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Introduction to Machine Learning

AI and Big Data

Simulate human intelligence in reasoning, learning, preception

Artificial Intelligence

- Symbolic
  - Rule based/expert systems
- Sub-symbolic
  - Machine Learning
    - Deep Learning

Big Data → Sub-symbolic

Volume, velocity variety

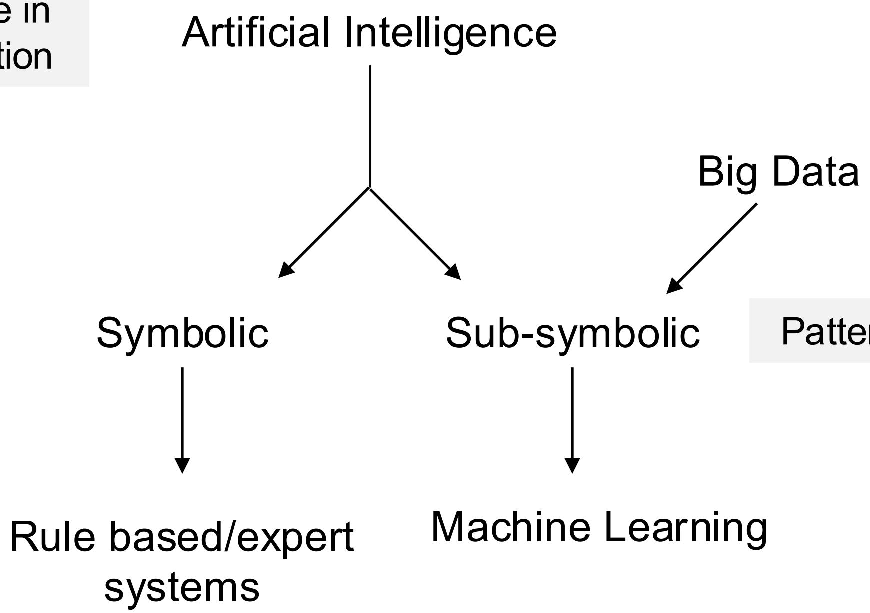
Information is represented in human-readable form

Pattern recognition from data

Neural networks with multiple layers

AI and Big Data

Simulate human intelligence in reasoning, learning, preception



Volume, velocity variety

Information is represented in human-readable form

Pattern recognition from data

„Machine learning is a field of study that gives computers the ability to learn without being explicitly programmed.“ (Arthur Samuel, 1959)

AI and Big Data

Simulate human intelligence in reasoning, learning, preception

Artificial Intelligence

Big Data

Volume, velocity variety

Information is represented in human-readable form

Symbolic

Sub-symbolic

Pattern recognition from data

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Machine Learning

Deep Learning

Neural networks with multiple layers

What is machine learning used for?

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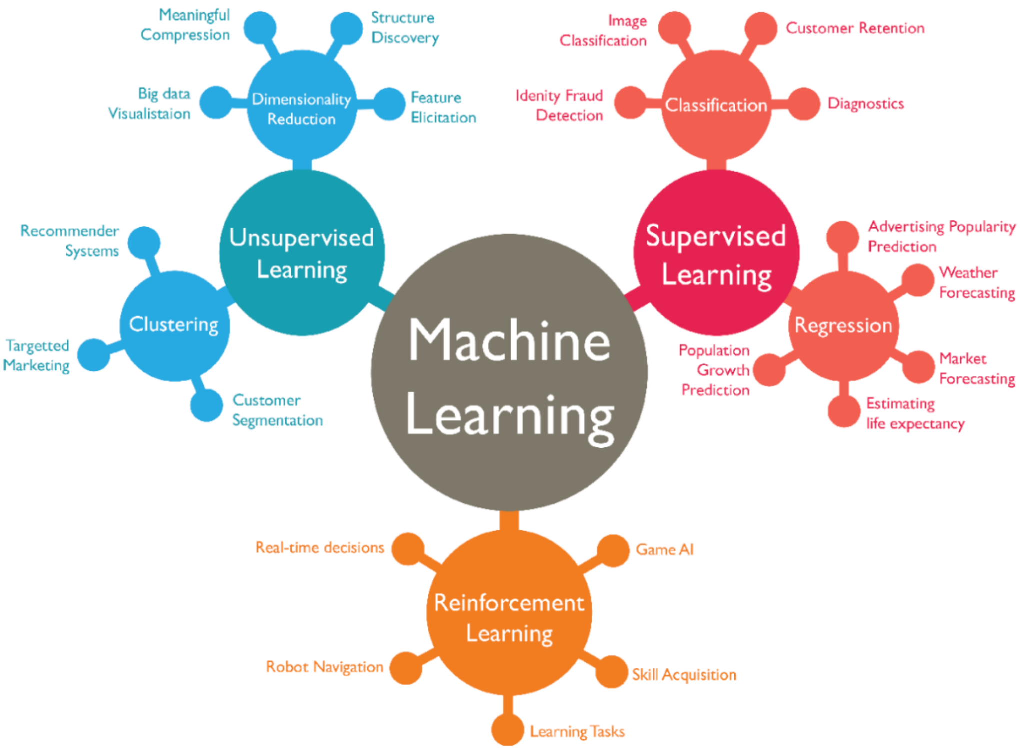
The computational methods in Machine learning
are used to discover patterns in the data and/or derive a corresponding generating process to

