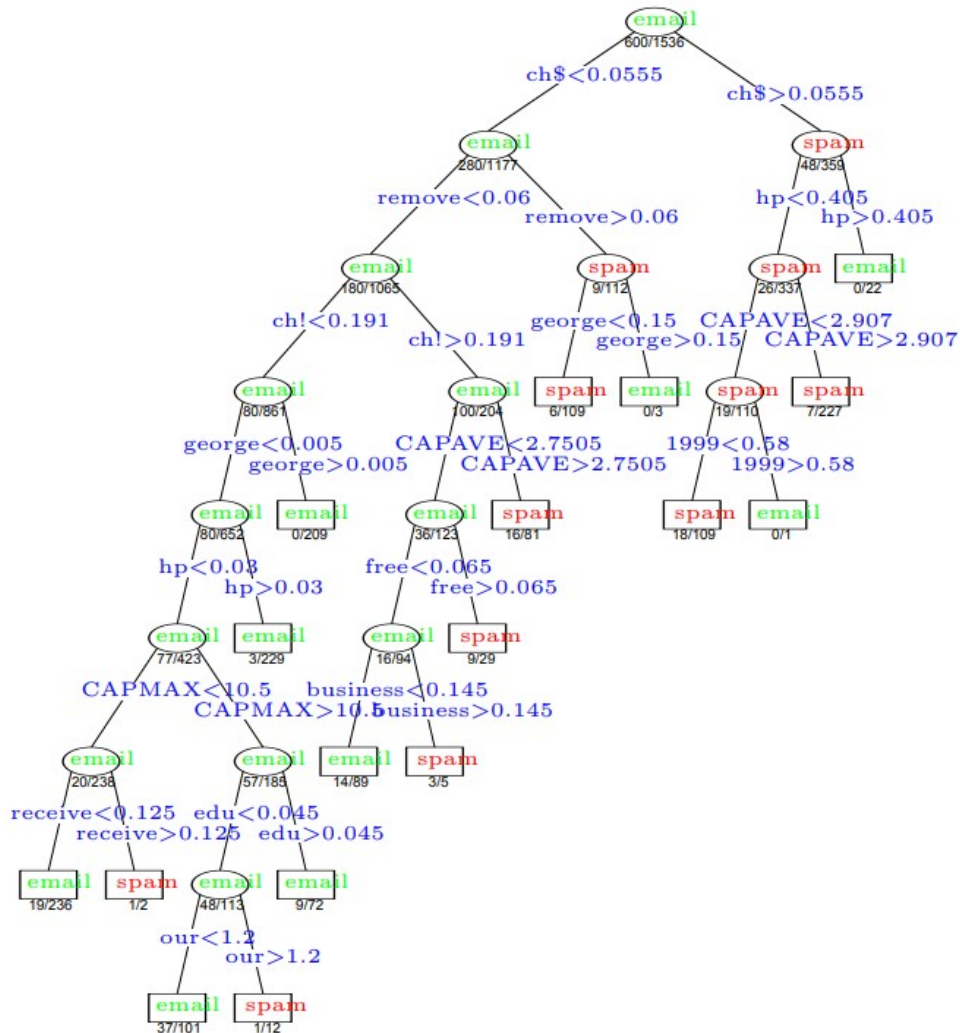


- Linear classifier maximizing margin
- Quadratic programming, dual programs
- Kernel trick: expansion into infinite dimensional vector space
 $K(x,y)$ – dot product in the expanded space
(intuition: similarity measure)

