Introduction to Machine Learning

Guest Lectures at TTK University of Applied Sciences, Tallinn, Estonia

8 – 12 December 2025

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Who’s Teaching Today?

Andy Louwyck

- Master and Doctor in Science: Geology
- Associate Degree in Programming
- Micro Degree in AI & Data Science
- Lecturer in IT at Vives University of Applied Sciences
- AI Coordinator at Flanders Environment Agency

Dominique Stove

- Master in Applied Economics
- Teaching Master’s Degree in Economics, Mathematics, and Physics
- Lecturer in IT at Vives University of Applied Sciences
- IT Consultant in Infrastructure
- Founder and Business Owner of IqPro

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Vives Campus in the City of Kortrijk

Informatics Program for Exchange Students

https://www.vives.be/en/commercial-sciences-business-management-and-informatics/informatics-kortrijk

The Informatics-programme is a programme consisting of lectures, group work, visits and projects in the field of Business and Informatics. Evaluation follows the rules of the European Credit Transfer System (ECTS). Incoming students can select a programme of up to 30 ECTS credits per semester.

New full-year program!

Title	ECTS	hours/week S1	hours/week S2	Semester
Introduction to Artificial Intellingence	5	3	0	1
Programming in Python	3	2	0	1
Digital Workplace	3	2	0	1
Android App Development	5	3	0	1
E-business en E-marketing	3	2	0	1
Introduction to linux	3	2	0	1
Cybersecurity	5	3	0	1
Professional and International Communication 3 (English)	3	2	0	1
	30	**19**	0	
Machine Learning - Fundamentals	6	0	4	2
IT-Project	5	0	3	2
Power Tools	3	0	3	2
Full-Stack Development in .NET	6	0	4	2
Mobile App Development iOS	5	0	4	2
Data Engineering	5	0	3	2
Node.js Development	3	0	2	2
	33	0	23	

Let’s Dive In!

1. What is Machine Learning?
2. ML applications and tasks
3. What is supervised learning?
4. Training and evaluation
5. Demo + exercise

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Introduction to Machine Learning

WHAT IS MACHINE LEARNING?

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Data

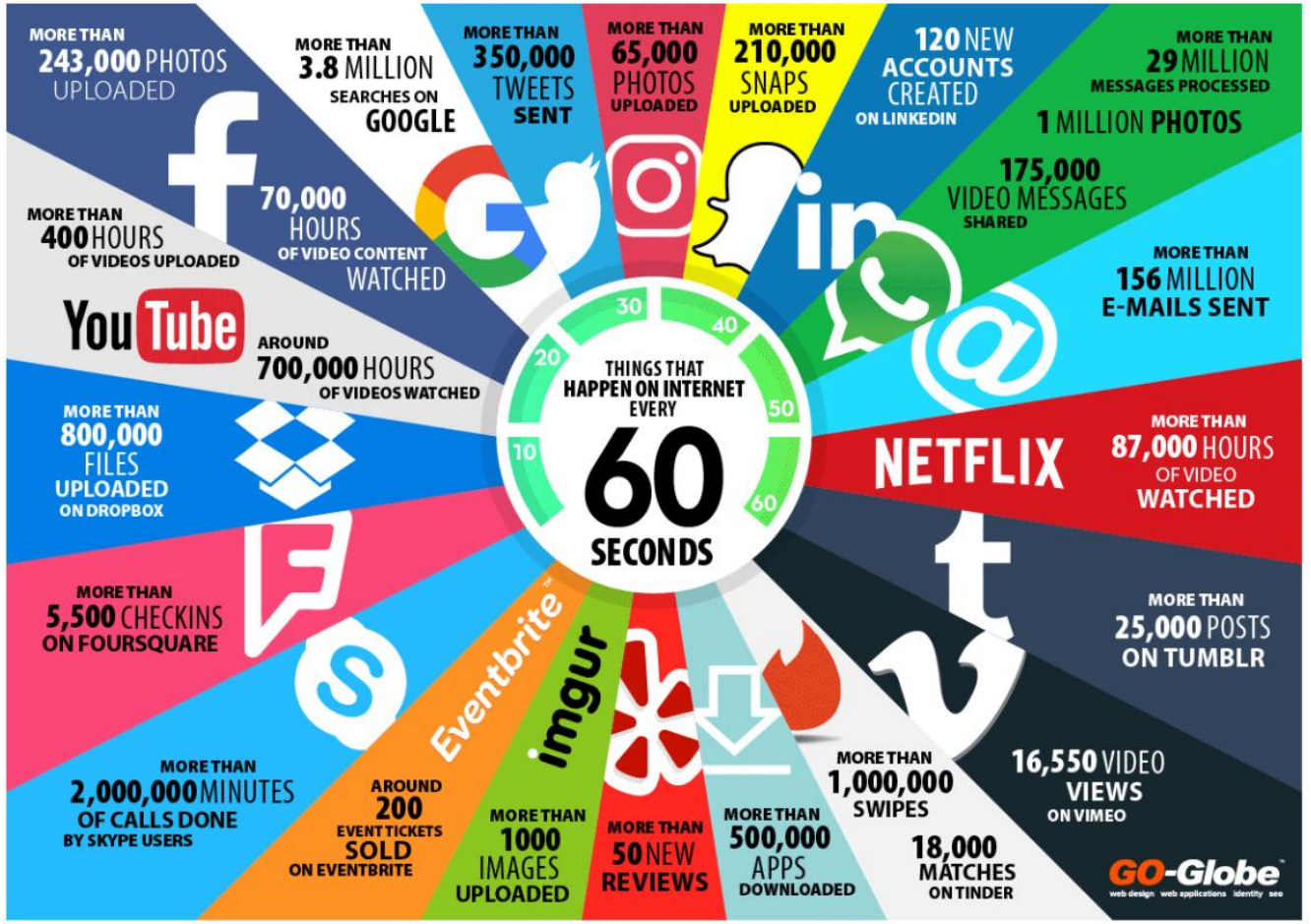
"We are drowning in data but starving for knowledge"

[Naisbitt, 1982]

– A lot of data is gathered, but never used

– It is easier to generate data than to analyze data

→ **MACHINE LEARNING**



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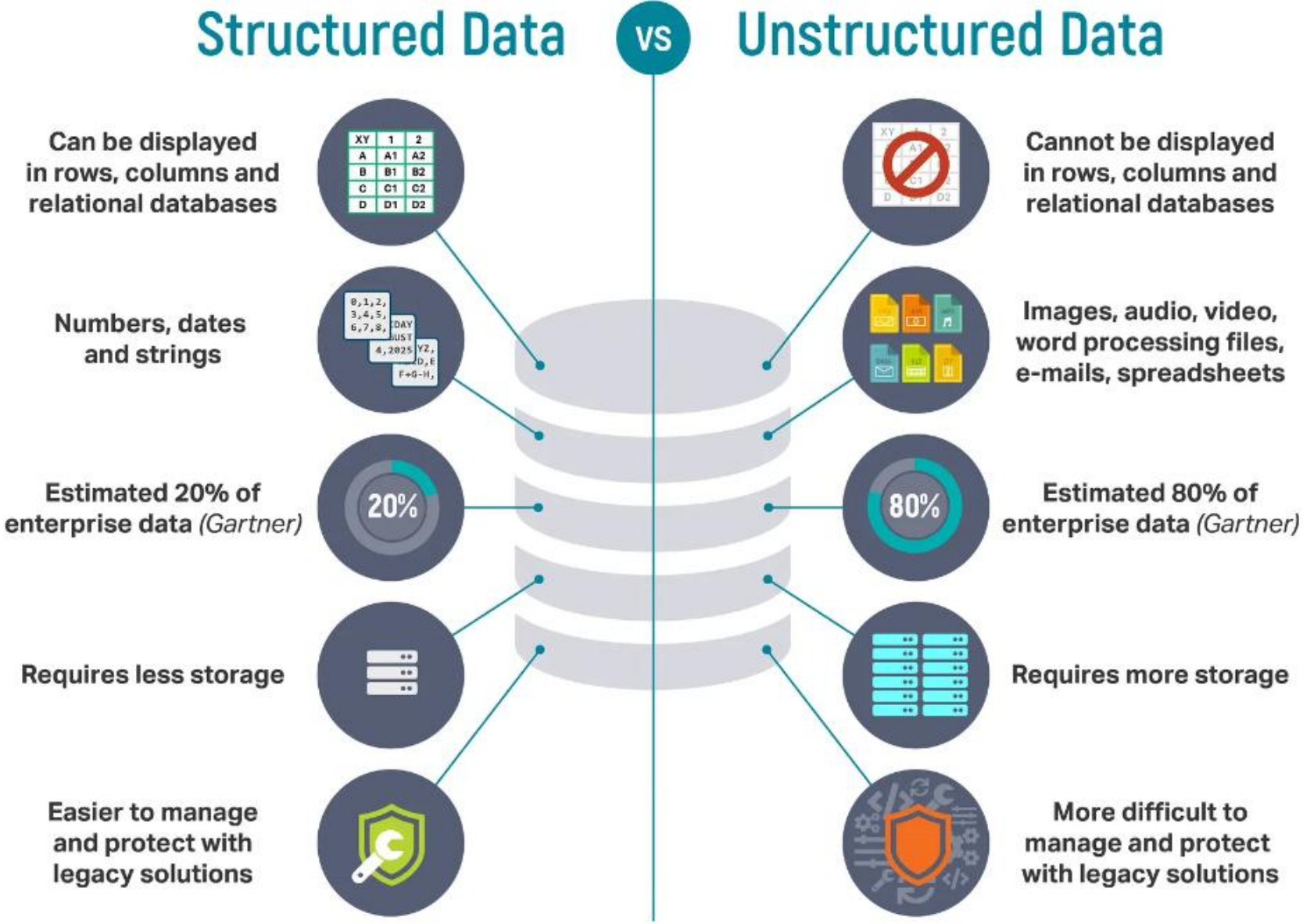
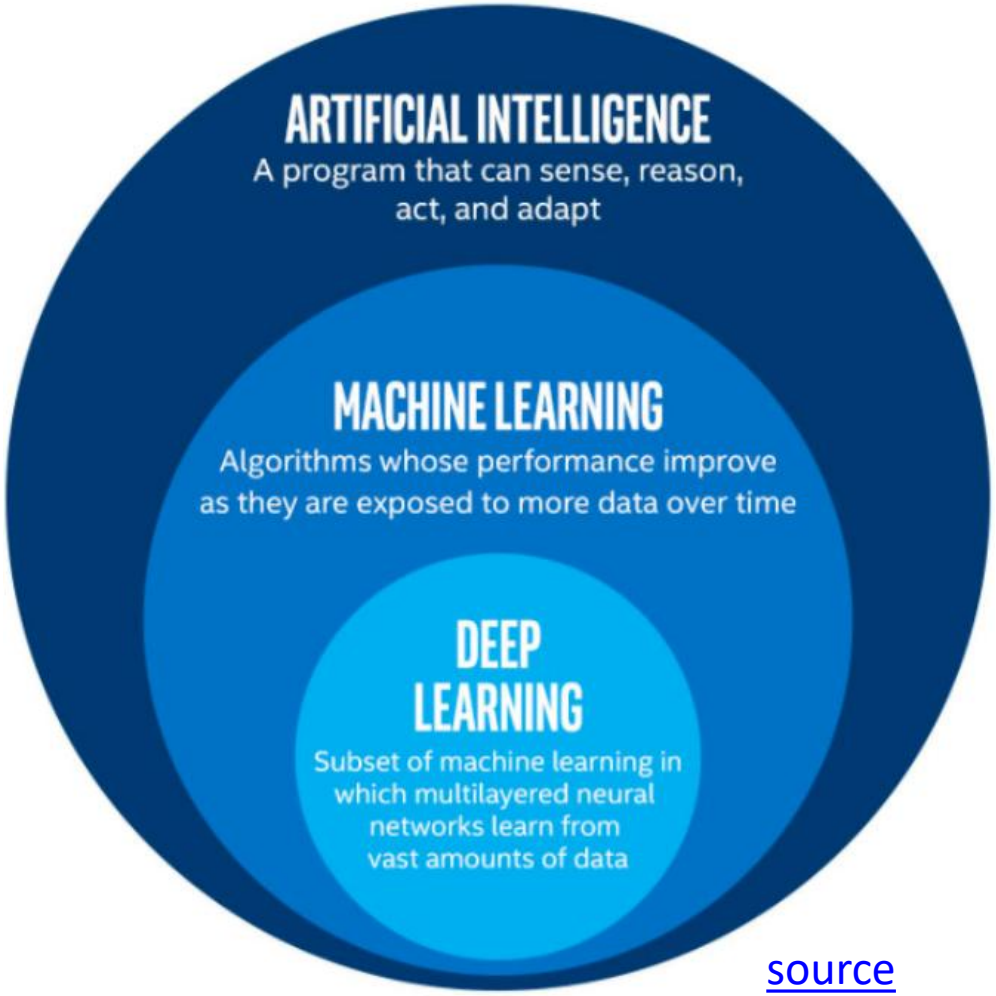


https://www.igneous.io/blog/structured-data-vs-unstructured-data

Machine Learning ⊂ Artificial Intelligence



source

- **Artificial Intelligence** (AI):

  "The set of all tasks in which a computer can make *decisions*."
- **Machine Learning** (ML):

  "The set of all tasks in which a computer can make decisions *based on data*."
- **Deep Learning** (DL):

  "The field of machine learning that uses certain objects called *neural networks*."