1) gain insights
2) predict events

In order to

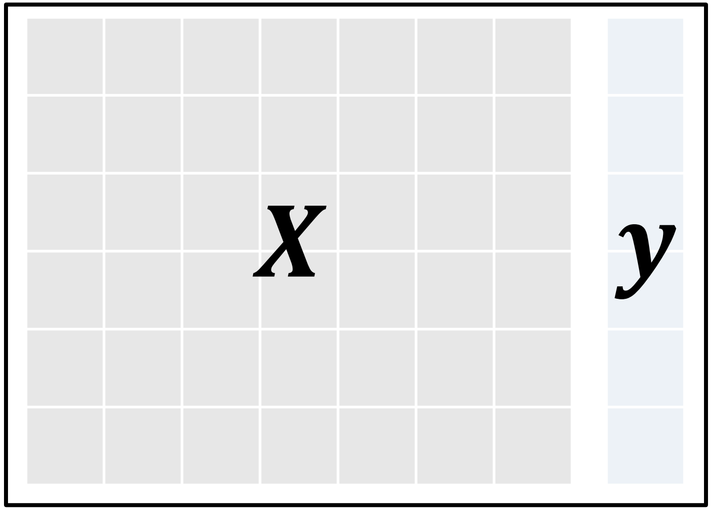
- provide a quantitative basis for decisions (actionable insights)
  e.g. determine target segment for marketing campagne
- influence the underlying process of the data
  e.g. adapt the user features of an app

Machine learning paradigms



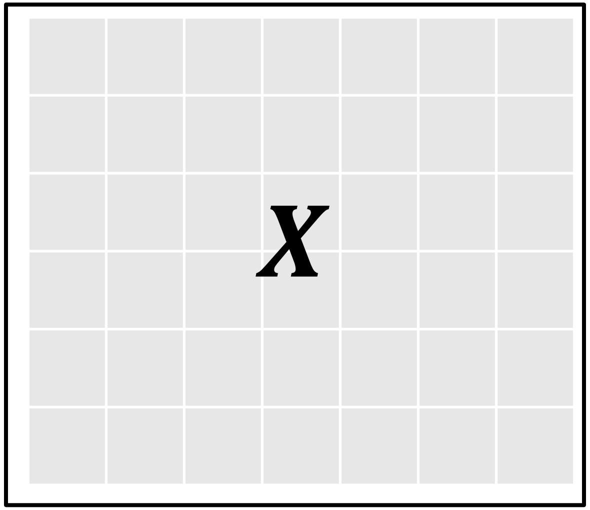
Supervised vs. unsupervised learning

Supervised learning



The training data consists of input samples $\mathbf{x}_{m,:}$ and their associated output values y_m

Unsupervised learning



The training data does not contain any output values

M: Number of training samples

N: Number of features

Dimension X: $M \times N$

Dimensions y: M

Supervised Learning

Goal: Derive a model that is able to accurately predict output values from new input values

Pre-requisite: Training data - labeled samples (input features + output values)

Approach: find a function f, which systematically produces the output values y_m associated with the input values $\mathbf{x}_{m,:}$ from the training data:

$$f\left(\mathbf{x}_{m,:}; \boldsymbol{\theta}\right) \rightarrow y_m$$

Process: Algorithm adapts parameters $\boldsymbol{\theta}$ of function f to predict the correct outputs for the known training samples.

$\longrightarrow$ Use f to make predictions on new data (unseen during training)

Model and Learning

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A **model** is a mathematical, statistical, or logical representation that describes the relationship between variables and can be used to make predictions or understand patterns in data.

Learning: Machine Learning employs adaptive models, which are configured and parametrised automatically based on the training data.

AI in Action

https://youtu.be/FnigvS_ul1w?feature=shared

Teachable Machine

The data: https://tinyurl.com/mvvhj2n5

The machine: https://teachablemachine.withgoogle.com

Structure of teaching the Teachable Machine

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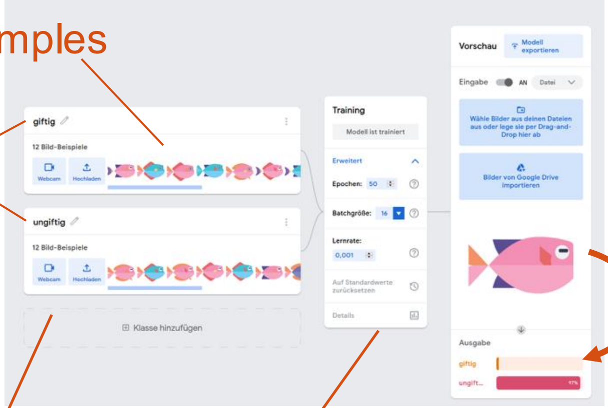
Samples