Support Vector Machines

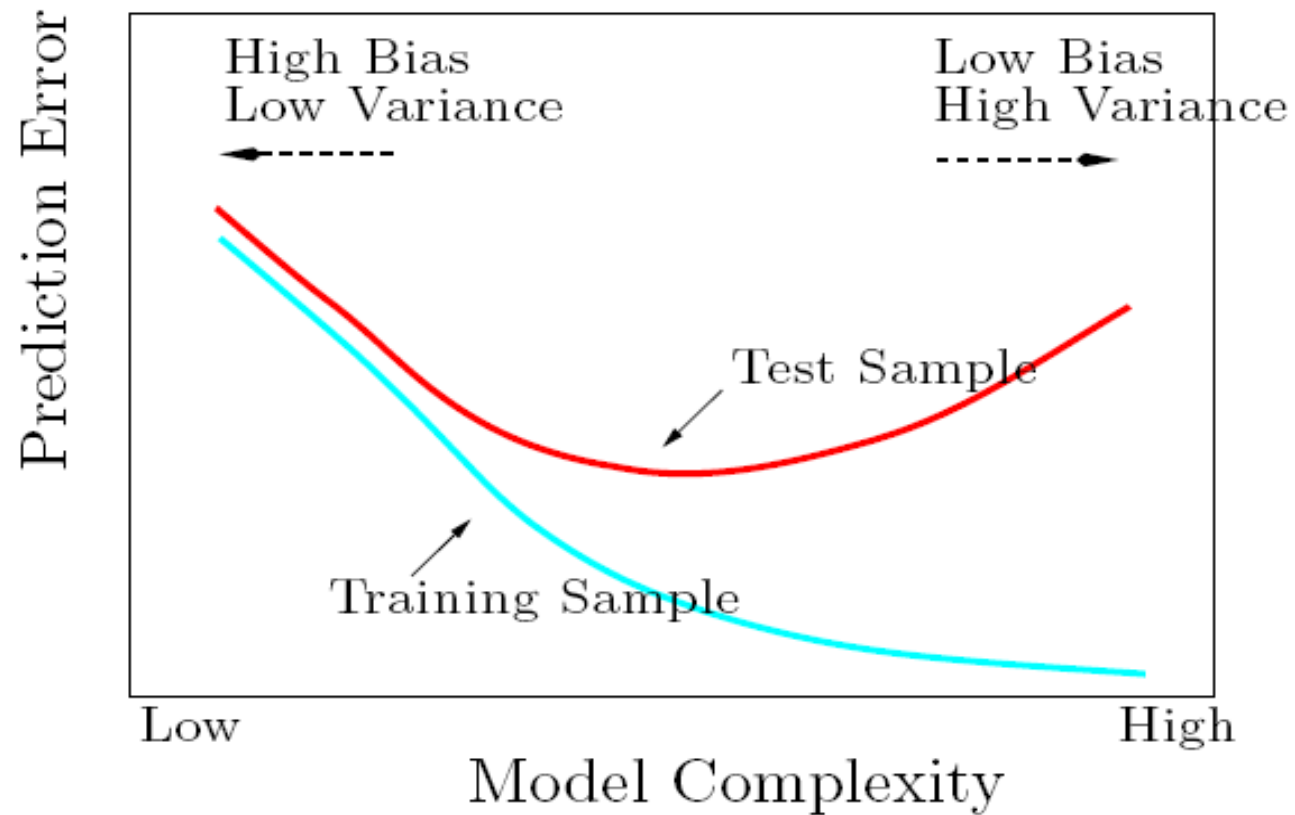


Decision Trees and Random Forests



- ID3 algorithm for building trees (based on entropy measure)
- Stopping criteria
- Bagging – ensemble of complex classifiers
- Boosting – ensemble of simple classifiers

Bias and Variance



PAC Learning

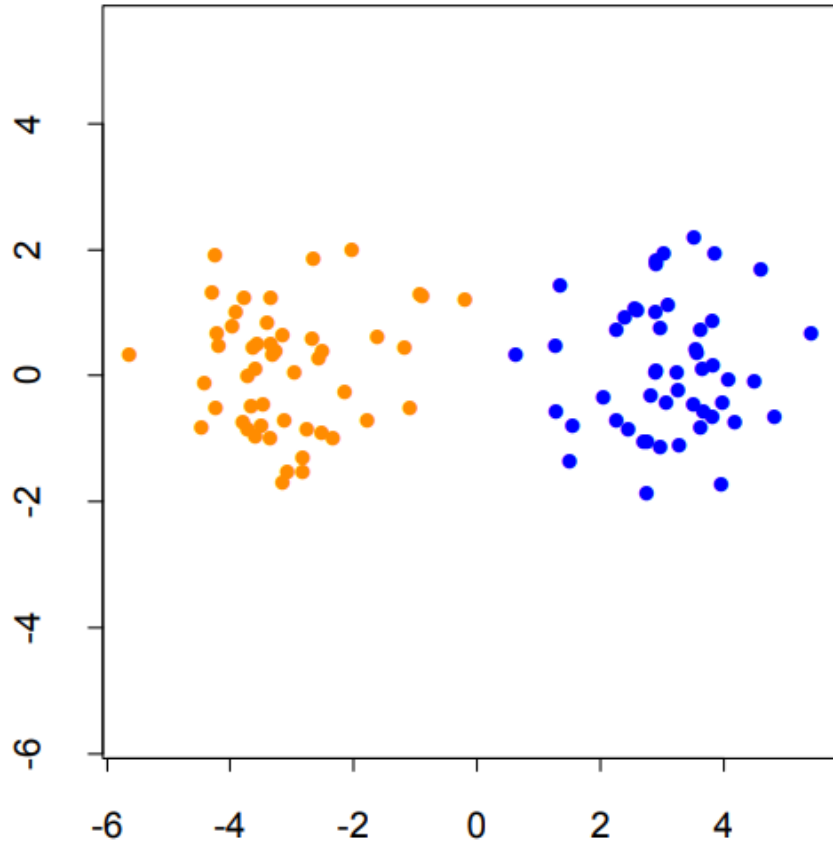
(Probably Approximately Correct)

