Multimedia Systems

Luka Čehovin Zajc

About the lecturer

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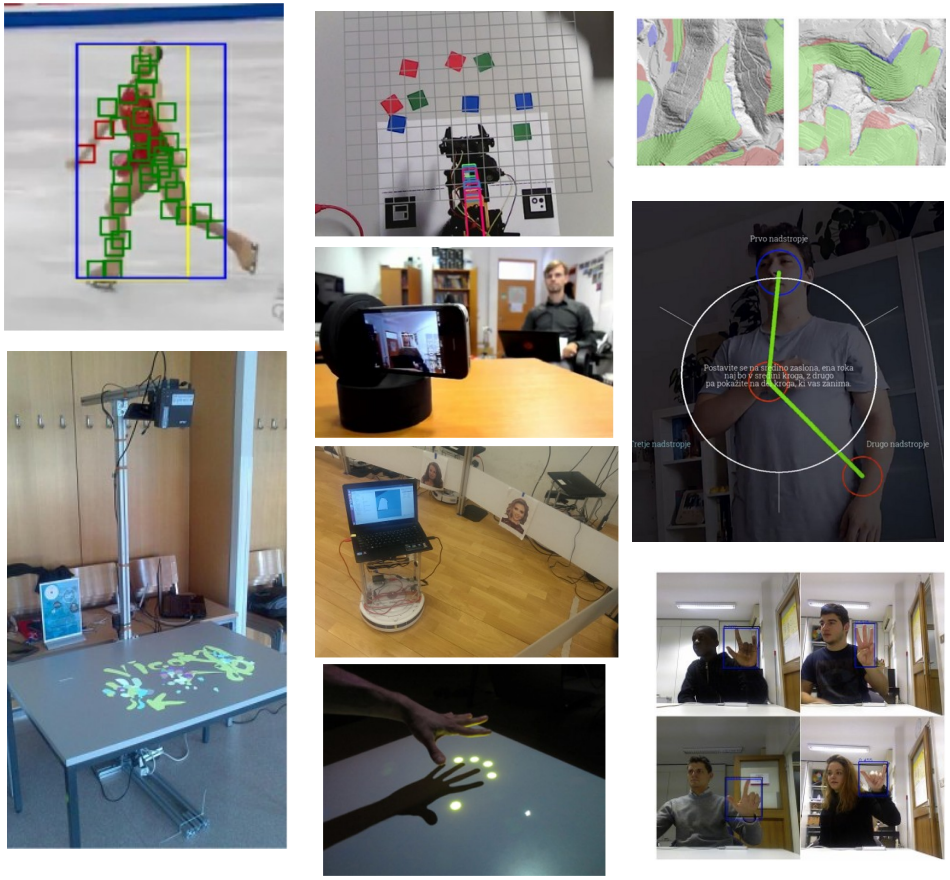


Course requirements

- **Laboratory exercises / project work > 50%**
  - Practical exercises - grading throughout semester
  - Single project – grading at the end of the semester
  - Only valid for the current school year
- **Exam (written + oral) > 50%**
  - Must pass laboratory exercises to attend
  - Theoretical and practical assignments
  - Optional oral exam for borderline students (50% to ~65%)
  - Only oral exam for less than ~10 students

May change due to COVID situation

Laboratory exercises

- Teaching assistant: **Me**
- Practical consolidation of selected topics
- Python (Jupyter, SciKit, NumPy, ...)
  - Hosted Jupyter hub at lab.vicos.si
  - Local installation (virtualenv, Docker)
  - Google Colab
- Each exercise is due in **two weeks** (approximately)
  - **Timely** assignment hand-in encouraged
  - Stick to your designated **laboratory cycles** (for defenses!)

Project assignment

- Alternative to regular laboratory execises
- Indepth project work on a selected topic
  - You have to pace your work yourself
  - Meetings can be arranged to discuss topic
- Work has to be finished by the end of semester
  - Presentation in classroom
  - Demonstration
  - Code hand-in
- Possible projects
  - 3D video stabilization using SfM
  - Content-based image retrieval with sketches
  - Content-based music retrieval in practice
  - Augmented reality without markers
  - Interactive / multitouch surfaces
  - Embedded devices for natural interaction

Write me an email
if you are interested!