Target values

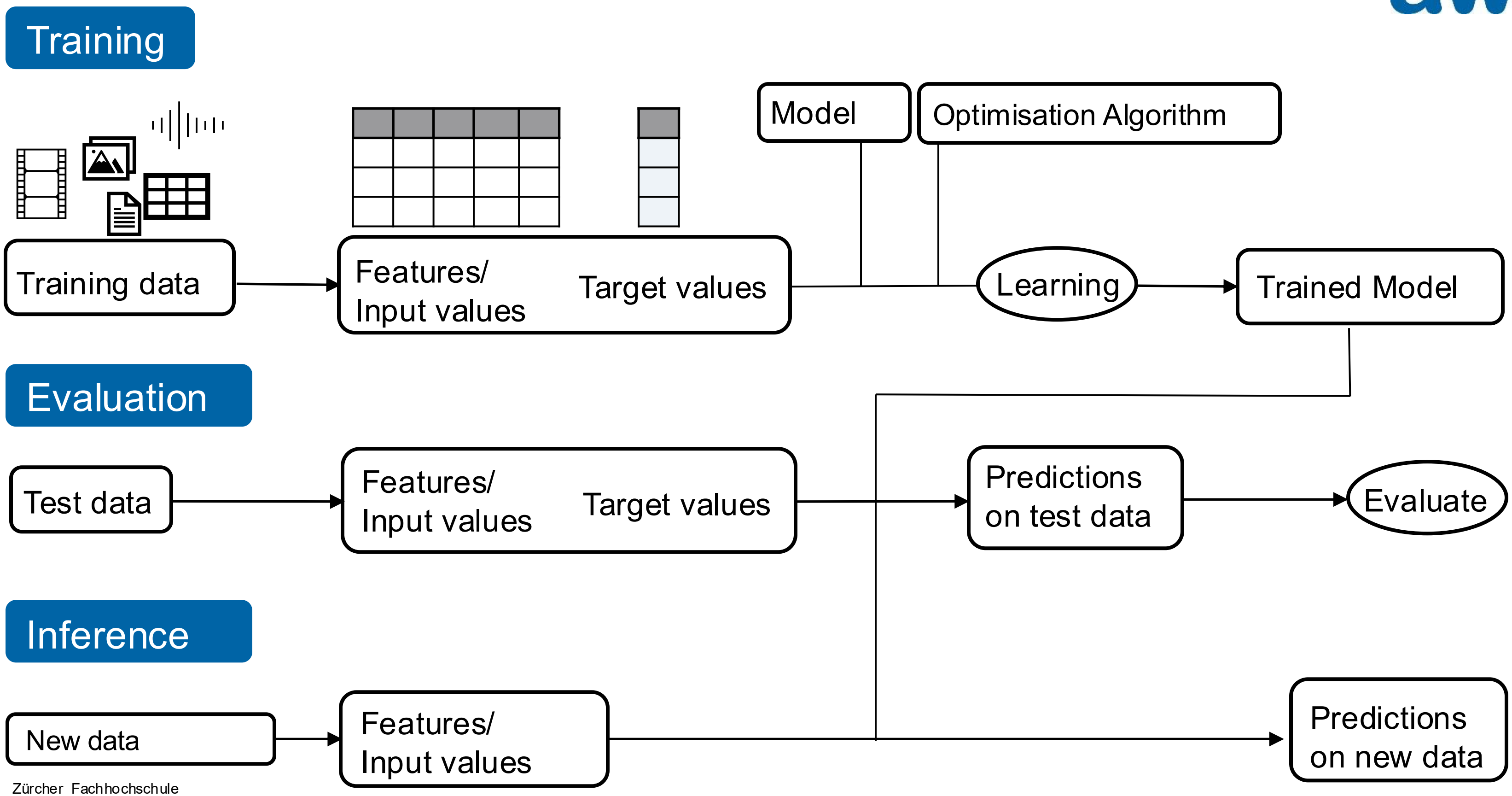


Test data

Predictions on new data

Provide training data → Training → Evaluation → Inference

Structure of a supervised learning problem



Classification vs. Regression

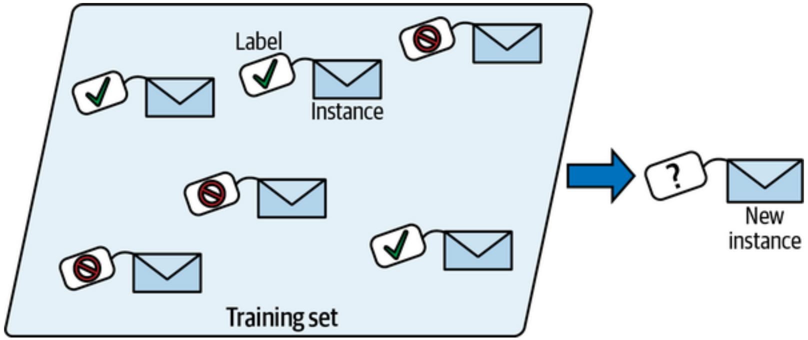
In supervised learning we try to find a function f, which systematically produces the output values y_m associated with the input values $\mathbf{x}_{m,:}$:

$$f(\mathbf{x}_{m,:}) \rightarrow y_m$$

Classification

Target variable y: categorical

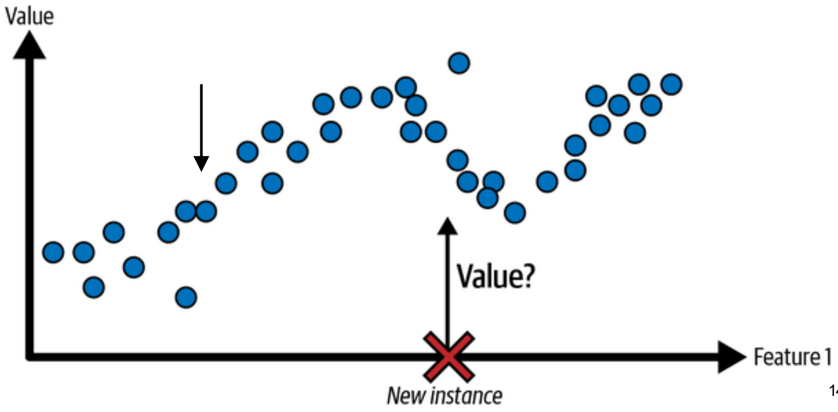
$$y_m \in \{C_1, C_2, \dots, C_K\}$$



Regression

Target variable y: numerical - continuous

$$y_m \in \mathbb{R}$$



Terminology

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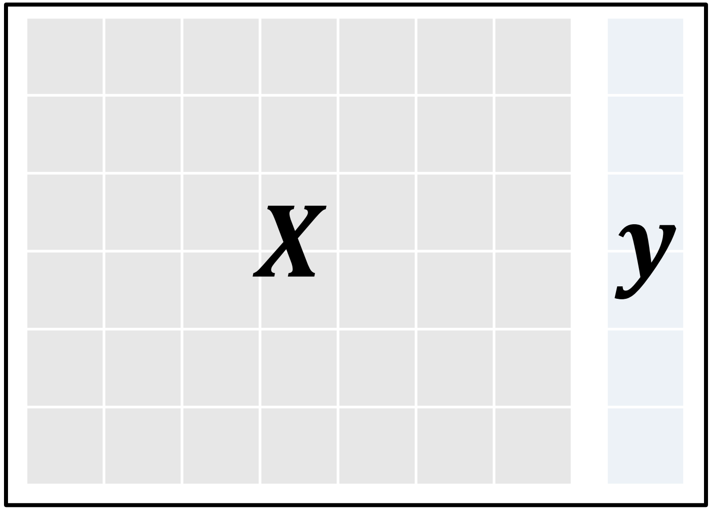
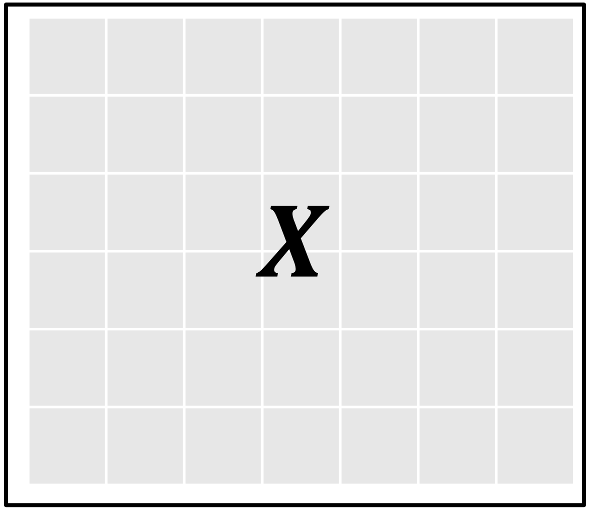
Input data: X
Output data: y
Sample: one row in X (and y)
Covariates = predictors = independent variables = features =attributes: columns of X
Dependent variable, target variable, outputs, labels: y

Supervised vs. unsupervised learning

Supervised learning	Unsupervised learning
	
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Dimension X: $M \times N$

Dimensions y: M

Unsupervised learning

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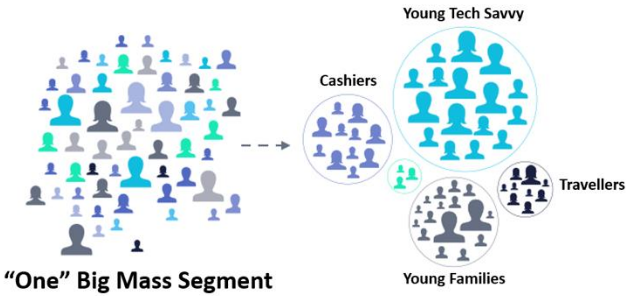
In unsupervised learning the goal is to model the underlying distribution without labels in the training data.

Tasks:

- Dimensionality reduction
- Clustering
- Anomaly detection



Challenges:

- Problem is often less clearly defined as in supervised learning
- Evaluation is difficult without labelled test data

Dimensionality reduction

Goal: Transforming the data into an optimal lower dimensional representation
- for visualisation (normally 2D, sometimes 3D) of the data
- to generate more informative features for supervised learning

Some methods for dimensionality reduction:
- **Principal Component Analysis - PCA**
- *t*-disributed Stochastic Neighbour Embedding (**t-SNE**)

Dimensionality reduction on the Iris dataset

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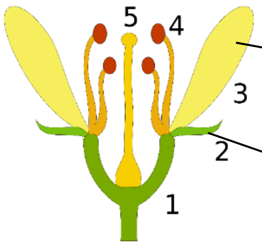
The dataset consists of measurements on 150 Iris flowers from 3 species



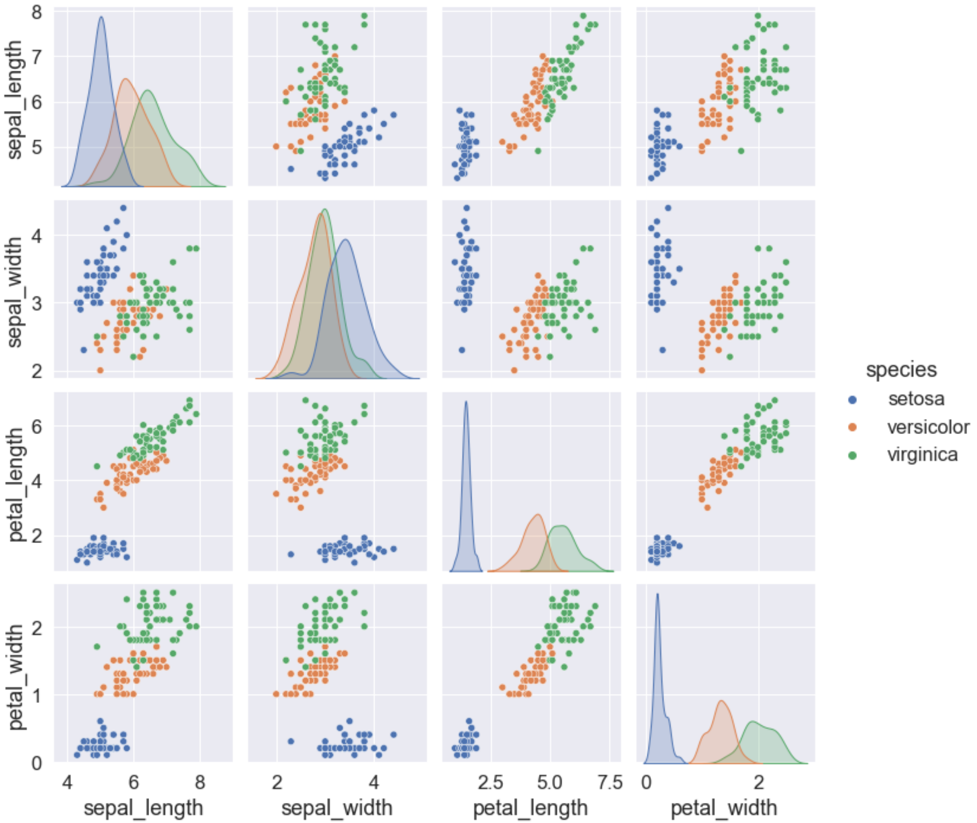
with **4 Features**: → Visualisation in 4 dimensions difficult