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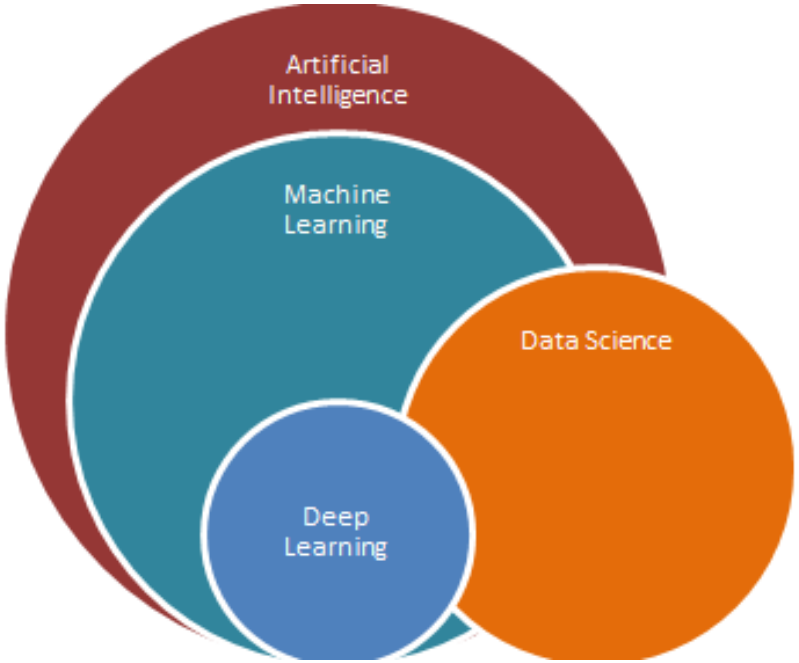
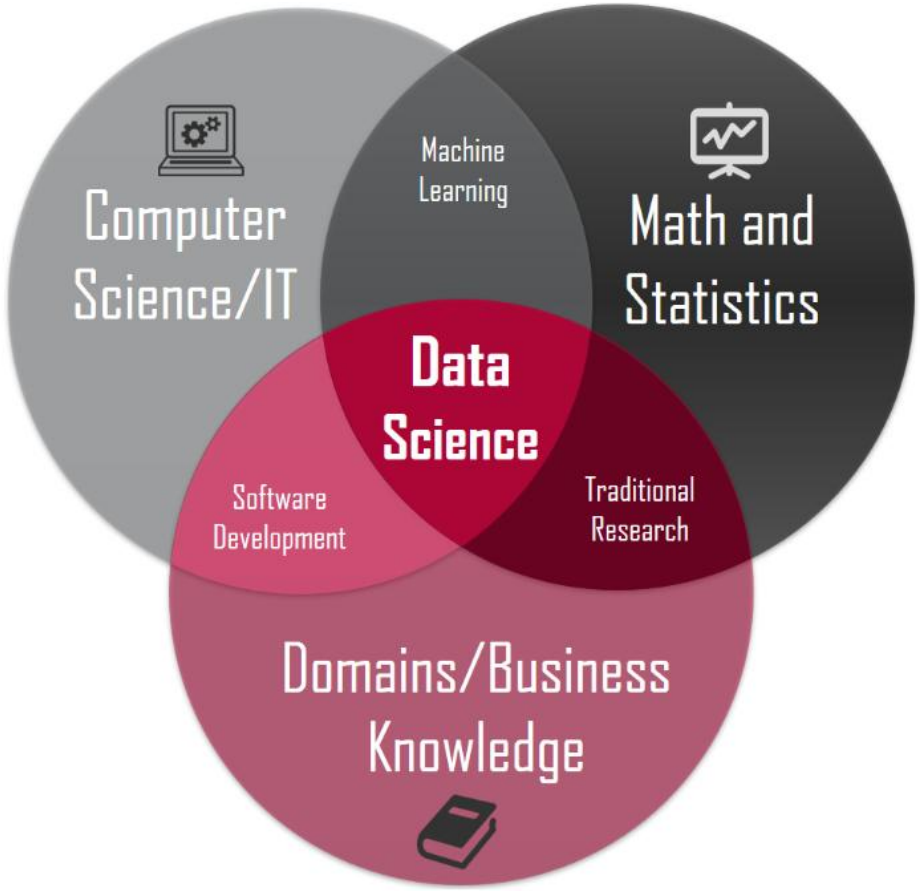
Machine Learning ≠ Data Science





In practice:

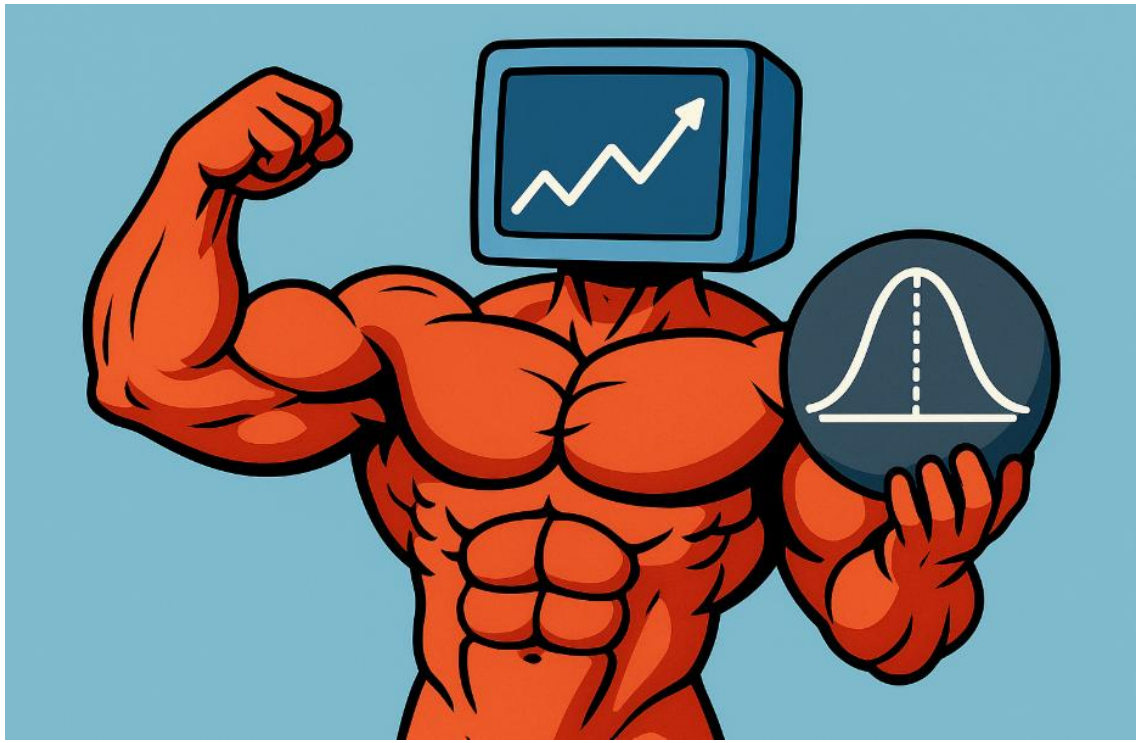
- ML team: delivers software
- DS team: provides new insights

source

Machine Learning = Statistics on Steroids?

Machine learning takes **core statistical ideas** and supercharges them with **computational power** and **flexibility**:

- ML builds on the **foundations of statistics** but amplifies its capabilities.
- ML uses **larger datasets**, more complex models, and automated learning.
- ML focuses on **prediction and scalability**, often with less emphasis on interpretability.
- ML applies **fewer explicit assumptions**, letting algorithms discover patterns directly from data.
- ML excels in domains like **computer vision**, **NLP**, and industrial **prediction**.



Machine Learning vs Statistics: Goals & Questions

Dimension	Traditional statistics	Machine learning
Primary goal	Explain relationships, test hypotheses, estimate effects	Maximize predictive performance on new data
Typical question	How does X affect Y, and is the effect significant?	Given X, how accurately can we predict Y?
Focus	Inference, uncertainty, interpretability	Prediction, automation, scalability
Typical use	Clinical trials, econometrics, social science studies	Vision, NLP, recommender systems, industrial prediction

source

Machine Learning vs Statistics: Modeling & Data

Dimension	Traditional statistics	Machine learning
Modeling	Specify parametric model + assumptions, then estimate	Learn flexible functions from data via optimization
Assumptions	Strong, explicit distributional assumptions	Fewer explicit assumptions, more data-driven structure
Data regime	Small–moderate, carefully designed datasets	Large, high-dimensional, less structured data
Evaluation	p-values, confidence intervals, goodness-of-fit checks	Hold-out / CV metrics (accuracy, AUC, RMSE, F1, etc.)

source

Intuitive Explanation of Machine Learning

Example: buying a new car

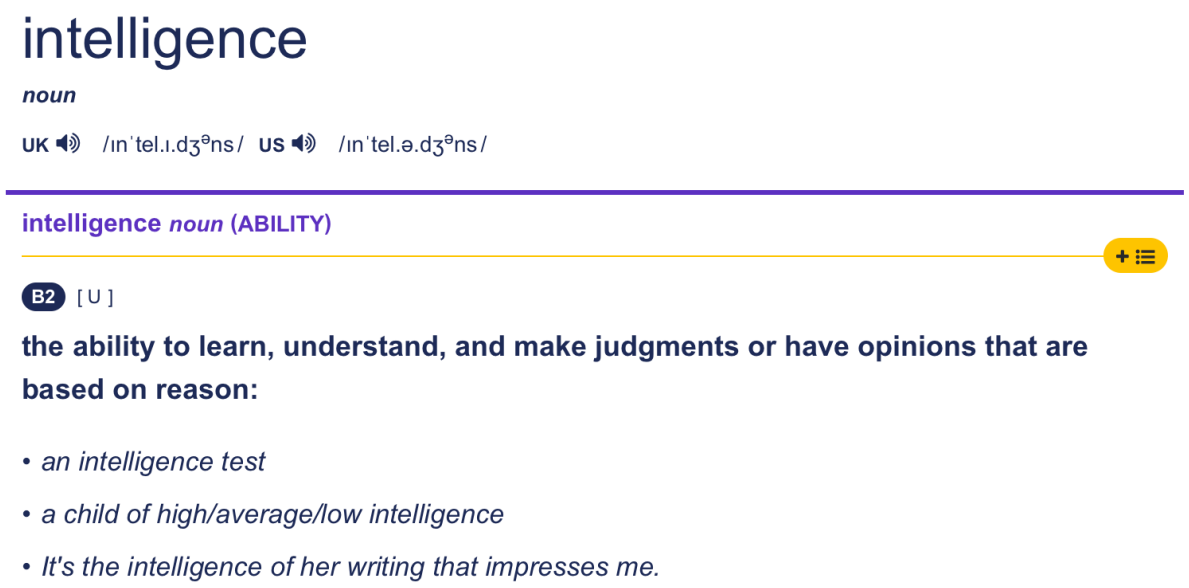
- How do we make decisions?
  - by logical **reasoning**
  - by relying on previous **experiences** (either our own or those of others)

- For a computer: **experiences = data**

"Machine learning is common sense, except done by a computer"

Formal Explanation of Machine Learning

- Core domain of AI, concerned with automatic learning



intelligence

noun

UK /ɪnˈtel.ɪ.dʒᵊns/ US /ɪnˈtel.ə.dʒᵊns/

intelligence *noun* (ABILITY)

B2 [U]

the ability to learn, understand, and make judgments or have opinions that are based on reason:

- *an intelligence test*
- *a child of high/average/low intelligence*
- *It's the intelligence of her writing that impresses me.*

- A computer is said to be able to learn if its performance in solving some task improves with its experience

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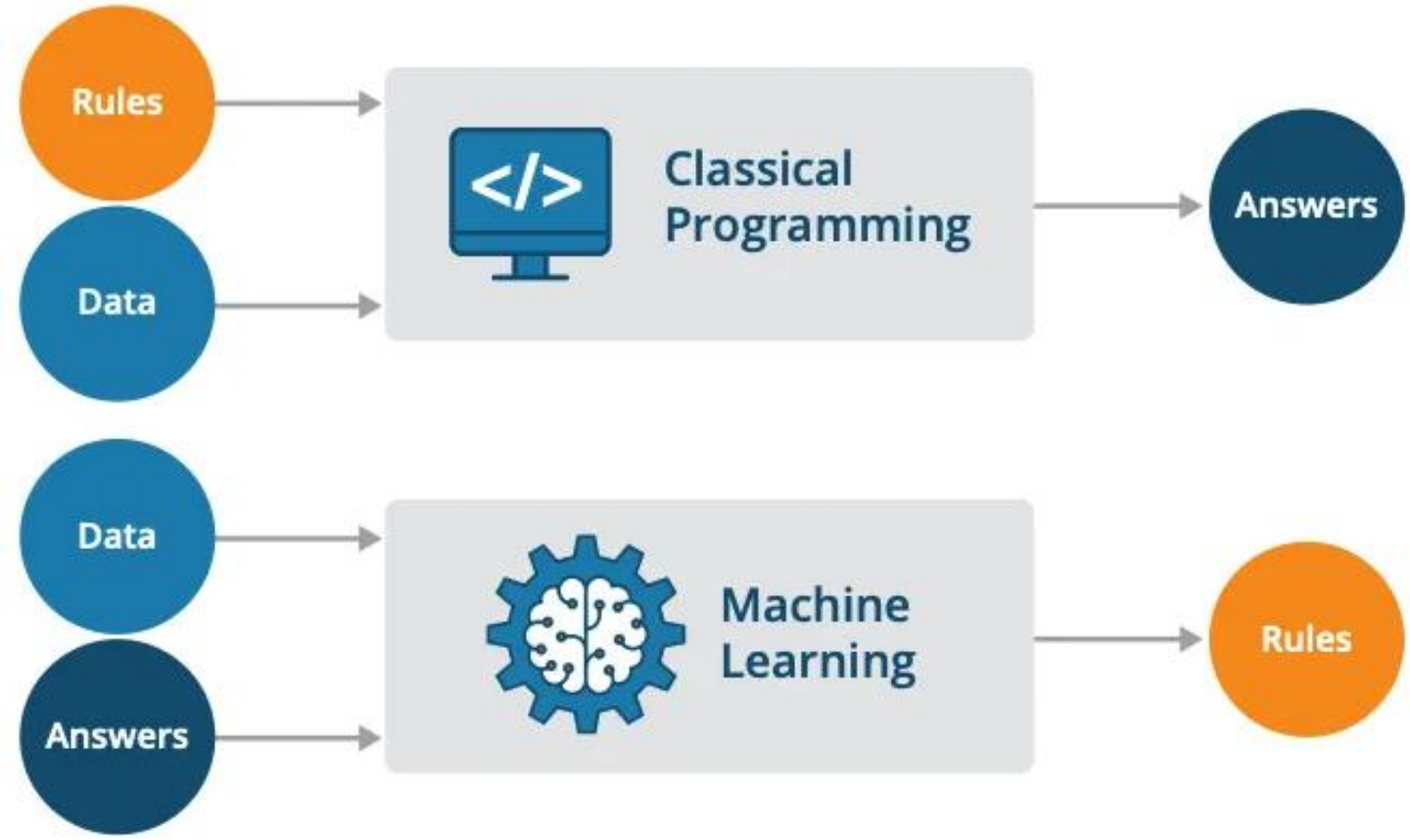
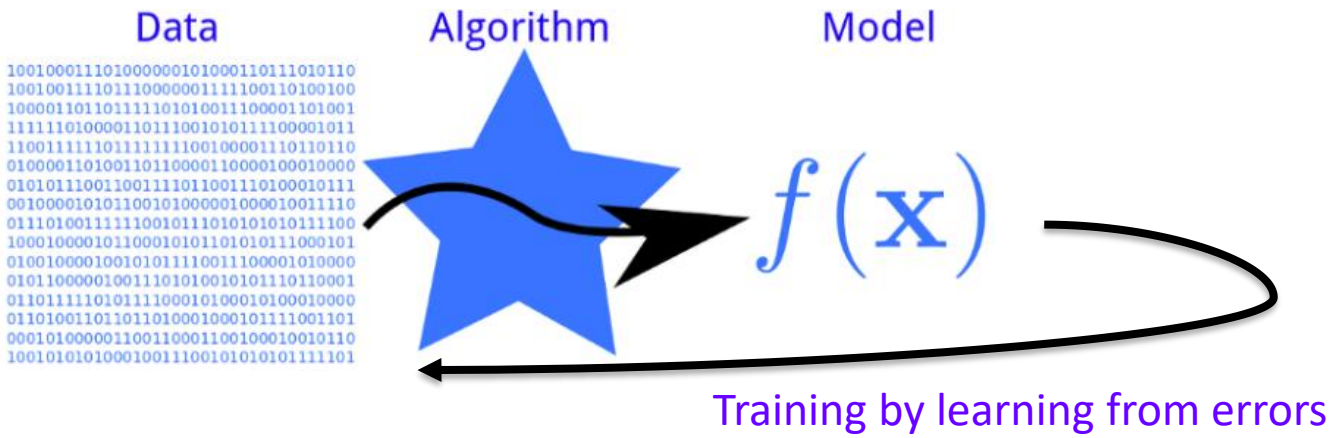
Machine Learning versus Classical Programming



Machine Learning: Algorithm versus Model

- **Algoritme**: A procedure, or a set of steps, used to build a model.
- **Model**: A set of rules that represent the data and can be used to make predictions.
- **Learning**: The process in which the algorithm improves the model by analyzing errors.