multimedia *(Latin)*
multum + medium

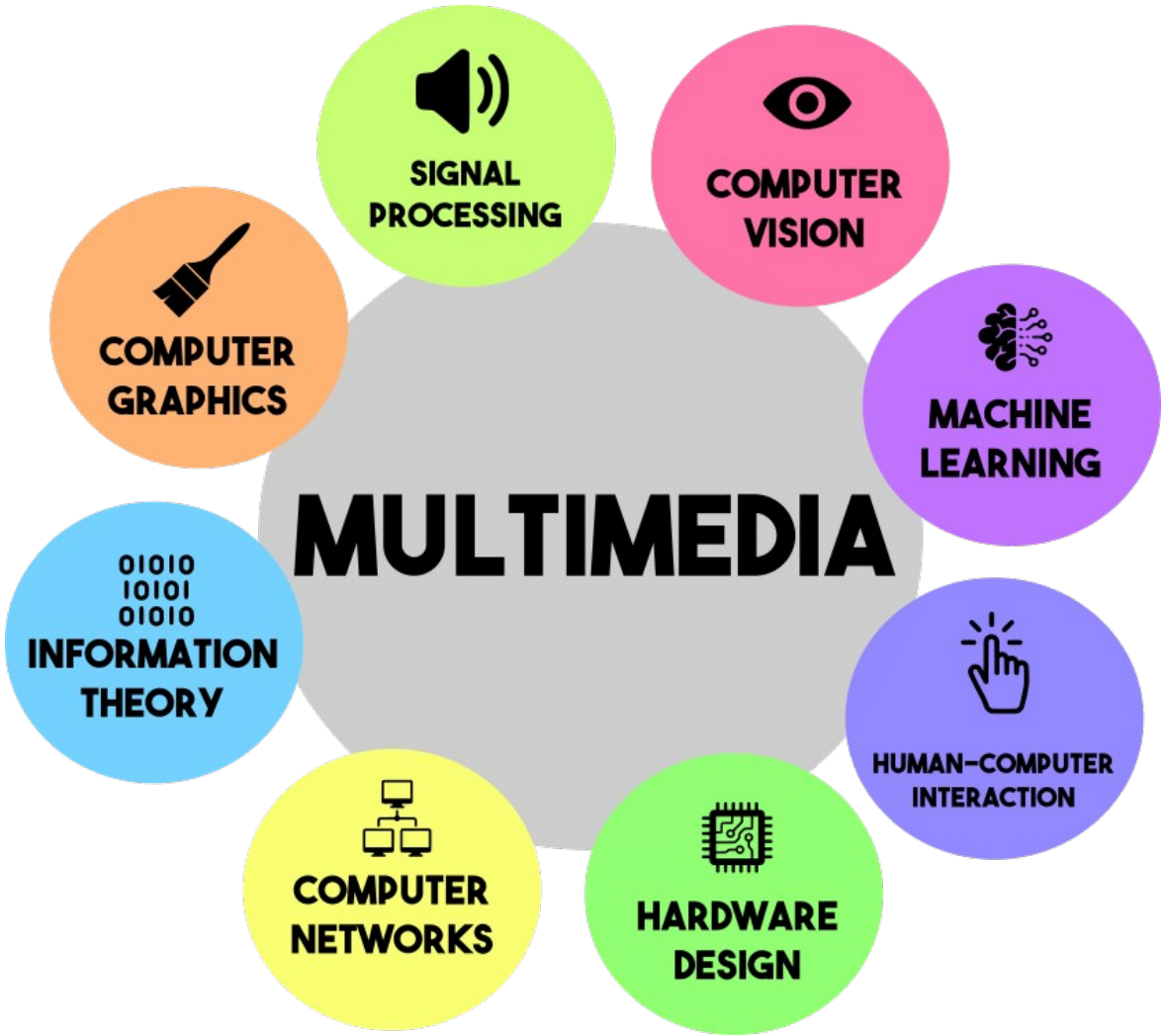
Different meanings

- **Computer salesman**
  PC with GPU, sound-card, Blu-ray player, speakers?
- **Entertainment industry**
  interactive digital TV with Internet connection, video on-demand
- **Computer science researchers / students**
  interactive applications that utilize multiple modalities, text, images, animation, sound, etc.

Convergence

Convergence of domains: graphics, visualization, human-computer interaction, computer vision, data compression, computer networks, machine learning, ... are used together.

Convergence of devices: Computers, video players, game consoles, broadcast TV, Internet, converge into a unified multimedia products.