- How many training data points do we need to train a classifier?
- For large enough t ,
**training and testing error
with high probability ($>1-\delta$)
will not differ much ($<\epsilon$)**
- PAC learning theory provides bounds on t for specific H , ϵ and δ

PAC learning - bounds

- **Finite hypothesis space:**
 $t = O(\log |H|)$
- **Infinite hypothesis space:**
 - Vapnik-Červonenkis (VC) dimension d
(t grow linearly with d)
Neural networks: $d = \Theta(W \cdot \log n)$
(W – # weights, n – # sigmoids)
 - SVM: $t = O(1/r^2 \log^2 1/r)$
(r – margin size)

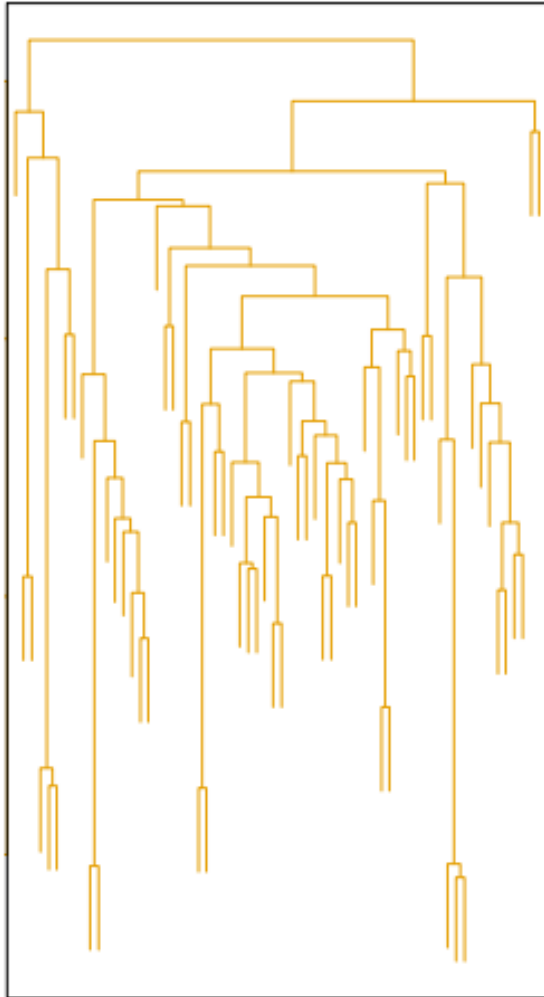
Clustering



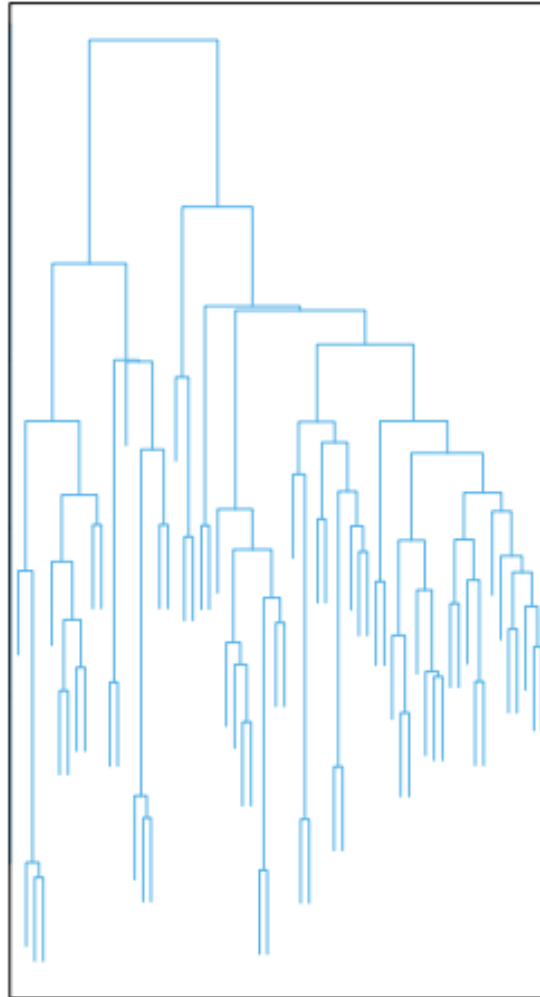
- K-means and k-medoids clustering
- Iterative methods to find a good solution
- Beware: slow!