"An algorithm is run on the data to create a model.
By learning from errors, the model improves itself."

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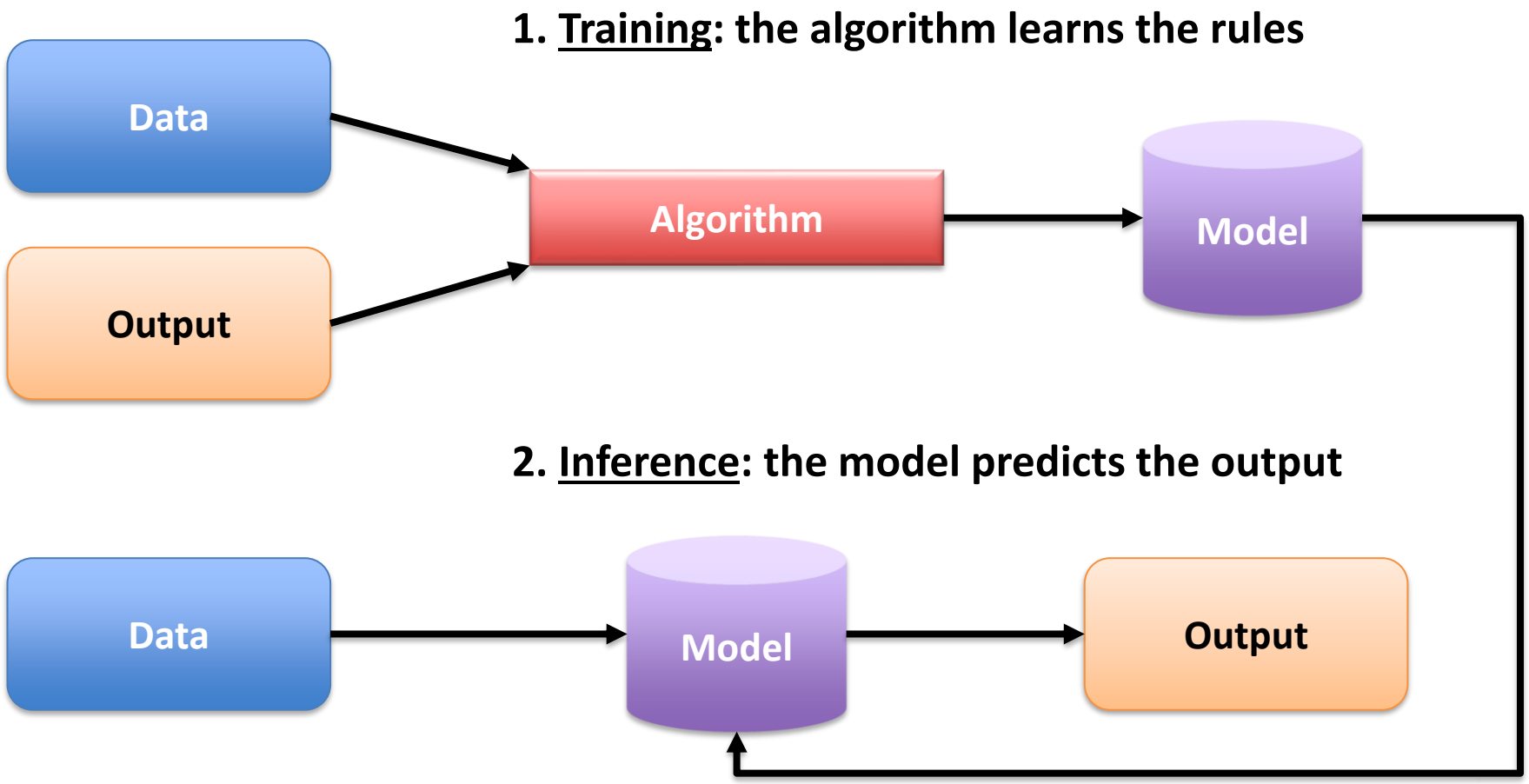
Machine Learning: Training versus Inference



Thermostat example

Traditional Programming Approach

- **The rule is given**:

  "If temperature is smaller than 17°C, then heating is on, otherwise it's off"
- The algorithm implements the rule
- No data required to derive the rule!

```
threshold = 17
temperature = float(input("What is the temperature?\n"))  # data
heating = 'on' if temperature < threshold else 'off'      # rule
print(f'The heating is {heating}!')                       # answer
```

```
What is the temperature?
18
The heating is off!
```

Machine Learning Approach

The rule is not known and must be derived from data!

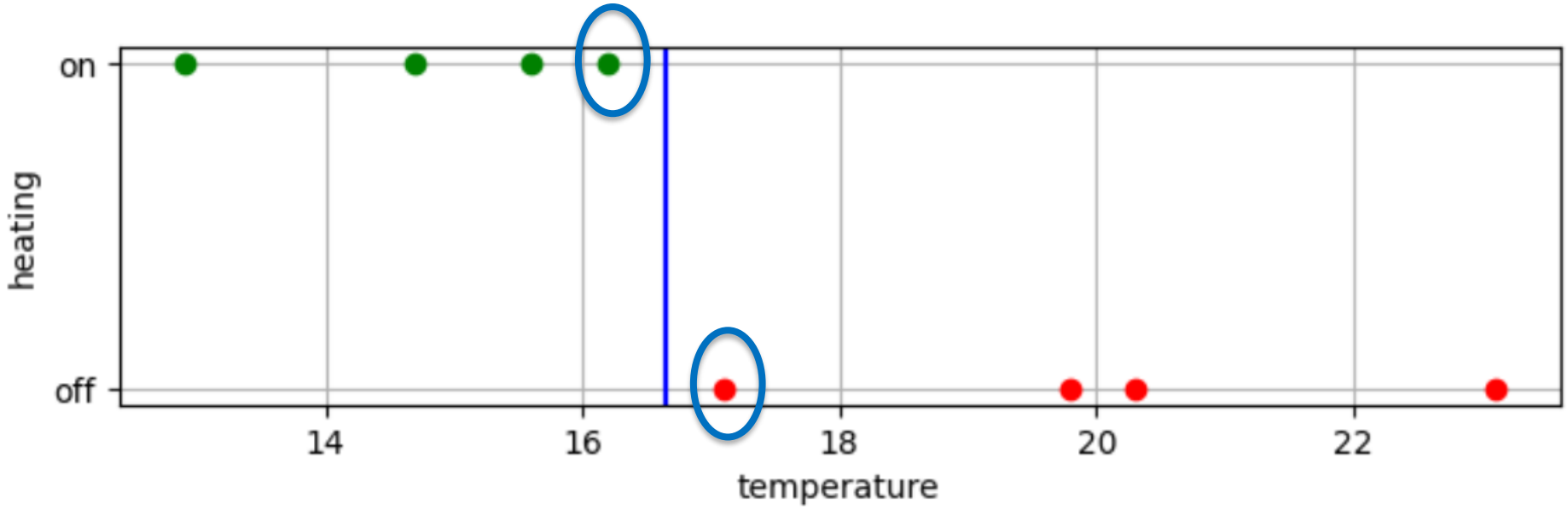
```
import pandas as pd
temperature = [17.1, 15.6, 23.1, 19.8, 12.9, 20.3, 14.7, 16.2]  # data
heating = ['off', 'on', 'off', 'off', 'on', 'off', 'on', 'on']  # answers
table = pd.DataFrame(dict(temperature=temperature, heating=heating))
```

	temperature	heating
0	17.1	off
1	15.6	on
2	23.1	off
3	19.8	off
4	12.9	on
5	20.3	off
6	14.7	on
7	16.2	on

Intuitive Algorithm

```
max_temperature_on = table[table.heating=='on']['temperature'].max()
min_temperature_off = table[table.heating=='off']['temperature'].min()
threshold = (max_temperature_on + min_temperature_off) / 2
print(f'maximum temperature if heating is on: {max_temperature_on}°C')
print(f'minimum temperature if heating is off: {min_temperature_off}°C')
print(f'threshold is {threshold}°C')
```

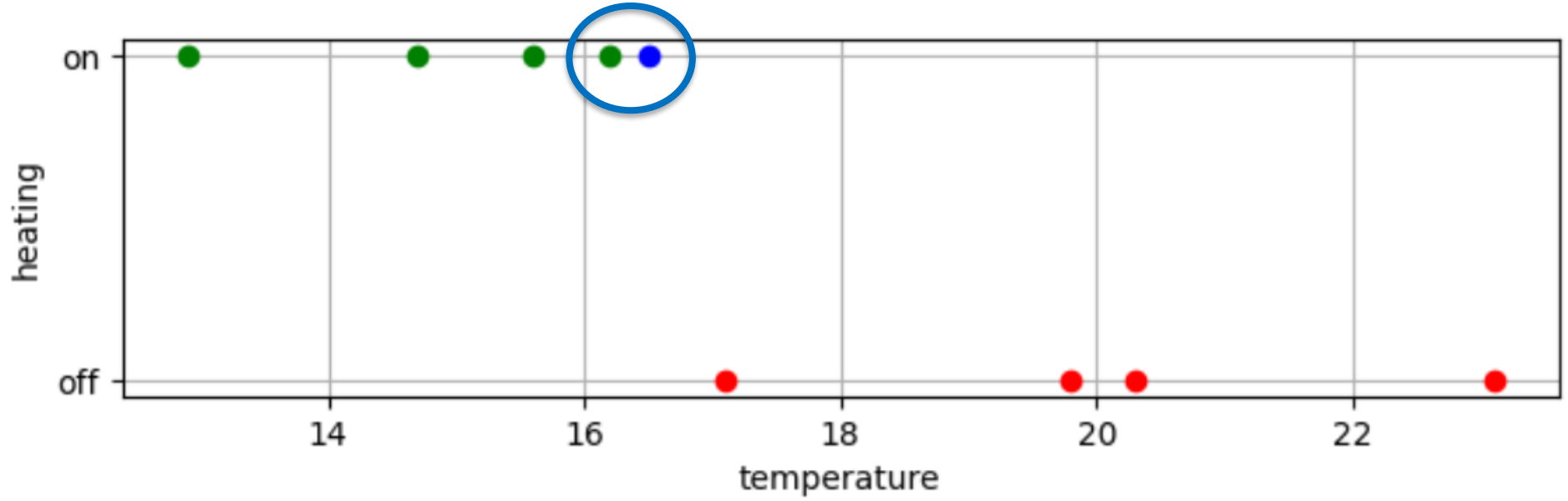
```
maximum temperature if heating is on: 16.2°C
minimum temperature if heating is off: 17.1°C
threshold is 16.65°C
```



Nearest Neighbor

```
temperature = float(input("What is the temperature?\n"))  # input temperature
abs_difference = (temperature - table.temperature).abs()  # absolute difference
heating = table.heating.iloc[abs_difference.argmin()]     # label of nearest neighbor
print(f'The heating is {heating}!')                       # answer
```

```
What is the temperature?
16.5
The heating is on!
```



Why simple models are not enough

- Real-life datasets are typically much larger:
  - more data points
  - more variables
- Real-life datasets often contain outliers or errors

- **Therefore we need more robust algorithms**
  - that take all samples into account
  - that measure and minimize the errors
- Examples:
  - **Decision Tree**: splits the data repeatedly into smaller, more homogeneous groups
  - **Logistic Regression**: finds the best boundary that separates the data
  - **K Nearest Neighbors**: considers K nearest data points instead of 1

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MACHINE LEARNING APPLICATIONS & TASKS

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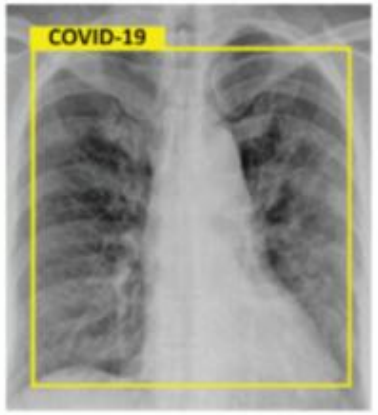
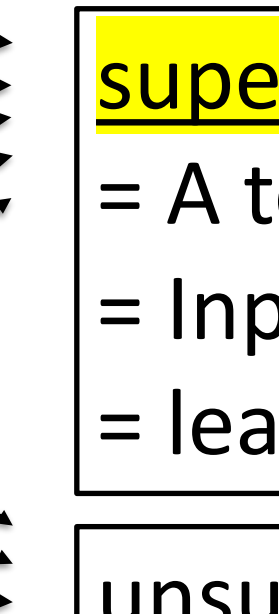
ML Applications