SIGNAL PROCESSING
COMPUTER VISION
COMPUTER GRAPHICS
MACHINE LEARNING
MULTIMEDIA
01010
10101
01010
INFORMATION THEORY
HUMAN-COMPUTER INTERACTION
COMPUTER NETWORKS
HARDWARE DESIGN

Application domains

- Digital television, video on demand (video + sound)
- Computer games (graphics + sound + interactivity)
- Teleconferences (video + sound)
- Remote lectures (video + sound + slides)
- Telemedicine (video + sound + haptic + manipulation)
- Large databases (e.g. Google, YouTube, Facebook, Amazon, Dropbox)
- Interfaces, augmented reality, virtual reality
- Data visualization (image + sound + interactivity)

Hypermedia

- Ted Nelson (~1965): HyperText
  - Book: linear medium
  - HyperText: non-linear (interactive)
- Hypermedia: not only text
  - Form of multimedia application
  - WWW – type of hypermedia application

Research challenges

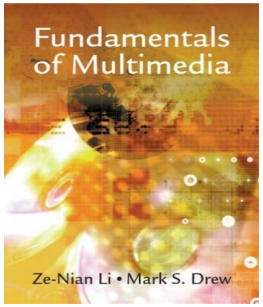
- **Processing and storage**
  Content analysis, information retrieval, compression, security, etc.
- **Tools and applications**
  Hypermedia systems, content manipulation, user interfaces, multi-modal interaction, content production systems, collaboration systems, etc.
- **Support systems**
  Network protocols, quality of service, distribution networks, storage systems, IO devices, etc.

Lectures overview

- Images
- Video
- Sound
- Compression
- Retrieval
- Interactivity

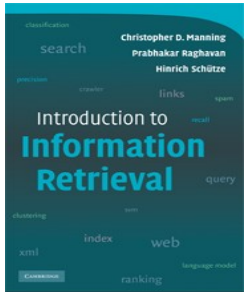
Literature

- Slides + lecture notes available at online Classroom (Učilnica)
- Multimedia overview, general topics



Li Ze-Nian, M. S. Drew,
Fundamentals of Multimedia, 2010.

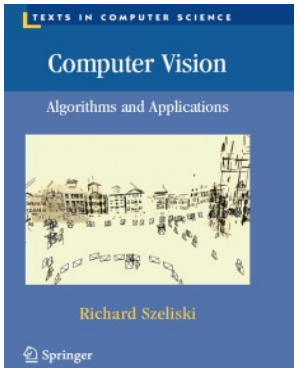
- General information retrieval concepts

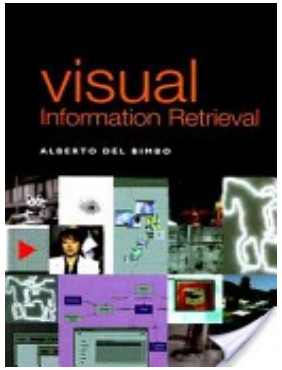


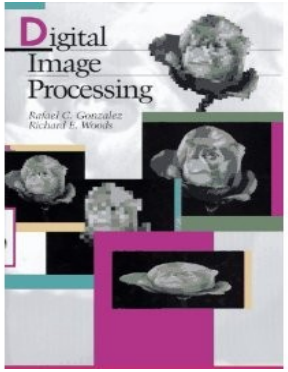
C. D. Manning, P. Raghavan, H. Schütze,
Introduction to Information Retrieval, Cambridge University Press. 2008.

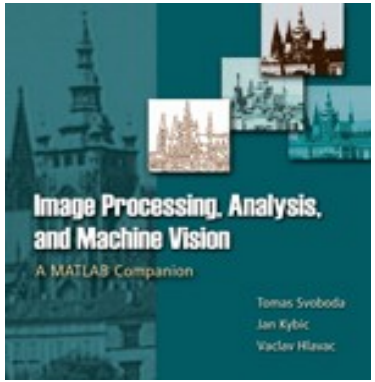
Additional literature

- R. Szeliski: Computer Vision: Algorithms and Applications
- A. del Bimbo: Visual information retrieval
- Gonzalez and Woods: Digital Image Processing
- Sonka, Hlavac, Boyle: Image Processing, Analysis, and Machine Vision
- J. O. Smith III, Introduction to Digital Filters