- petal width (Kronblatt Breite)
- petal length (Kronblatt Länge)
- sepal width (Kelchblatt Breite)
- sepal length (Kelchblatt Länge

(https://de.wikipedia.org/wiki/Kronblatt)

sepal_length	sepal_width	petal_length	petal_width	class
5	3.3	1.4	0.2	Iris-setosa
…				
5.7	2.8	4.1	1.3	Iris-versicolor
…				
6.3	3.3	6	2.5	Iris-virginica
…				

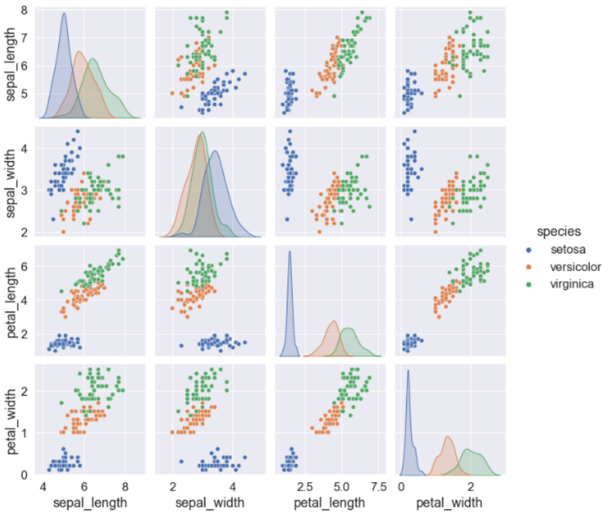
Iris dataset: Visualisations of the four features



Dimensionality reduction on the Iris dataset

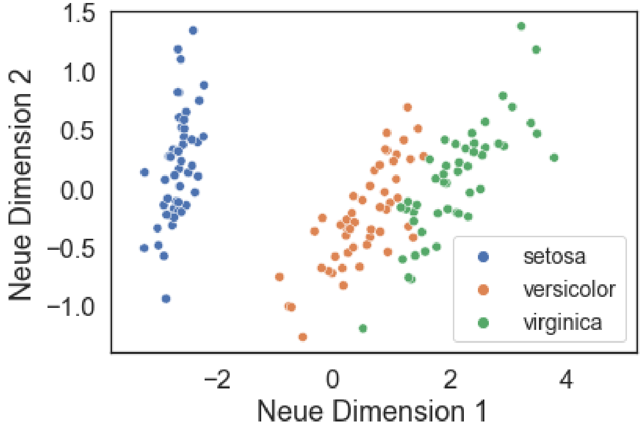
4 Dimensions:

Visualisation difficult



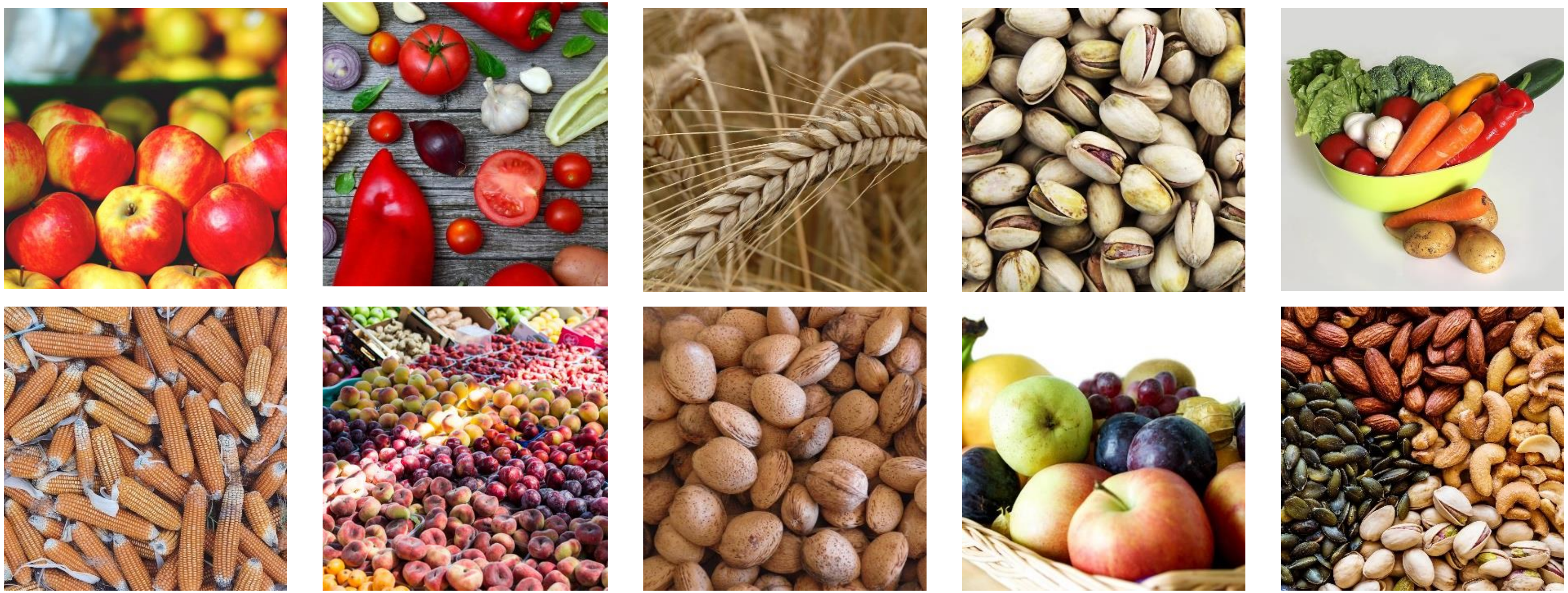
Dimensionality reduction

2 new dimensions, that contain the «most information»:



Clustering

Goal: **Identify subgroups** of datapoints that are more similar to each other than to the elements in other subgroups.



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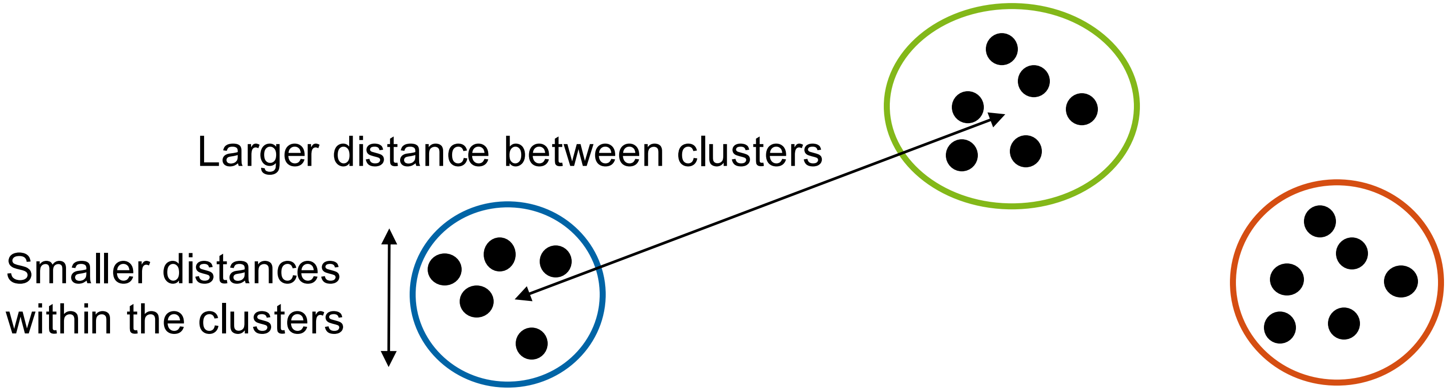

→ Needs metric to quantify similarities.

Unsupervised machine learning

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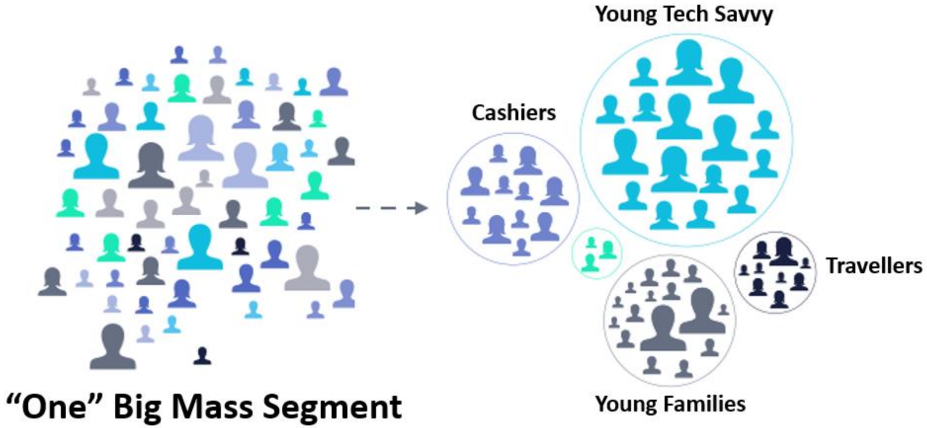
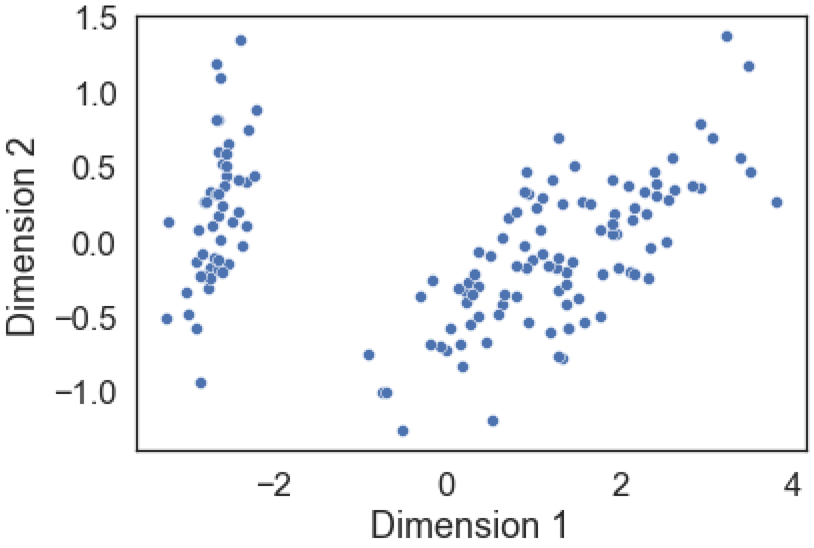
Example: Clustering is the task of ***grouping a set of objects*** in such a way that objects in the same group (called a cluster) are more similar (in some sense) to each other than to those in other groups (clusters)