- Spam filters
- Recommender systems
- Personalized shopping
- Voice assistants
- Self-driving cars
- Search engines
- Chatbots
- Fraud prevention
- Face recognition
- Medical imaging
- Robotics
- Route planning
- Sales forecasting
- Deepfakes
- …



Machine Learning Tasks

- Classification
- Regression
- Forecasting
- Prediction
- Anomaly detection
- Association rule mining
- Clustering
- …



supervised learning

= A to B mapping

= Input to output mapping

= learning from (input, output) pairs

unsupervised learning

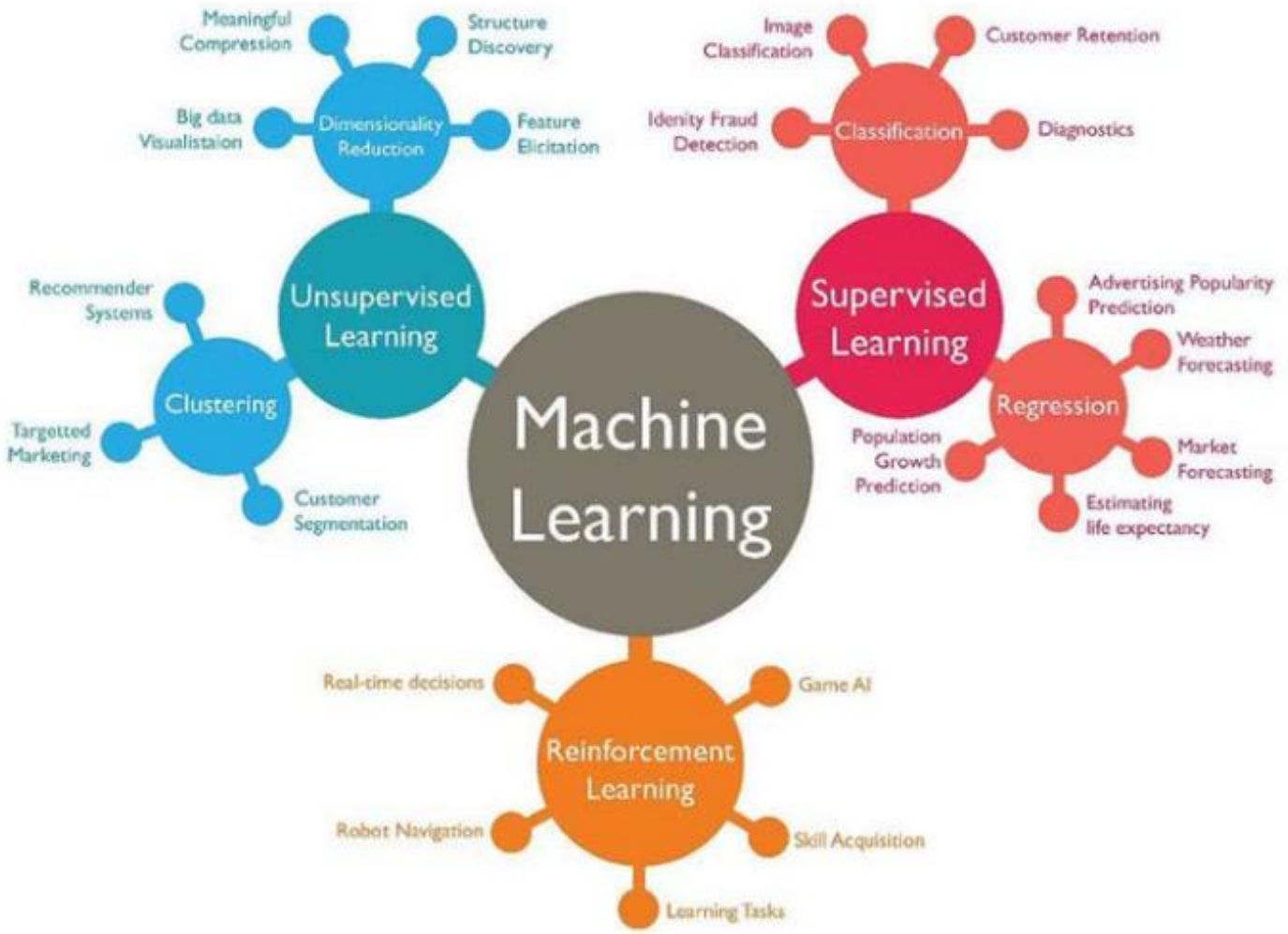
= learning from data without output

= based on identifying similarities and hidden structures in the data.

Supervised Learning

Input (A)	Output (B)	Application
email	spam? (0/1)	spam filtering
audio	text transcript	speech recognition
English	Chinese	machine translation
ad, user info	click? (0/1)	online advertising
image, radar info	position of other cars	self-driving car
image of phone	defect? (0/1)	visual inspection

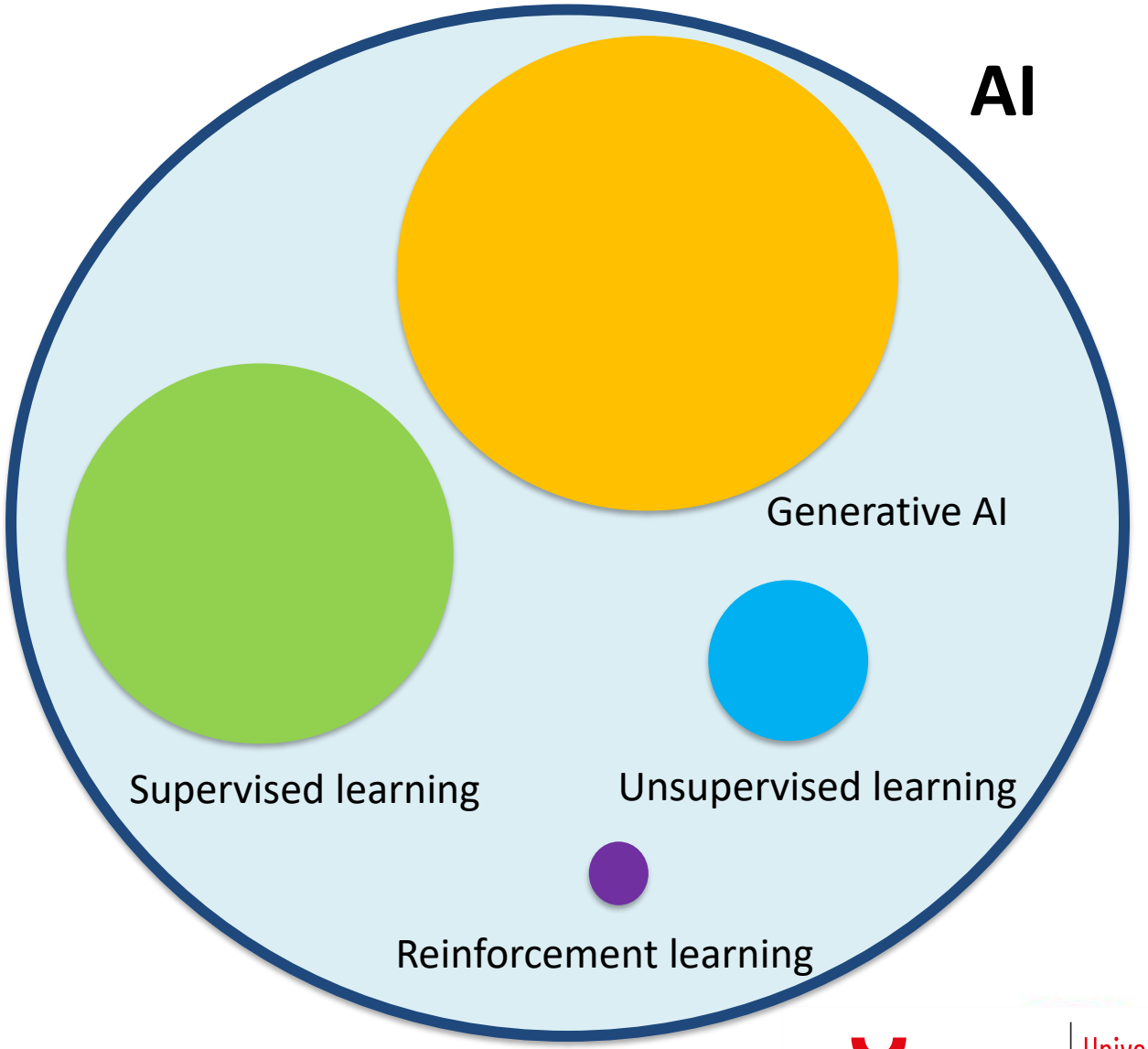
The Big Three



Category of machine learning. Image by https://www.techleer.com/articles/203-machine-learning-algorithm-backbone-of-emerging-technologies/

What about GenAI?

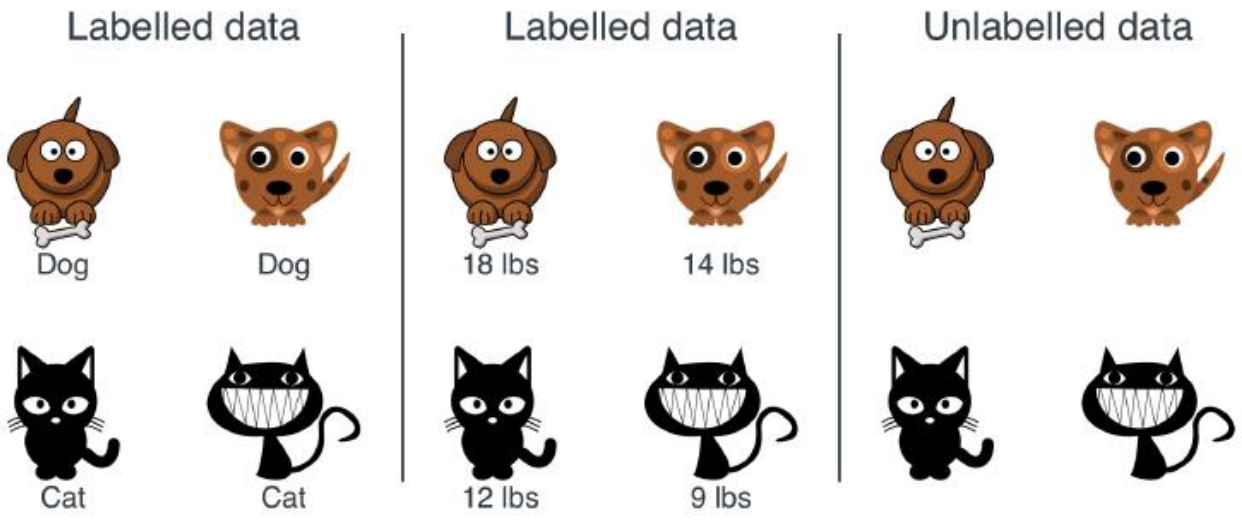
- **Supervised learning**
  = learning from labeled data
- **Unsupervised learning**
  = learning from unlabeled data
- **Reinforcement learning**
  = learning from rewards
- **Generative AI**
  = generating new data



Supervised Learning versus Unsupervised Learning

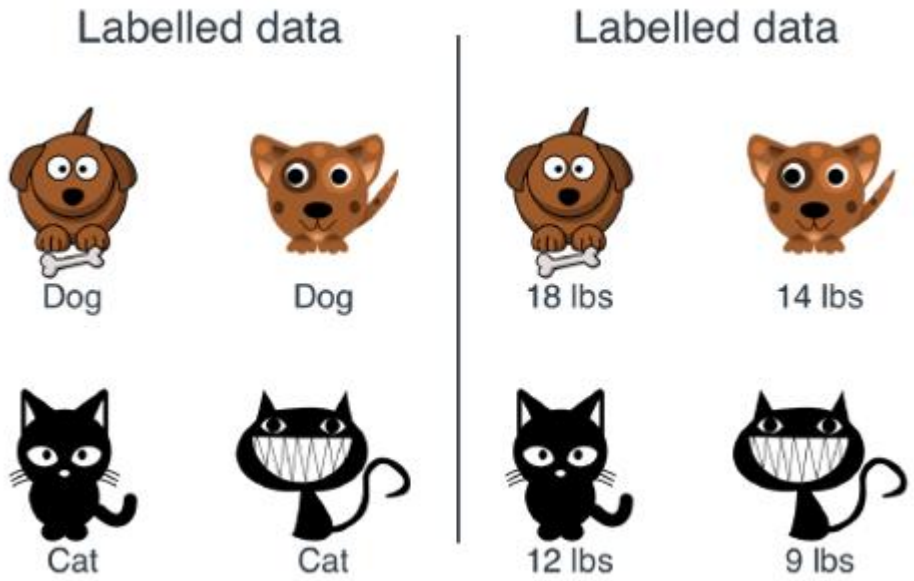
- **Labeled data**: data with label
  → **SUPERVISED** LEARNING

- **Unlabeled data**: data without label
  → **UNSUPERVISED** LEARNING

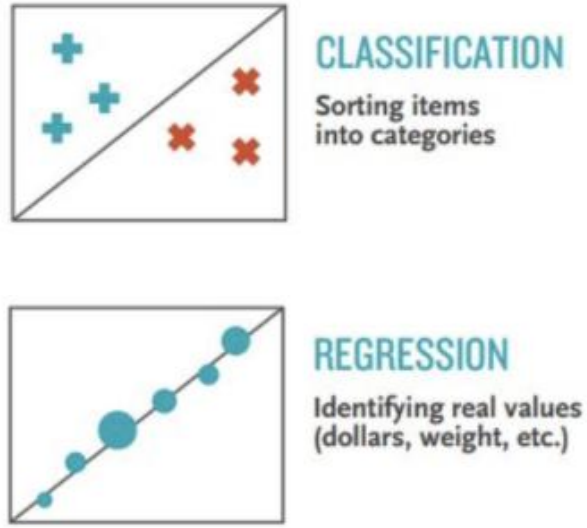


Classification vs Regression

- **Qualitative or Categorical** target ➔ **Classification**
- **Quantitative or Numerical** target ➔ **Regression**