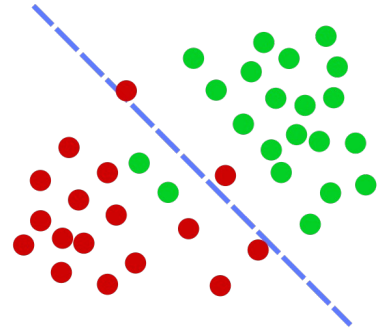


Machine learning for multimedia

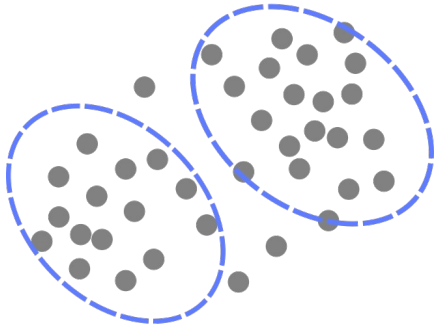
- Machine learning != artificial intelligence
- Function/model approximation
  - Without explicit programming
  - Improve with data

Learning scenarios

- Supervised
  - Known output
  - Optimization of objective function
  - Classification, regression
- Unsupervised
  - No annotations
  - Knowledge (structure) discovery, data mining
  - Clustering, latent variable estimation
- *Reinforcement*



supervised learning



unsupervised learning

Prediction model

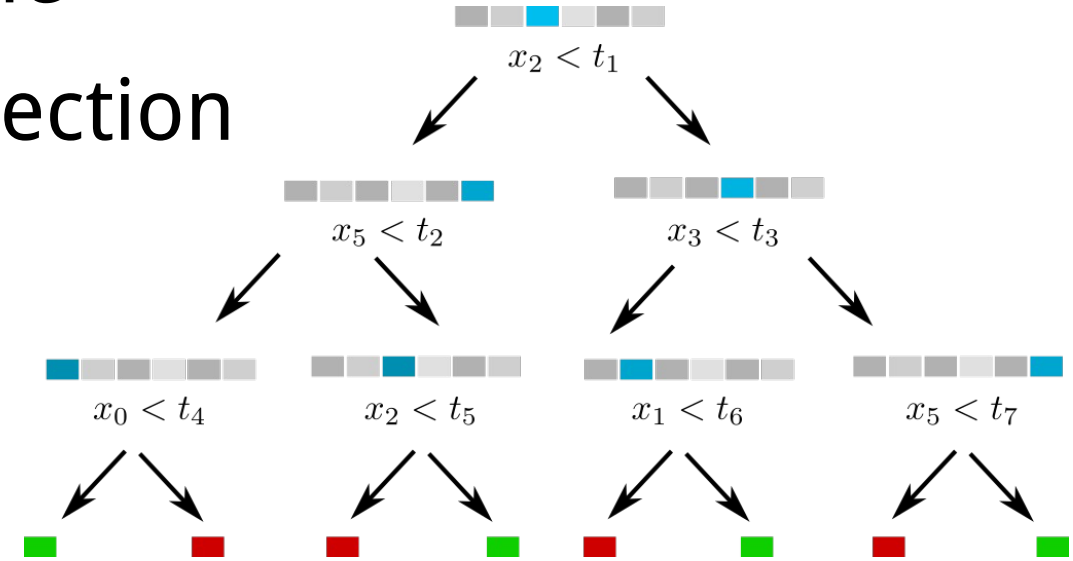
- Input (sample)
  - Vector of attributes
  - Image, soundform, …
- Output (prediction)
  - Class
  - Property

Classification

- Fixed number of classes
  - Binary – yes/no
  - Multi-class
- Use-cases in multimedia
  - Detection (interactivity)
  - Object categorization (retrieval)
  - Tracking