Source: https://www.smartera3s.com/products/customer-segmentation/

Example in 2D

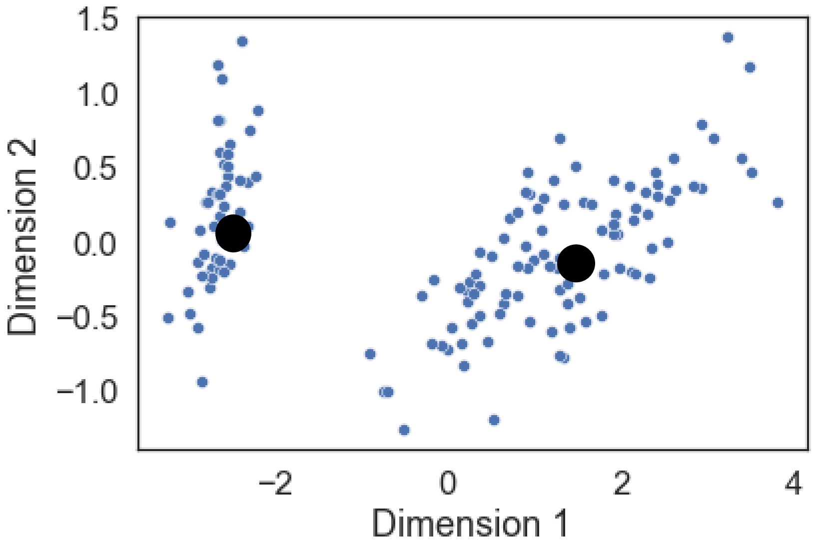


K-Means: A simple clustering method

Hyperparameter ***k***: number of clusters to determine

Means: The centroids of the clusters

Assumption: **spherical distribution** within clusters



Iterative algorithm – until stopping criterium is statisfied:

1. Random **Initialisation** of the *Means*
2. **Each datapoint is assigned** to closest *Mean*.
3. **Recalculate the *Means*** from the newly assigned datapoints.
4. **Repeat steps 2 and 3** until *Means* do not change anymore.

K-Means on 2D Example-Dataset

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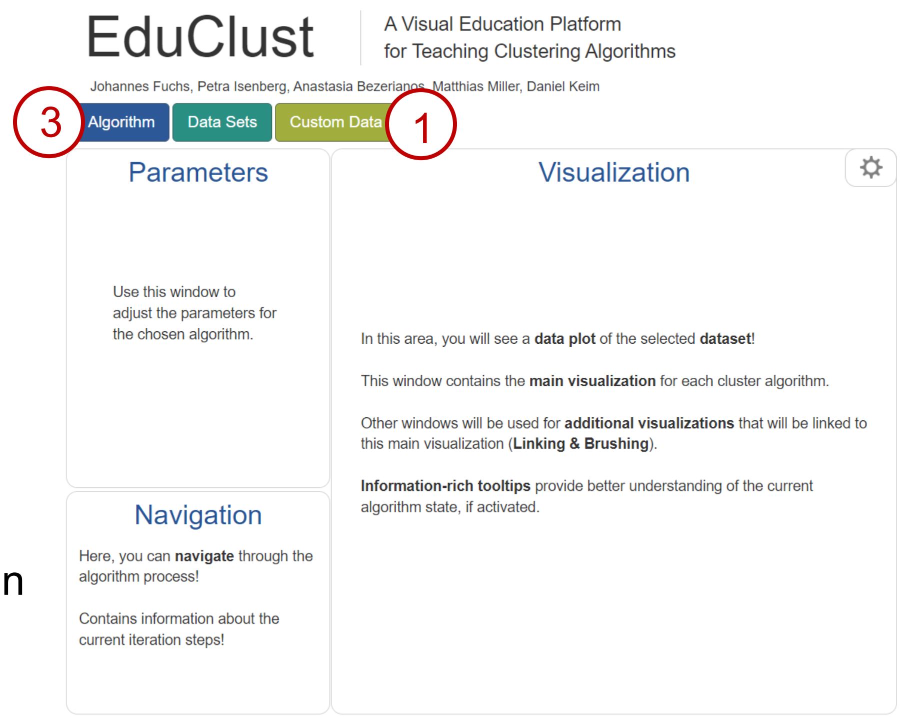
https://educlust.dbvis.de/