Categorical **Numerical**



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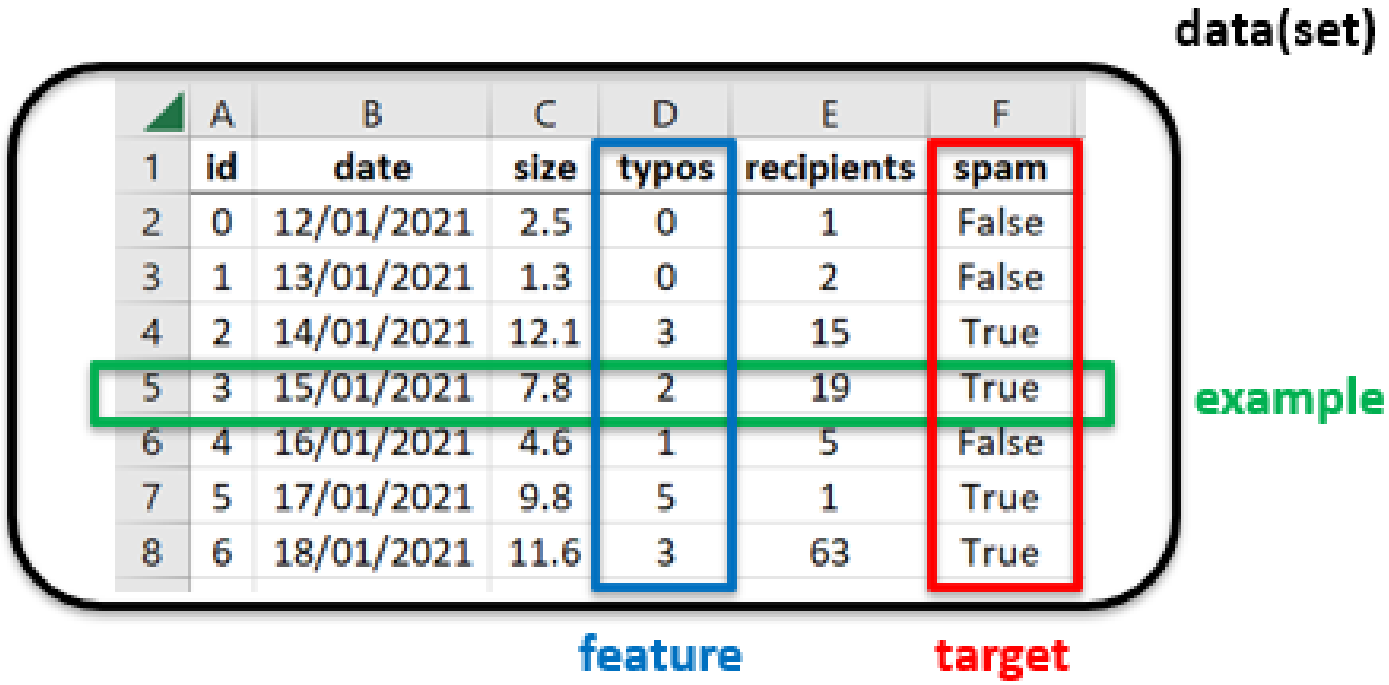
Structured Data

- **Data** = dataset = information (= table)
- **Example** = sample = instance = data point = observation (= table row/record)
- **Feature** = predictor = independent variable = input variable (= table column/attribute)
- **Target** = labels = dependent variable = response variable = output variable



	A	B	C	D	E	F
1	id	date	size	typos	recipients	spam
2	0	12/01/2021	2.5	0	1	False
3	1	13/01/2021	1.3	0	2	False
4	2	14/01/2021	12.1	3	15	True
5	3	15/01/2021	7.8	2	19	True
6	4	16/01/2021	4.6	1	5	False
7	5	17/01/2021	9.8	5	1	True
8	6	18/01/2021	11.6	3	63	True

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WHAT IS SUPERVISED LEARNING?

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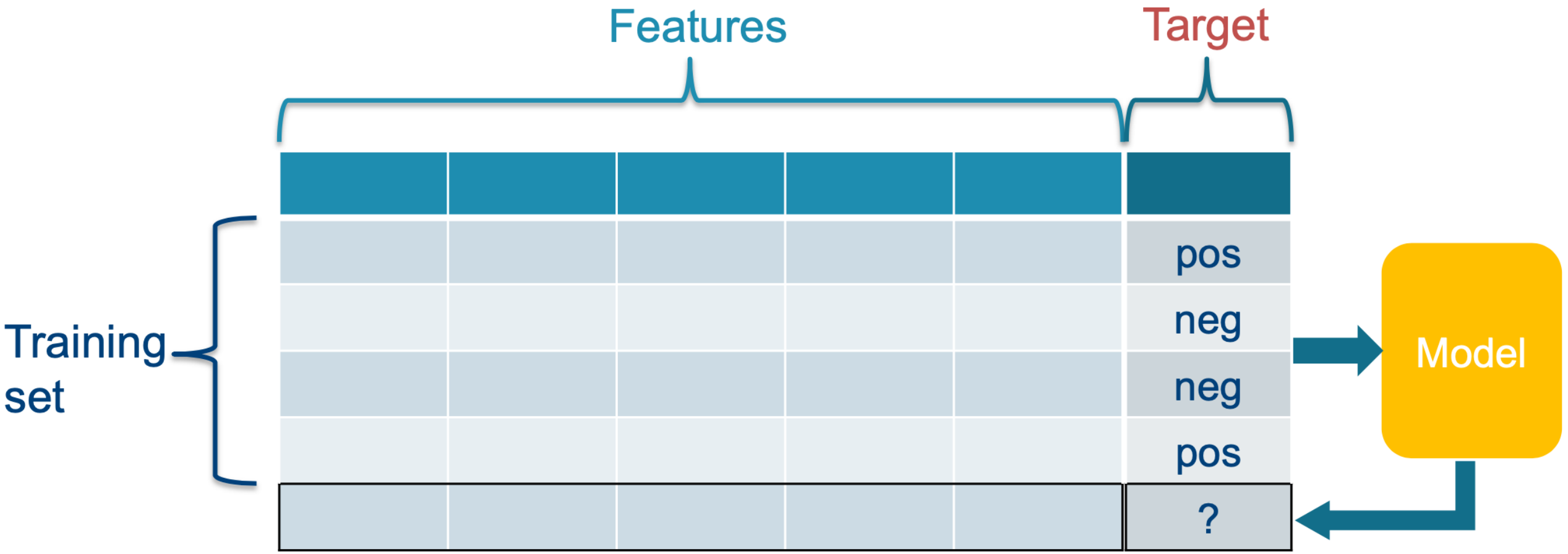
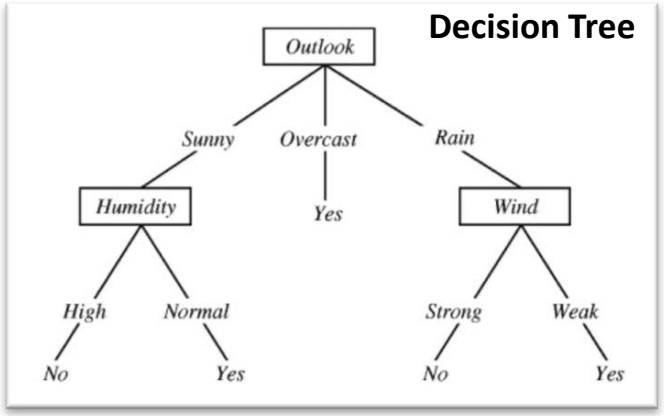
Supervised Learning Task

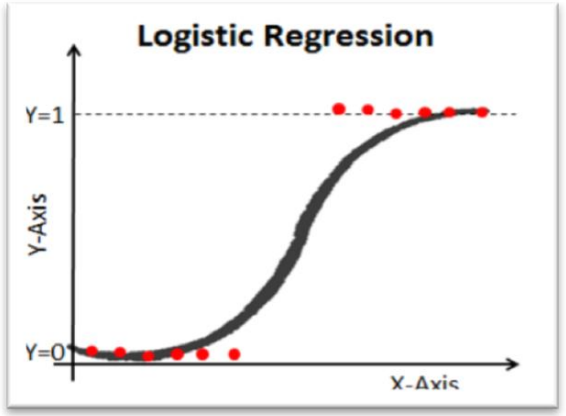
- Task: learn a model to predict a target for new data instances,
  based on a training set of data instances for which the target is known

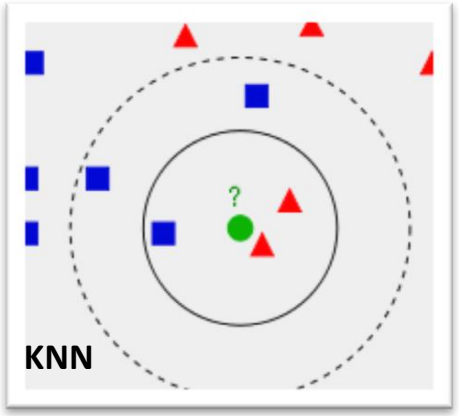


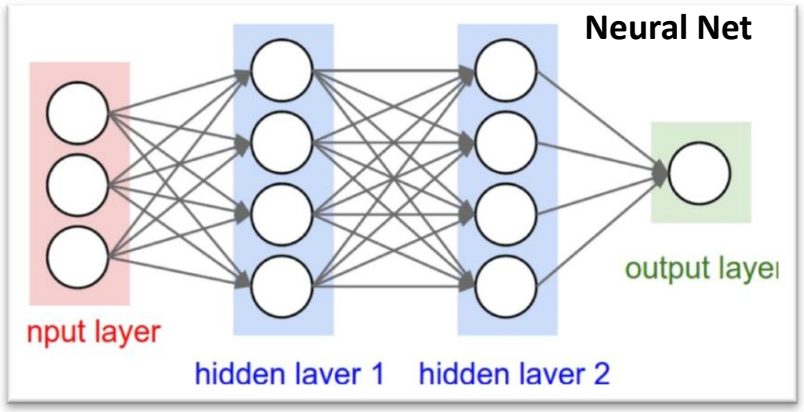
Supervised Learning Algorithms

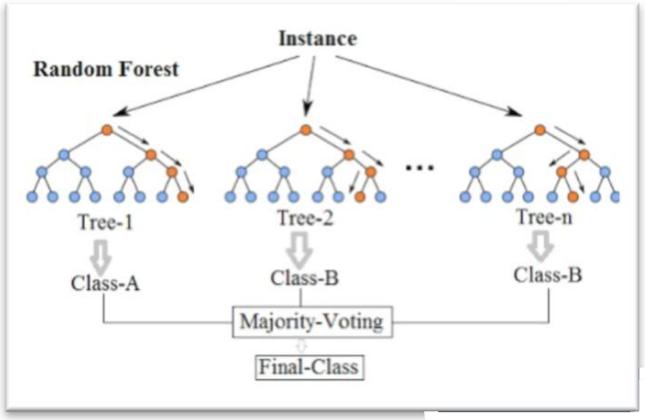
- There exist plenty of supervised learning algorithms
- **No free lunch**: there is no algorithm that works best for every problem











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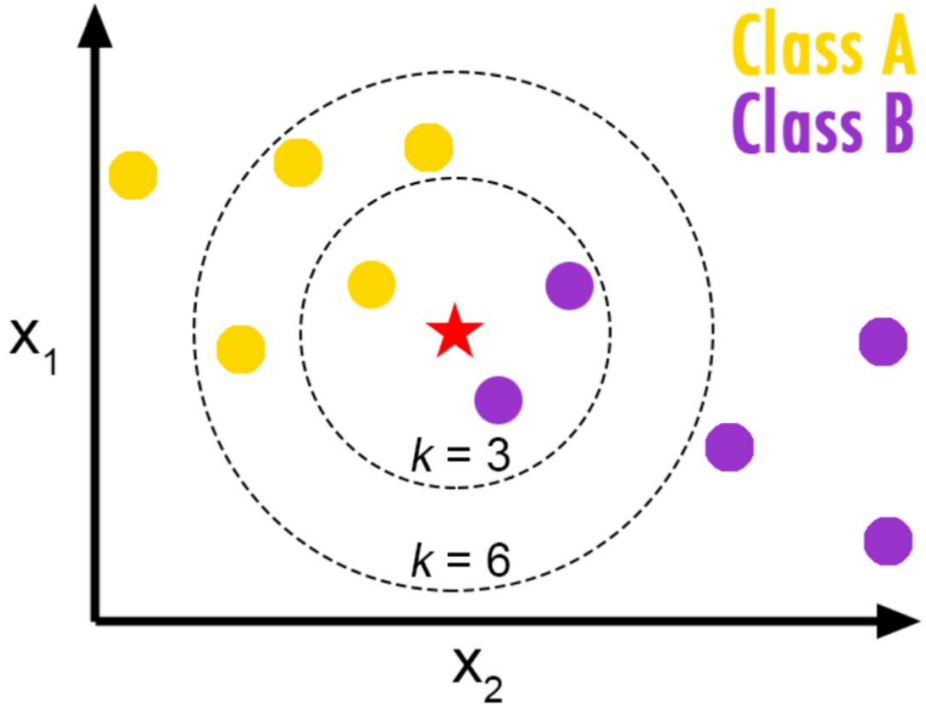
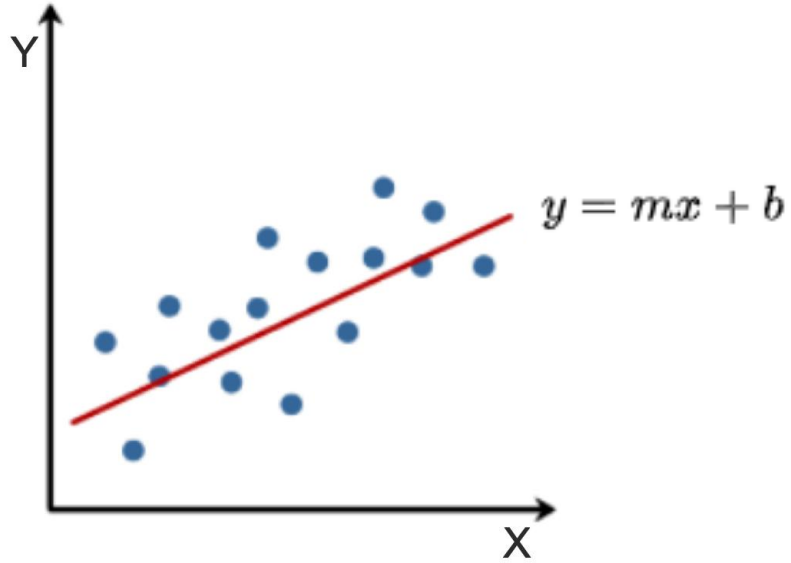
K Nearest Neighbors (KNN)

- Classification (regression is also possible)
- Requires no training (= lazy learning, as opposed to eager learning)
- Main task: find suitable distance function (Euclidean, Manhattan, …)