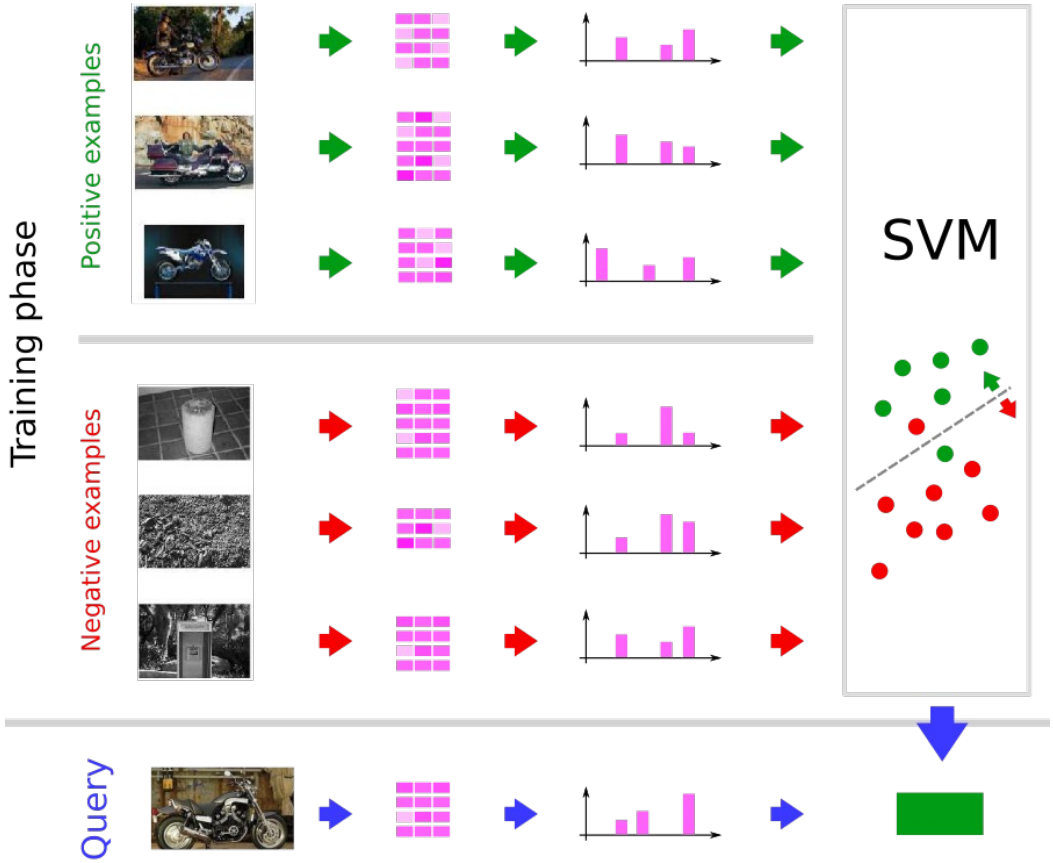
Decision tree

- Inner nodes – test attribute value
- Leaf nodes - outcome
- Greedy attribute selection
- Generalization
  - Boosted trees
  - Random forest



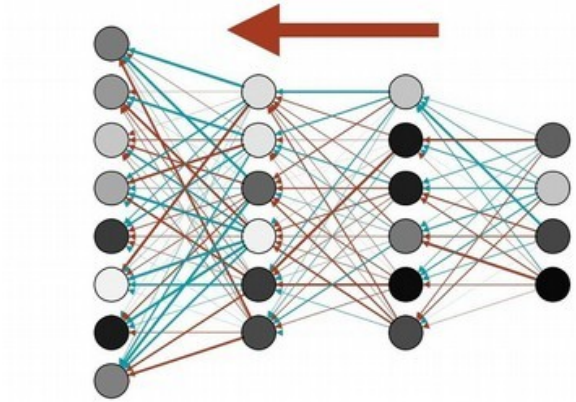
Support vector machine

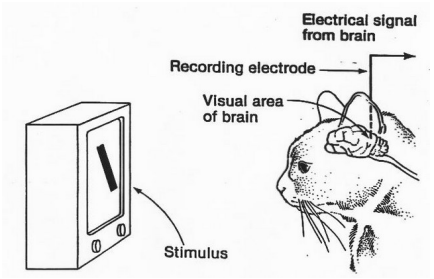
- Supporing samples
  - Close to boundary
- Kernel
  - Space projection
  - RBF

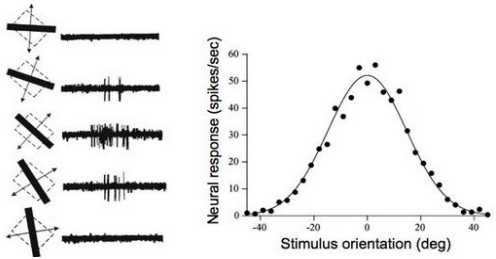


Artificial neural network

- Biological motivation (~1960)
- Character recognition
- High number of parameters





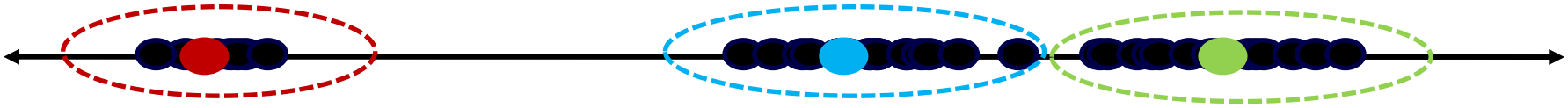


Clustering

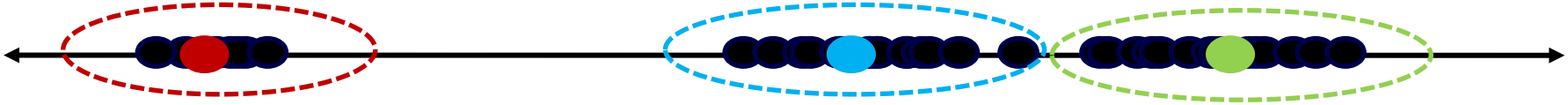
- Input – feature vectors
- Output – cluster assignments (labels)
- Use cases in multimedia
  - Segmentation
  - Visual dictionary formation
  - Efficient searching