Hierarchical clustering

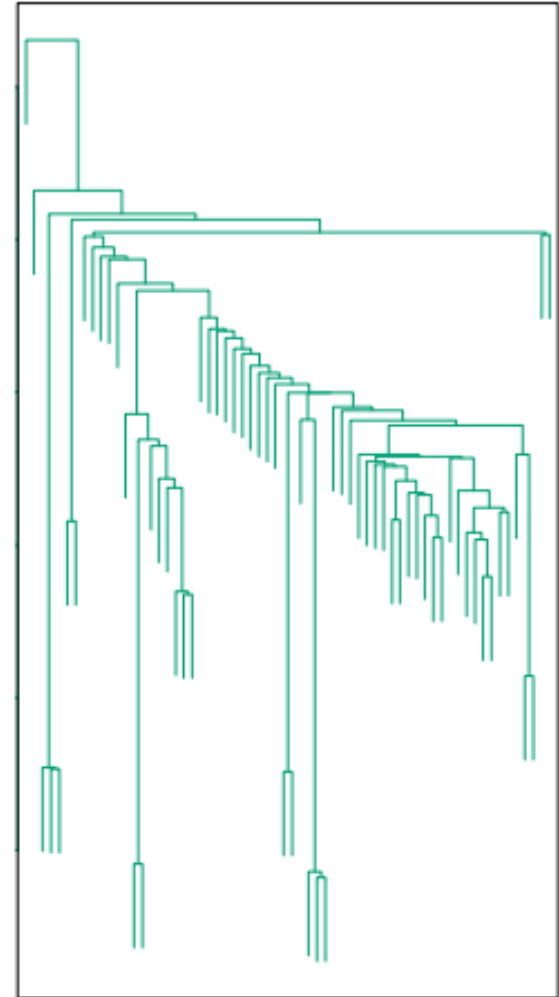
Average Linkage



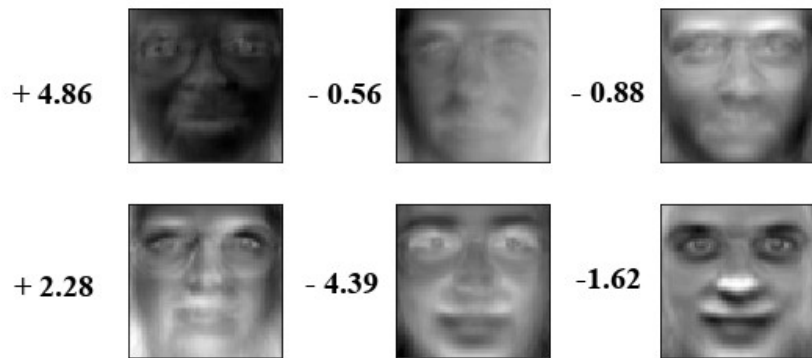
Complete Linkage



Single Linkage



Dimensionality reduction



- Principal Component Analysis (PCA)
- Kernel trick (again)
- Multi-dimensional scaling (i.e. t-SNE)

Mathematical Methods

- Matrix algebra, solving systems of linear equations
- Eigenvectors and eigenvalues
- Partial derivatives, Lagrange multipliers
- Numeral mathematics: Gradient descent
- Optimization: linear and quadratic programming, duality
- Analytical geometry
- Vector spaces

(Ne)súvisiace predmety

Leto 2022:

- 2-INF-188: Moderné techniky ML (Boža)
- 2-AIN-132: Neurónové siete (Farkaš)
- 2-AIN-235: Algoritmy UI v robotike (Petrovič)
- 2-AIN-288: Rozpoznávanie reči (2023)

Zima 2022:

- 1-BIN-301: Metódy v bioinformatike (Vinař, Brejová)
- 2-AIN-268: Neur. siete pre počítačové videnie (Černeková)
- 2-PMS-129: Stochastické optimalizačné metódy (Harman)