Simple Linear Regression

- Regression for numeric targets
- 1 independent variable (feature *x*) and 1 dependent variable (target *y*)
- Main task: estimate parameters *m* and *b*, such that predictions (red line) and targets (blue dots) are as close as possible (= best-fitting straight line)



Simple Linear Regression: Algorithm versus Model

Example: predicting weight from height

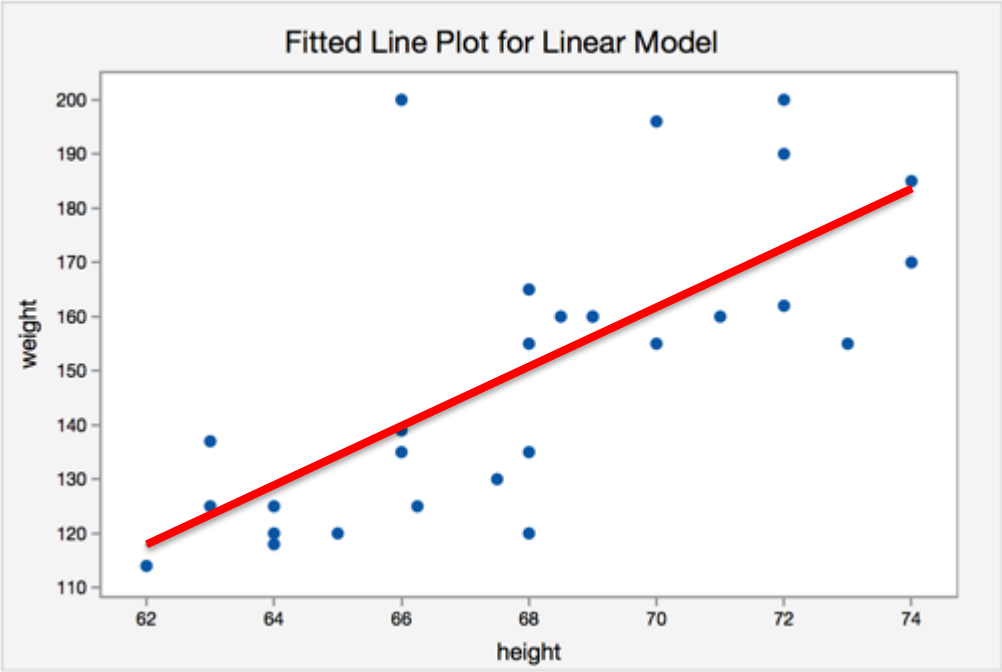
- **Input**: (*x*, *y*) data with *x* = height (inches) and *y* = weight (pounds)
- **Output**: predicted weight
- **Algorithm**: *calculates* the best fitting line

  find parameters m and b in

  $$y = mx + b$$

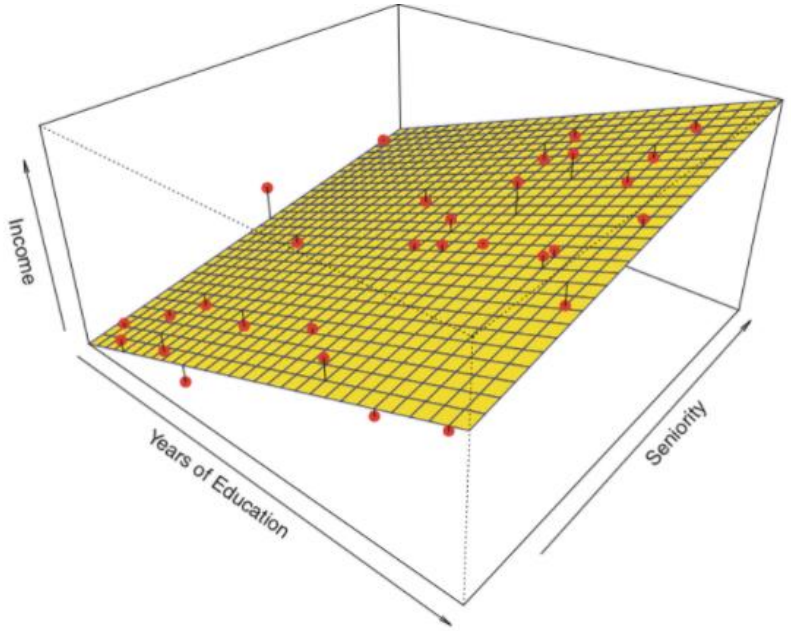
- **Model**: the best fitting line

  $$\text{weight} = -222.5 + 5.49\ \text{height}$$

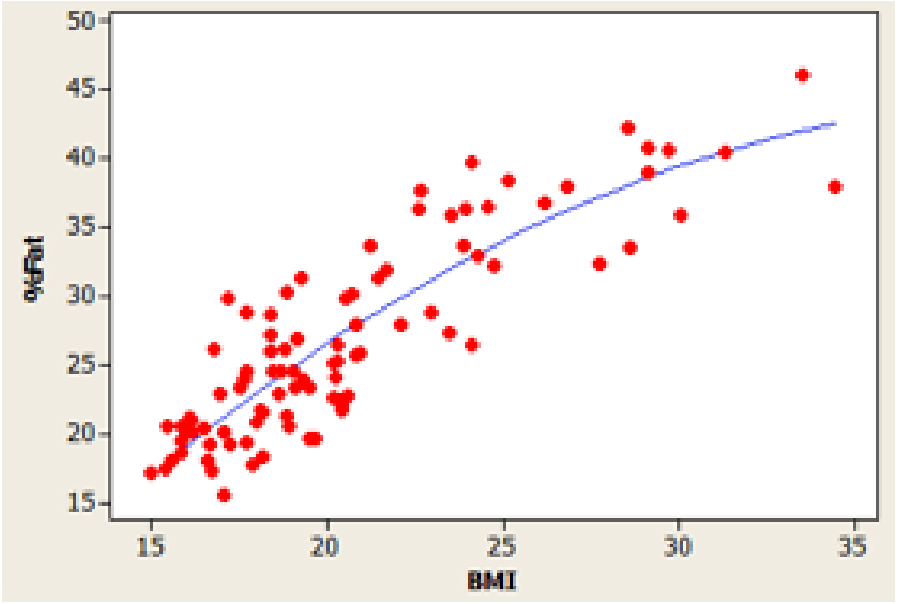


Linear & Nonlinear Regression

- Linear Regression: 2 features and 1 target (left)
- Nonlinear regression: 1 feature and 1 target (right)



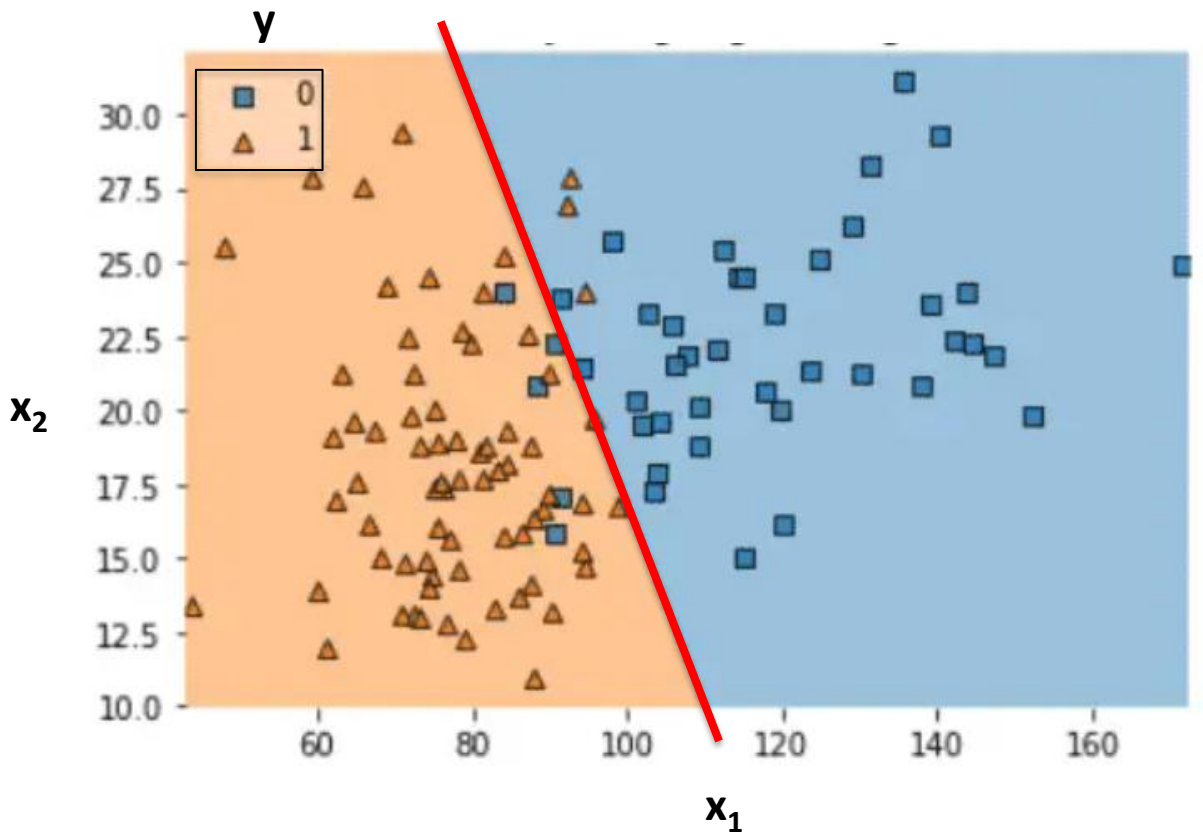
Source: James et al. *Introduction to Statistical Learning* (Springer 2013)



Source: the minitab blog

Logistic Regression

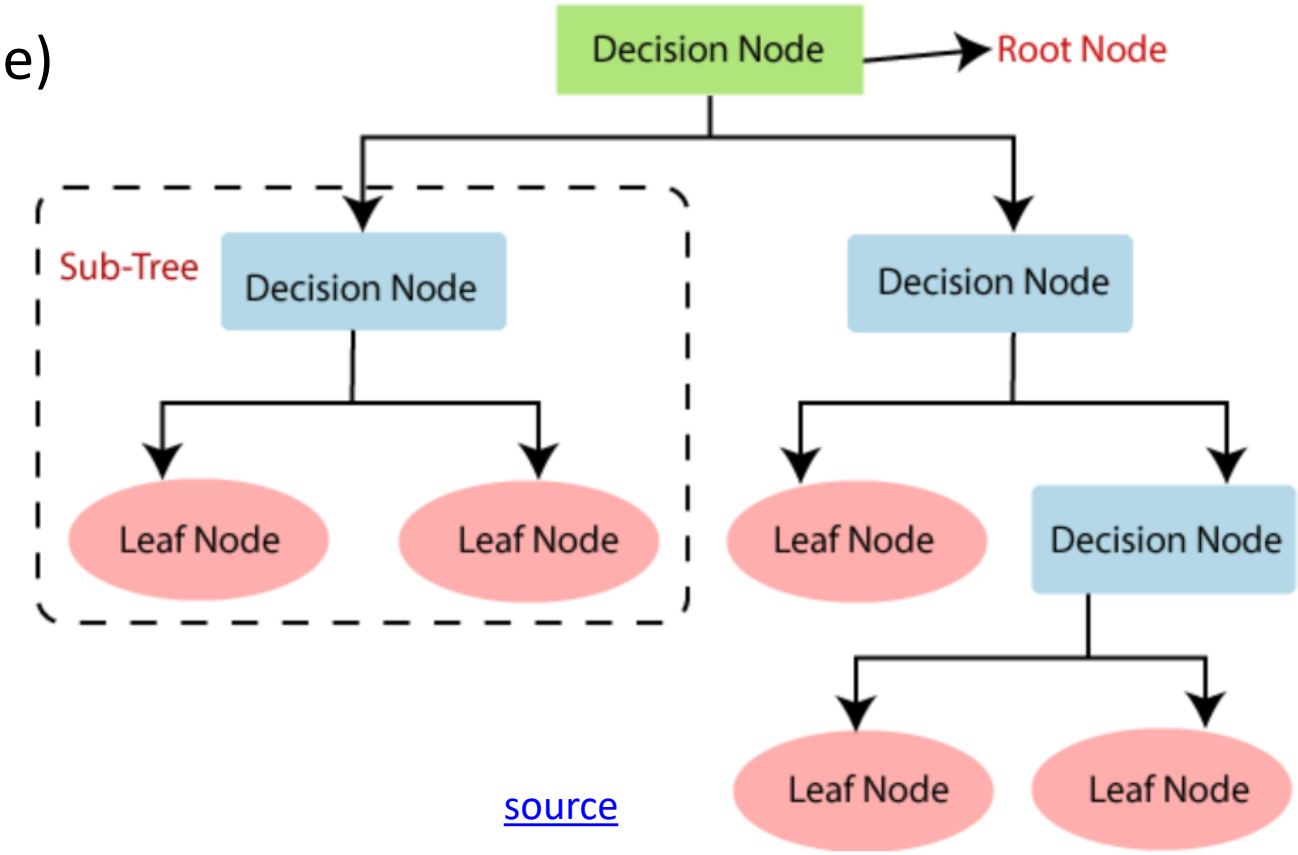
- Regression for binary targets
- Features x_i and target y
- Main task: find a separating straight line
  = binary classification
- N dimensions: separating hyperplane



source: https://www.jcchouinard.com/logistic-regression/

Decision Trees

- Very popular data mining methods
- High interpretability/explainability (e.g.medicine)
- Efficient learning and prediction procedures
- Classification (regression is also possible)