Chicken-and-egg problem

- If we know the centers of clusters each point can be assigned to the closest

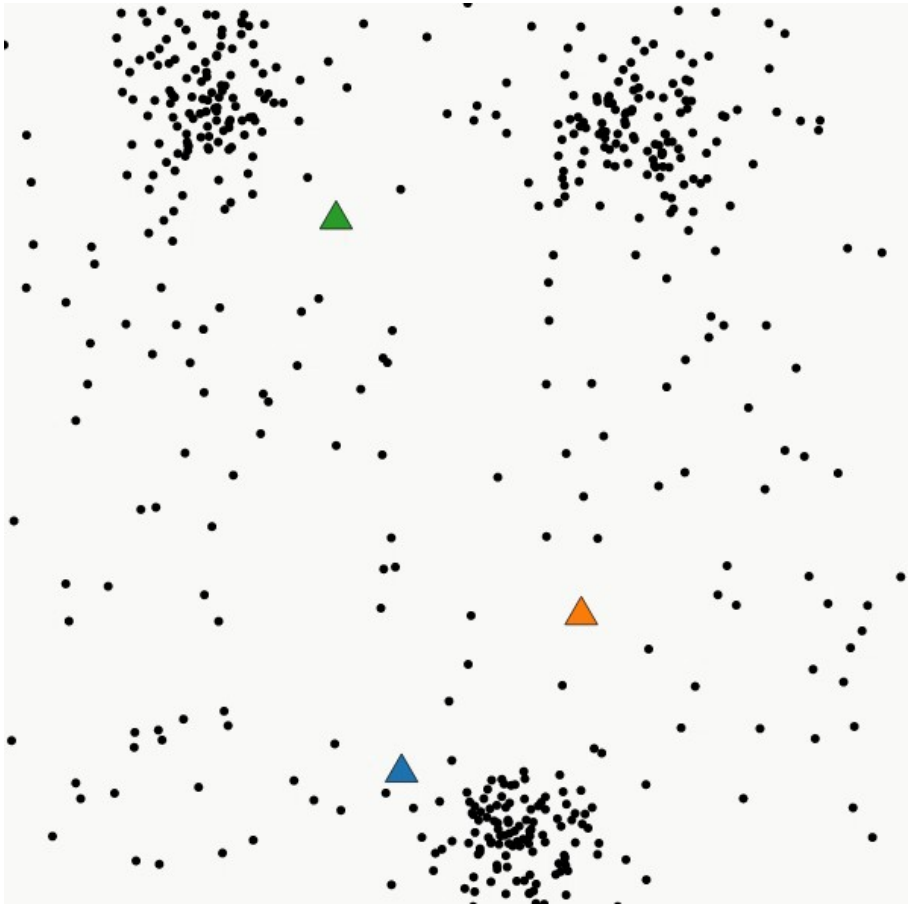


- If we know which points belong together we can calculate centers



K-means clustering

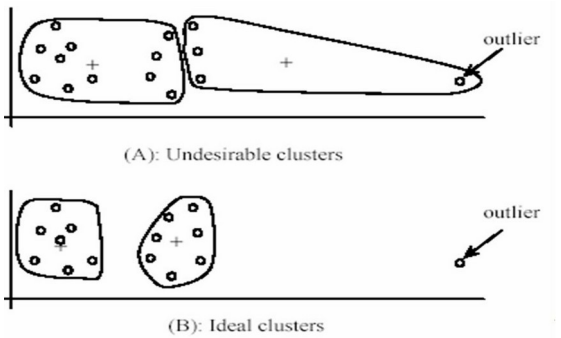
- Fixed number of clusters (K)
- Randomly initialize cluster centers
- Iterate until convergence:
  - For all p: assign p to cluster k if it is the closest
  - Recompute centers as mean of assigned points