1 Custom Data

Data Set Creator

Import Data Set

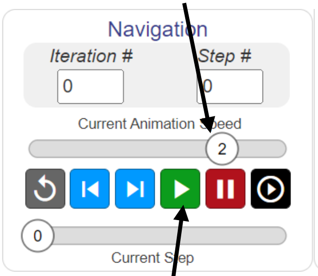
2 Upload iris_2d_scaled.json



3 Choose method: k-means

4 Parameters: Choose *k*

5 Set speed



6 Start animation

Download: https://tinyurl.com/5f9mkxmb

Structure of an unsupervised learning problem

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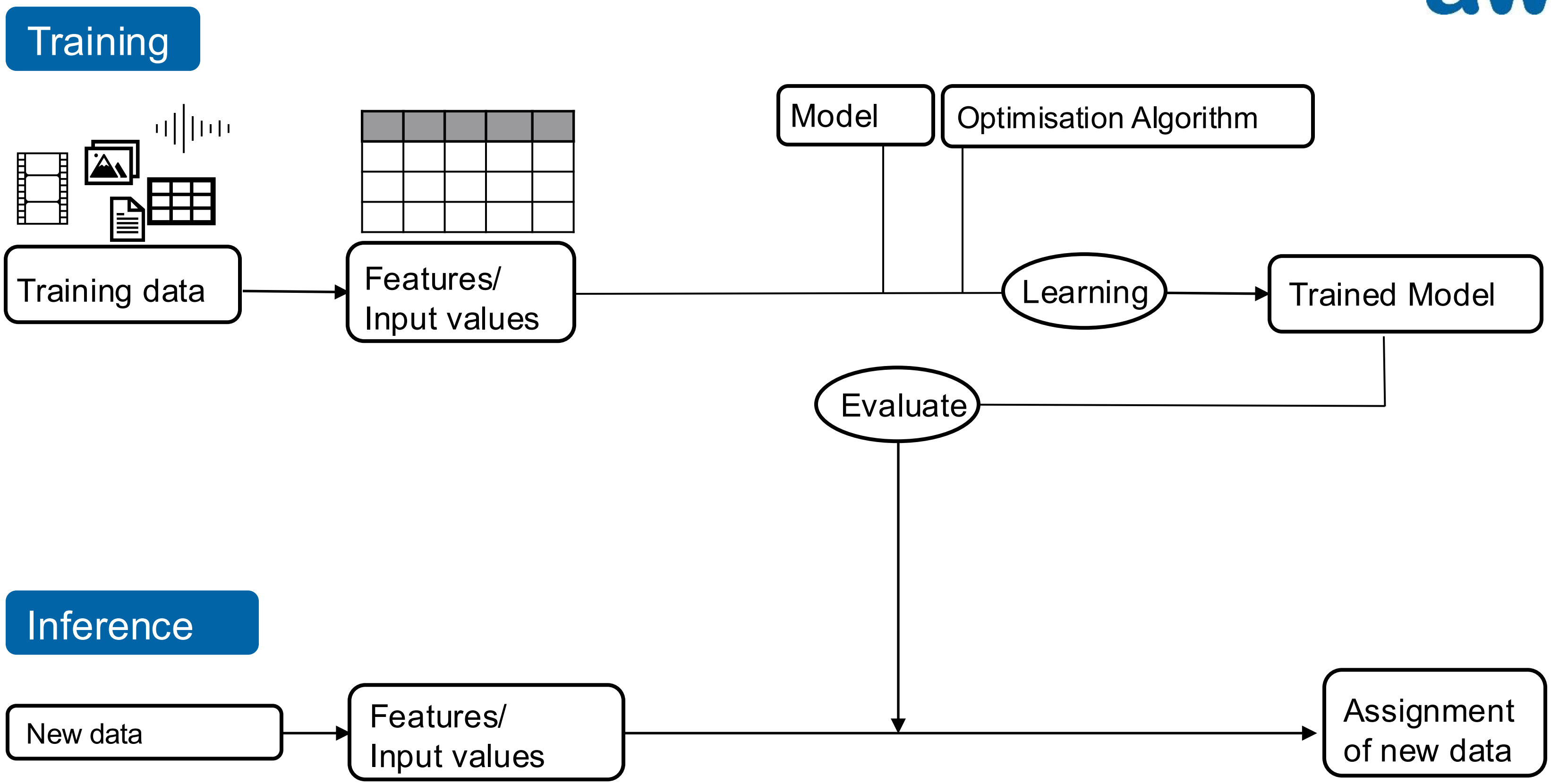

Reinforcement-Learning

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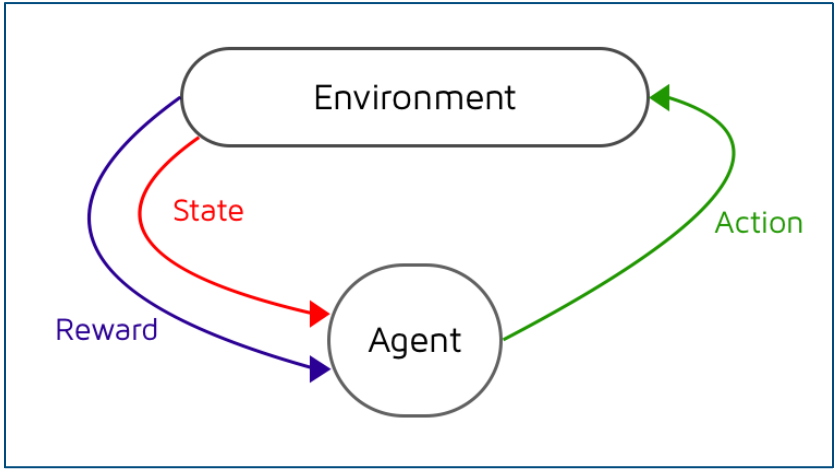

"Play games without knowing the rules"