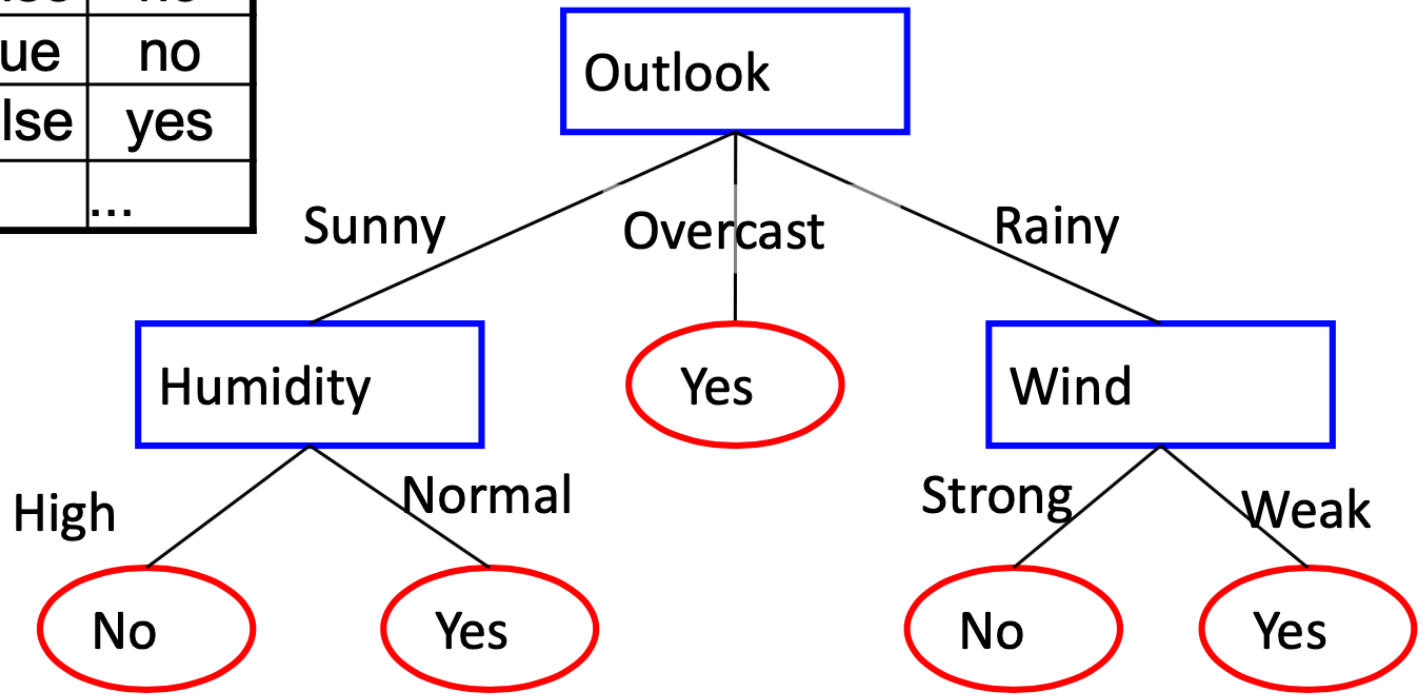
source

Decision Tree: Example

- Play tennis or not? (depending on weather conditions)

Outlook	Temp.	Hum.	Wind	Play?
Sunny	85	85	False	no
Sunny	80	90	True	no
Overcast	83	86	False	yes
...	...	...	...	...

- Leaf nodes versus internal nodes
  = labels = features

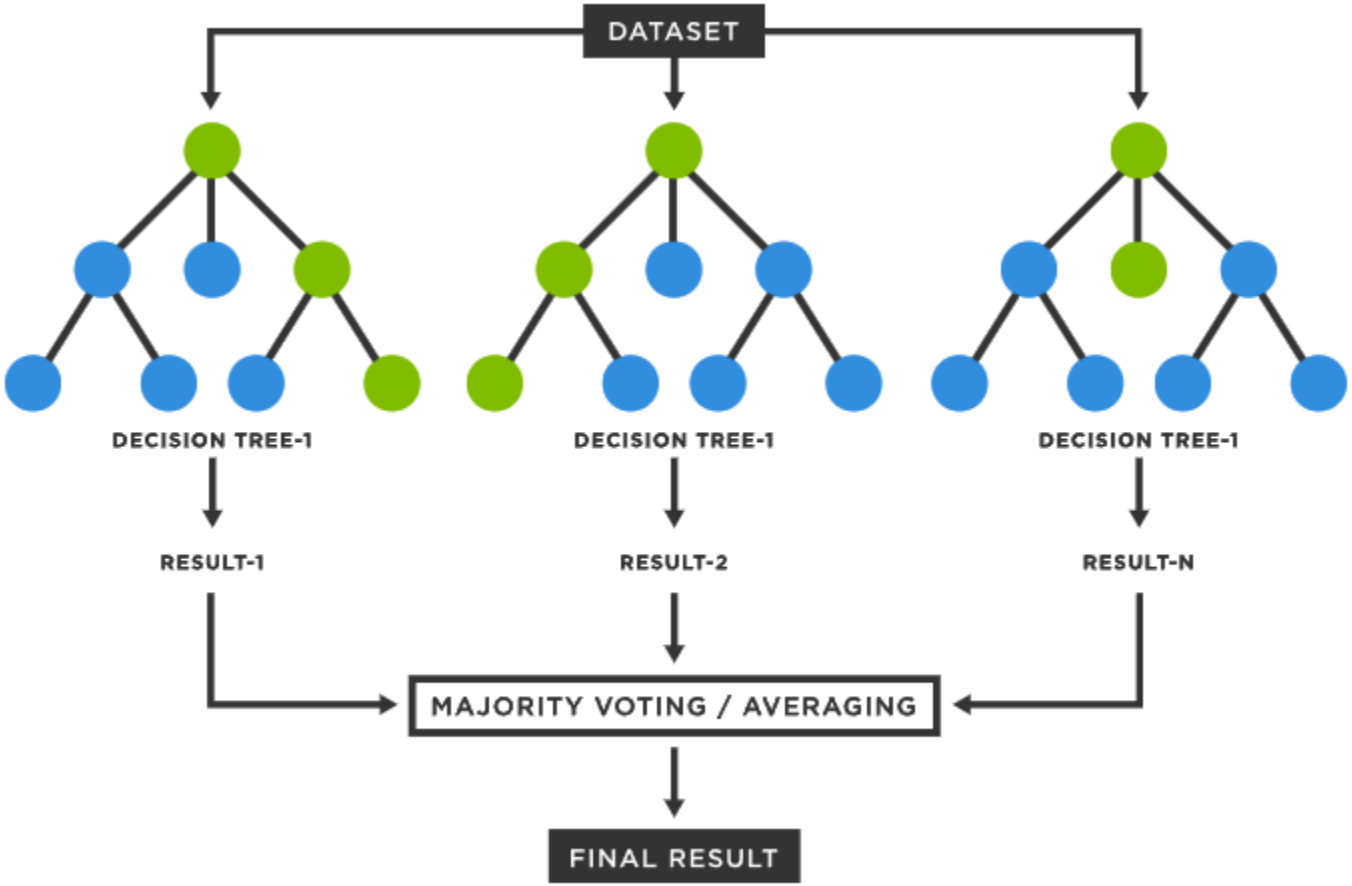


Random Forests

= Ensemble of decision trees

- Each tree is trained on a random subset (= **bagging**)

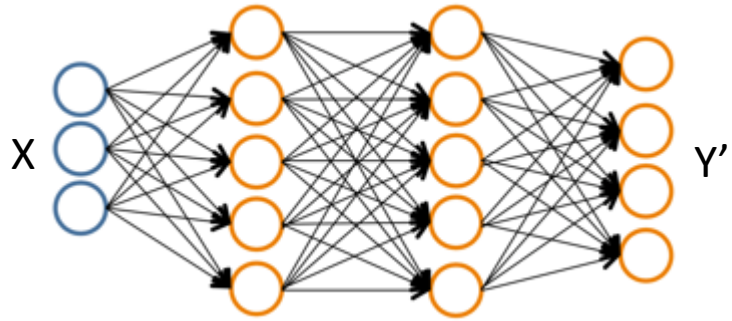
- Voting mechanism:
  - Classification: majority voting
  - Regression: averaging

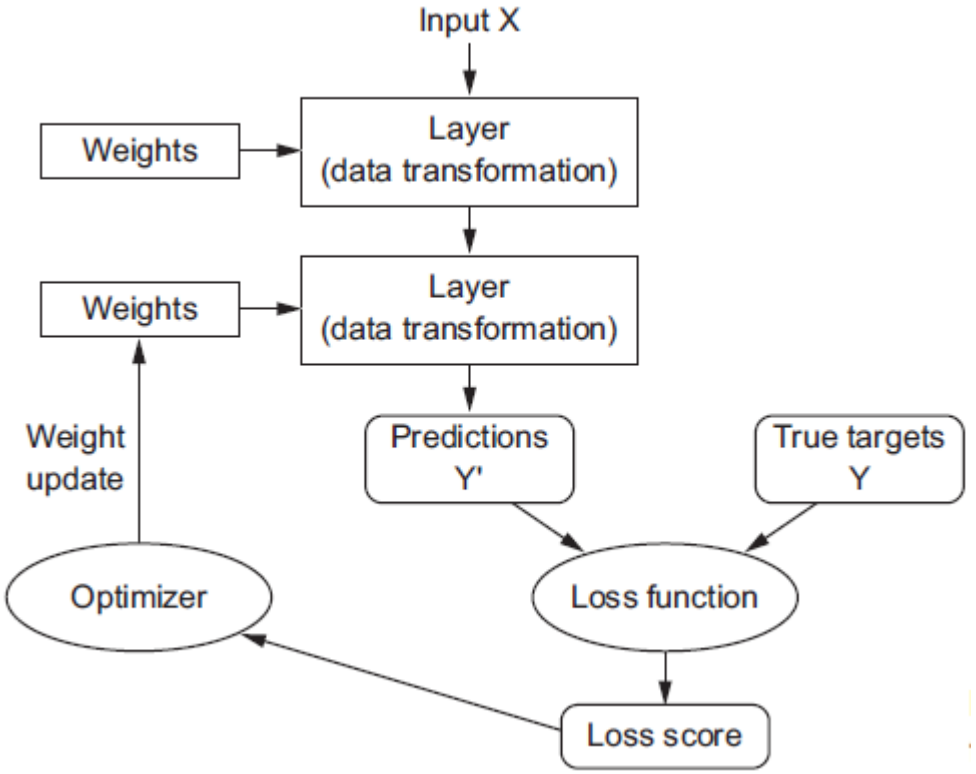


https://www.spotfire.com/glossary/what-is-a-random-forest

Artificial Neural Network

- Regression or classification
- Features X and targets Y
- Loss: function quantifying differences
  between targets Y and predictions Y’
- Optimization: find optimal weights
  that minimize the loss





Cocktail example

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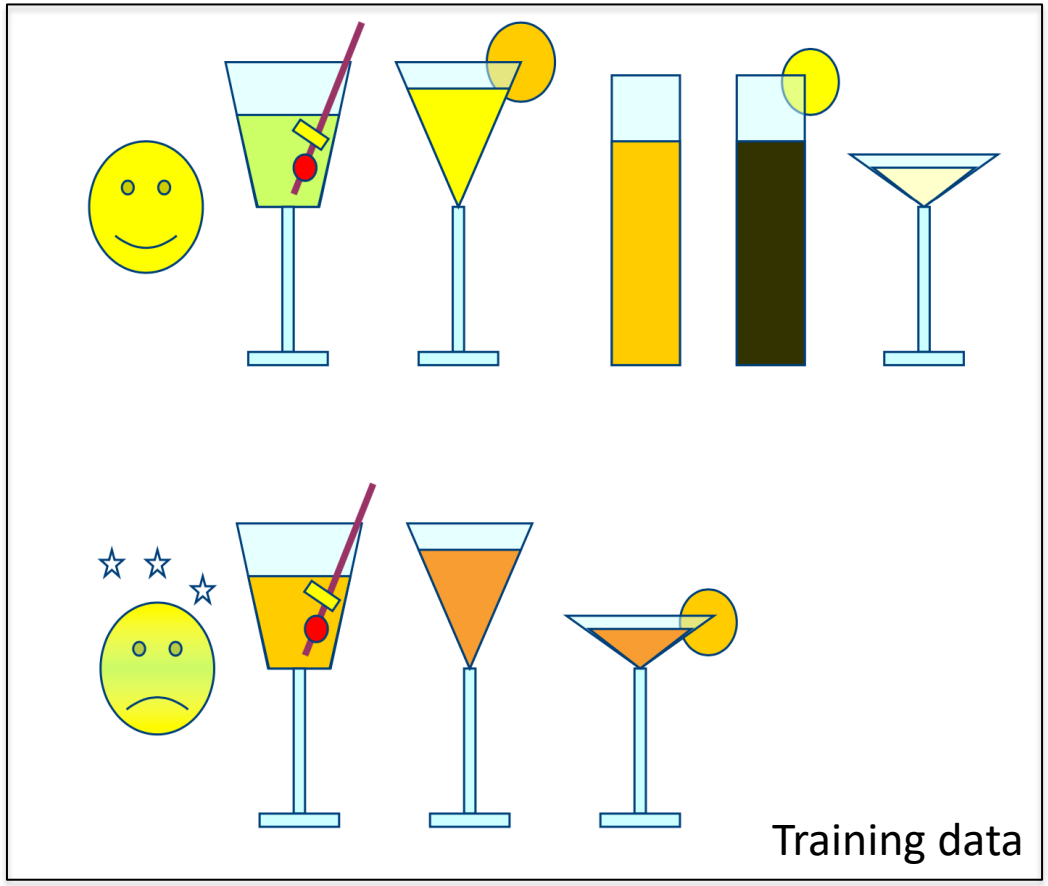
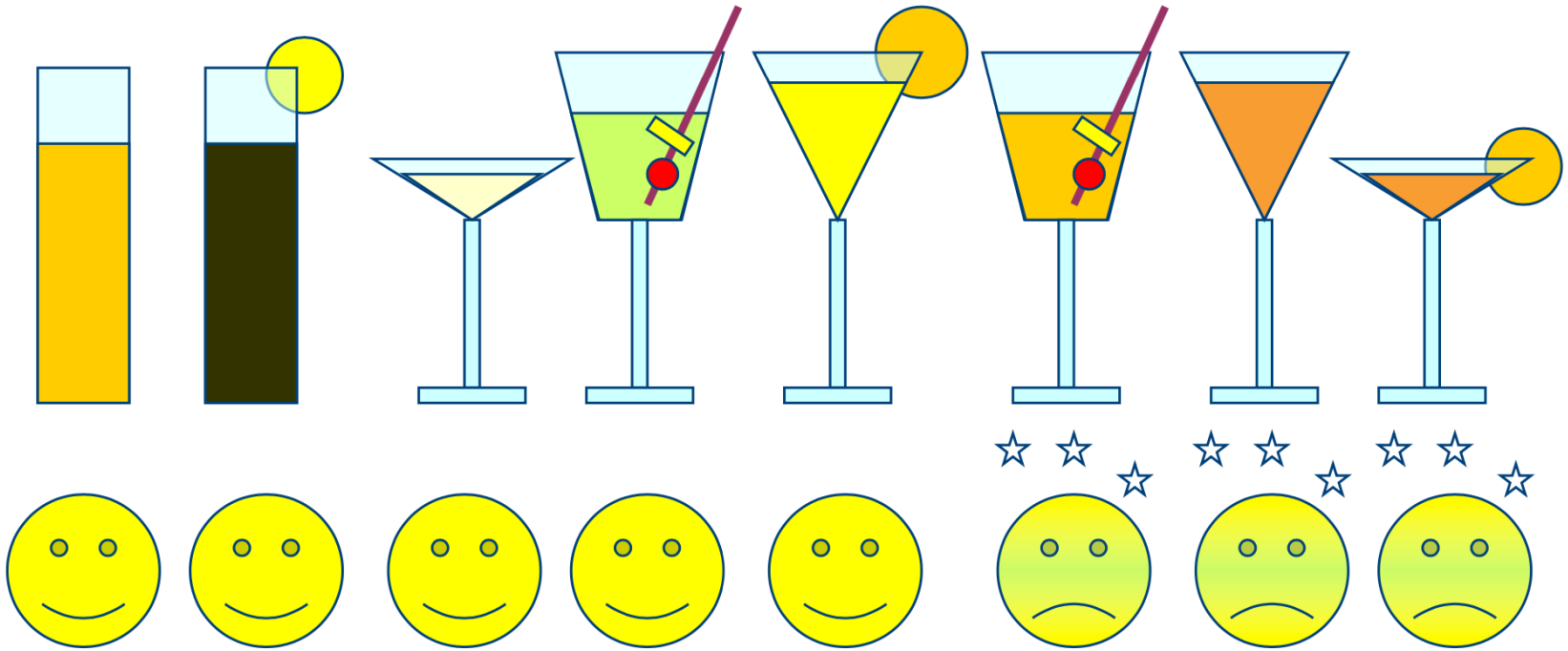
How to create a decision tree?