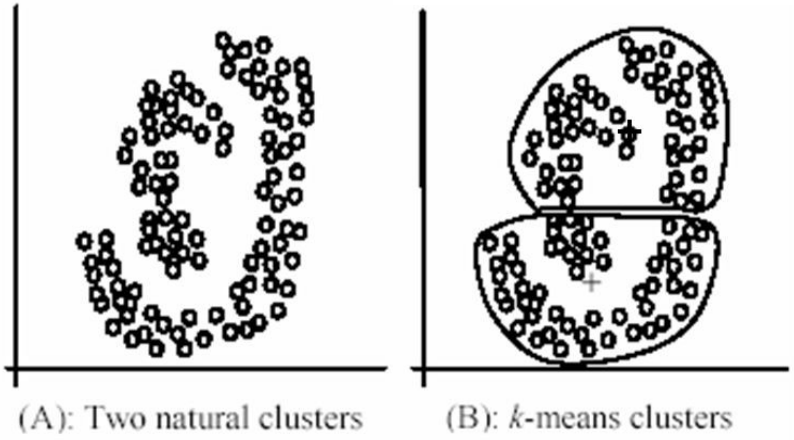


http://stanford.edu/class/ee103/visualizations/kmeans/kmeans.html

K-means properties

- Advantages
  - Fast
  - Convergence ensured (local minimum)
- Weaknesses
  - Manual K selection
  - Sensitive to initial centroids selection
  - Outliers sensitivity
  - Assumes spherical clusters
  - Computing mean values



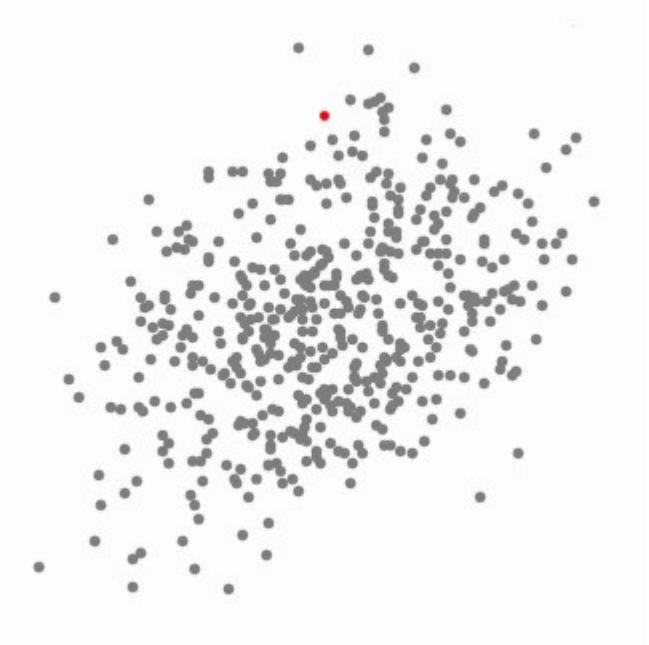


Hierarchical clustering

- Hierarchy of clusters
- Distance metric
- Iterative algorithm
  - Agglomerative
  - Divisive

Mean-shift clustering

- Cluster - points that converge to the same modus
  - Cluster number determined automatically
  - Kernel bandwidth
  - Attraction field – region where all points lead to the same modus
  - Does not scale well to high number of dimensions

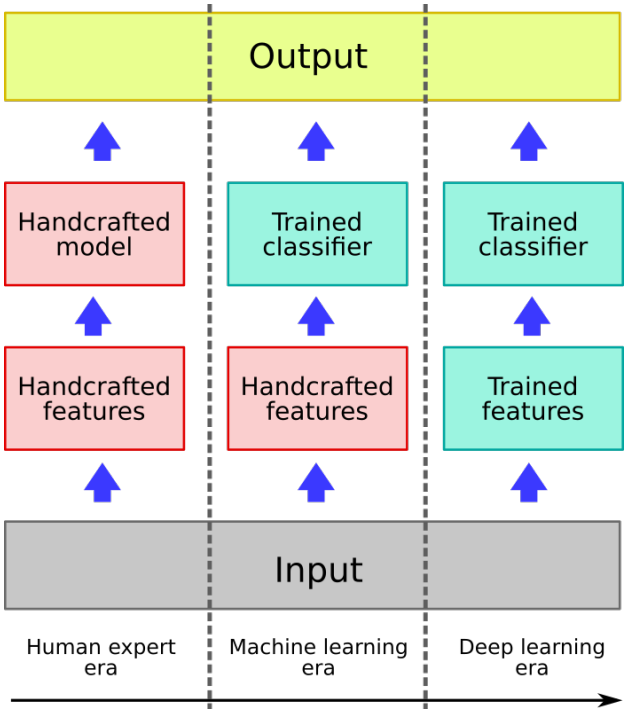


Deep learning

- Large models
  - Neural networks, convolution
  - Many parameters
- Highly non-linear
- Optimization
  - Automatic differentiation
  - Backpropagation of loss function
  - Gradient descent

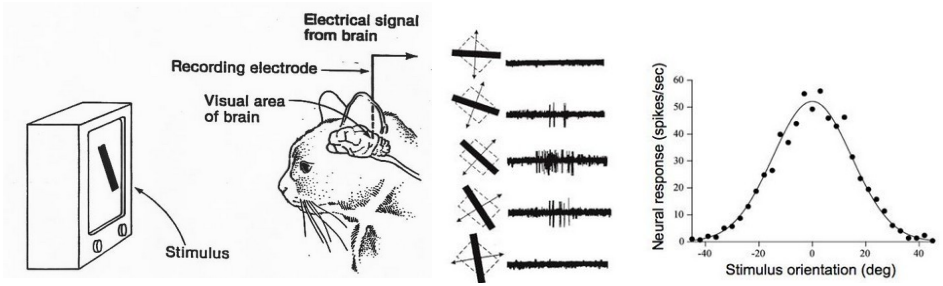
Big data and end-to-end learning

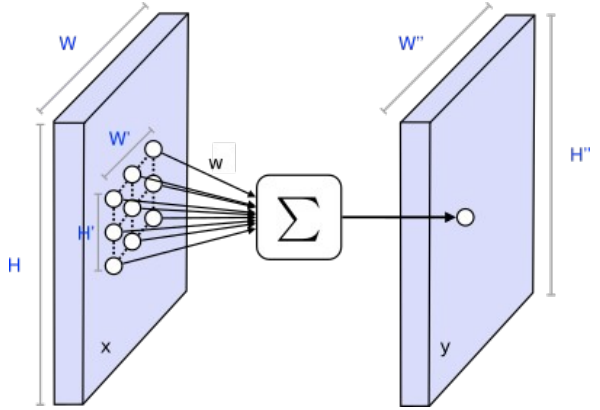
- End-to-end learning
  - Learning features and classifier
  - From pixels to high-level decisions
- Big data
  - More data (Internet, Mechanical Turk)
  - Hardware (storage, GPUs)
  - Learning techniques



Convolutional neural networks

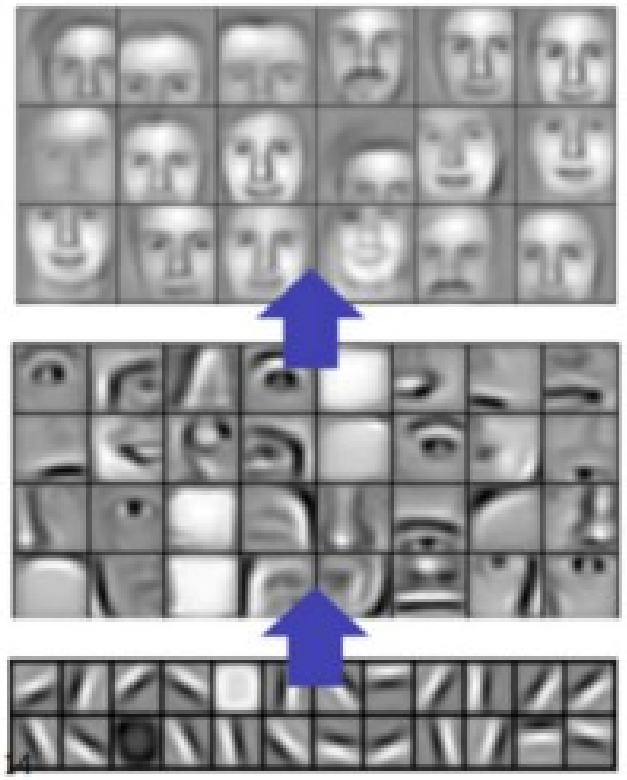
- Neural networks
  - Biological motivation (~1960)
  - Character recognition
  - High number of parameters
- Convolution
  - Receptive field
  - Same operation on entire image
  - Reduced number of parameters





Hierarchy of filters

- Training
  - Back-propagation
  - Gradient descent
- Layers
  - Convolutional
  - Fully-connected
  - Max-pooling
  - Soft-max



High level features
Objects

Object parts
Circles, squares, ...

Low-level features
Edges, corners