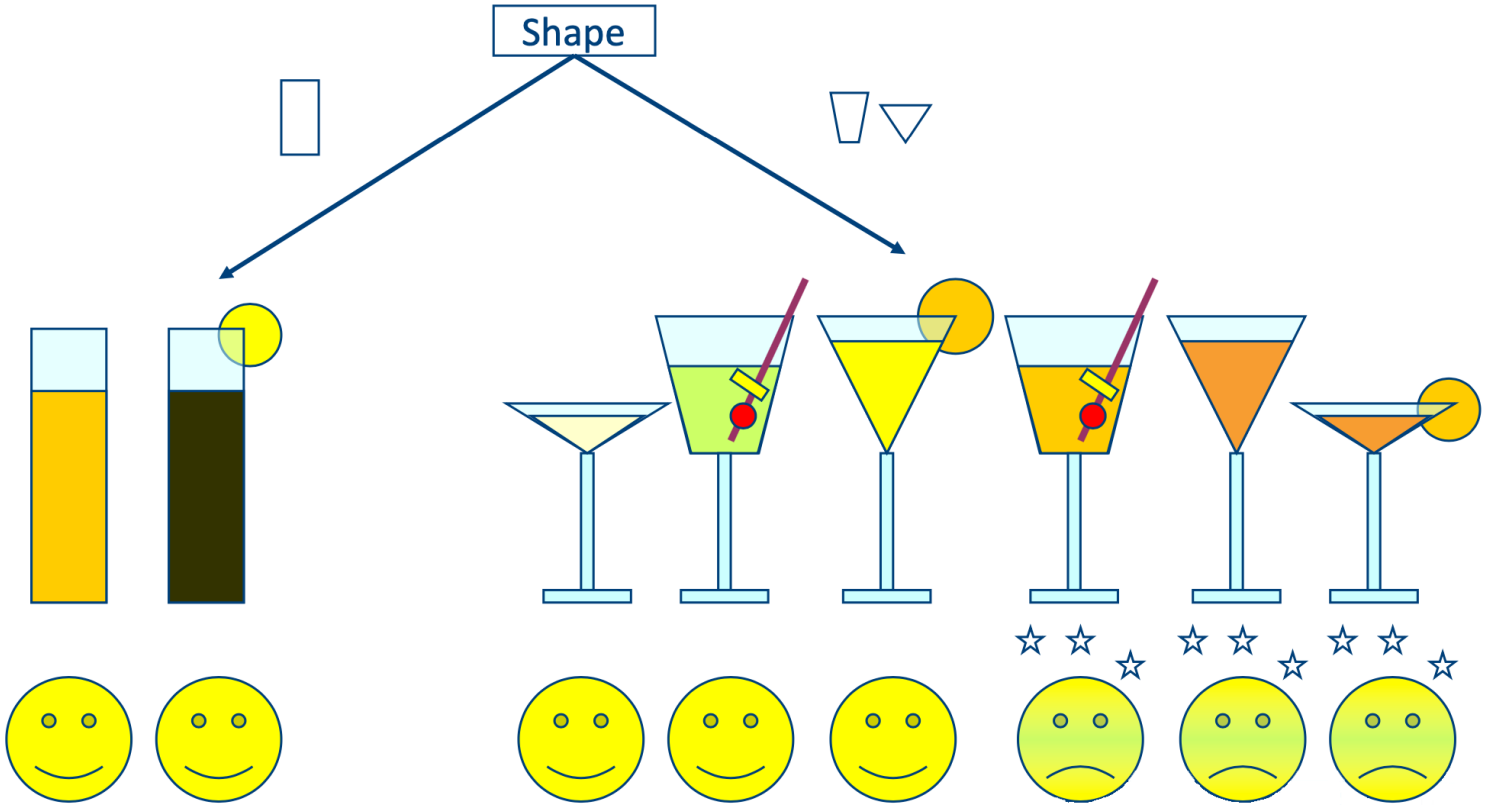
How to create a decision tree?

Step 0: exploring the full dataset



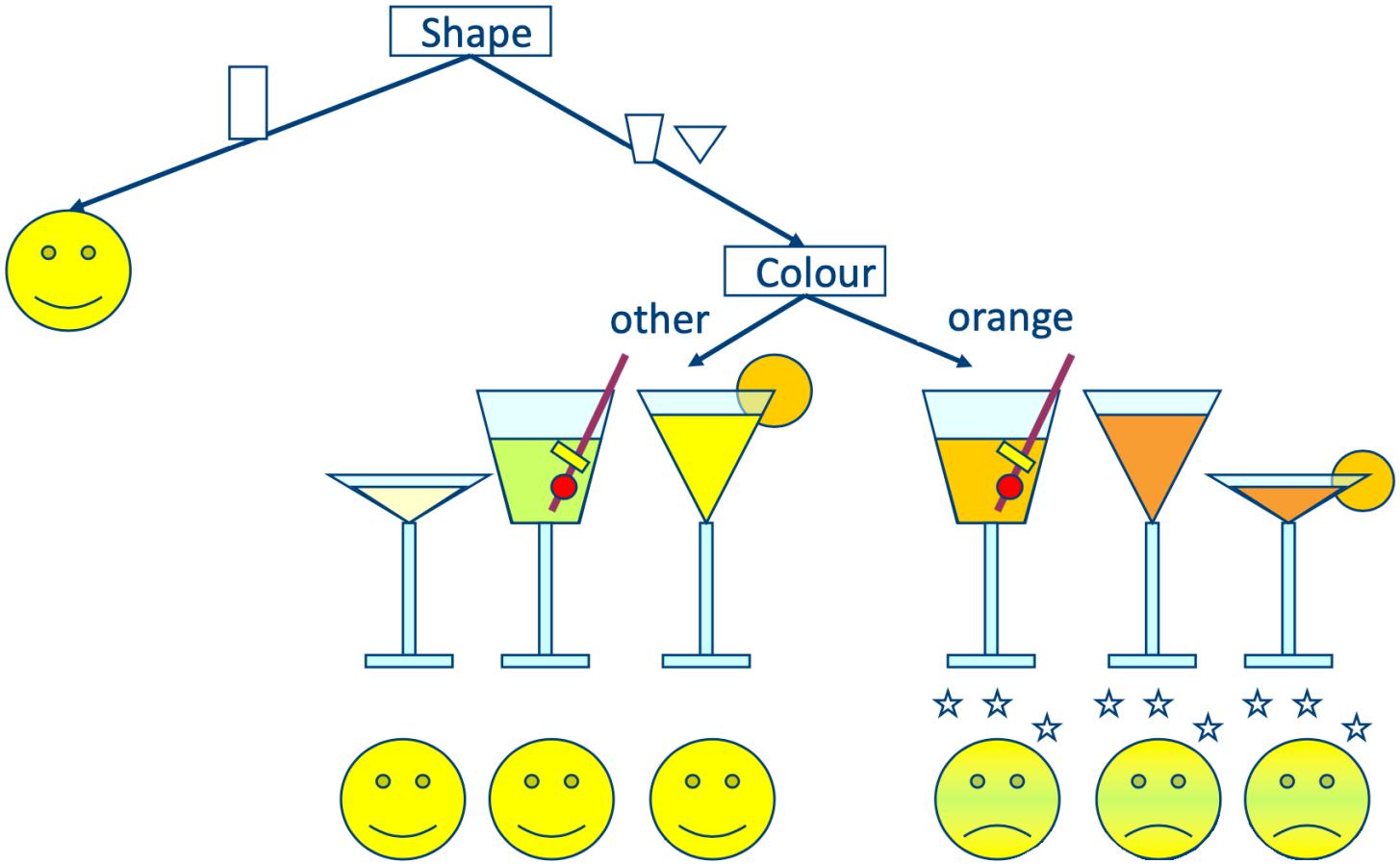
How to create a decision tree?

Step 1: splitting the dataset based on the shape of the glasses



How to create a decision tree?

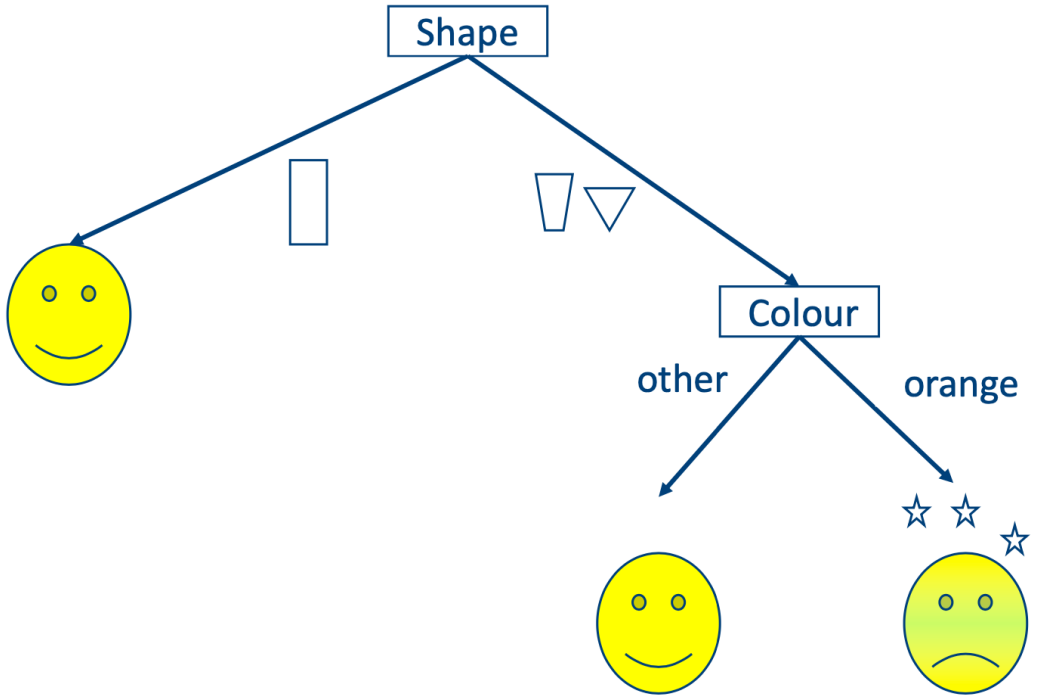
Step 2: splitting the subset of non-rectangular glasses based on the cocktail <u>color</u>

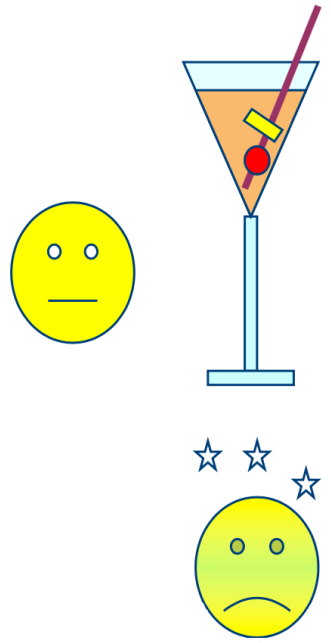


How to use the decision tree to make predictions?

Predict: applying the trained decision tree to the new cocktail:

(1) The glass is not rectangular and (2) the color is orange. so we'll get sick!





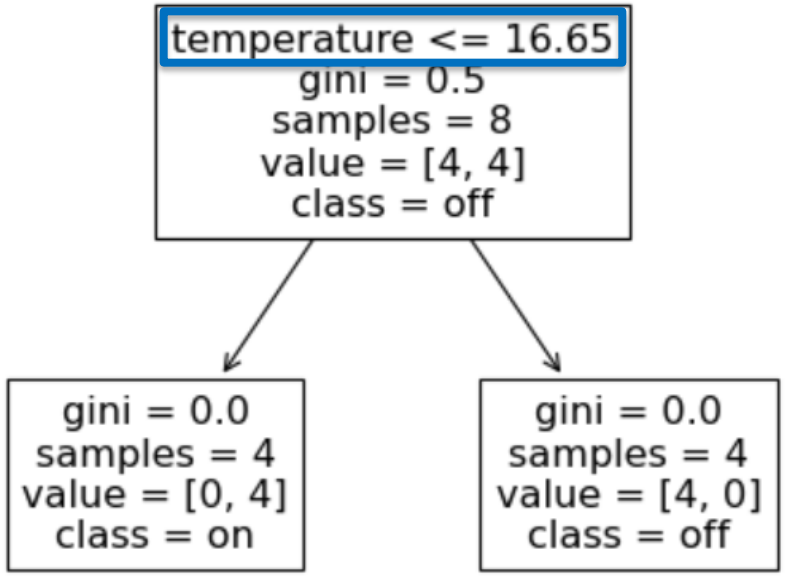
Thermostat example

Decision Tree

```
from sklearn.tree import DecisionTreeClassifier, plot_tree
model = DecisionTreeClassifier()   # instantiate
model.fit(table[['temperature']].values, table.heating=='on')  # fit data
model.predict([[17.0]]).item()  # predict label for new temperature value
```

```
False
```

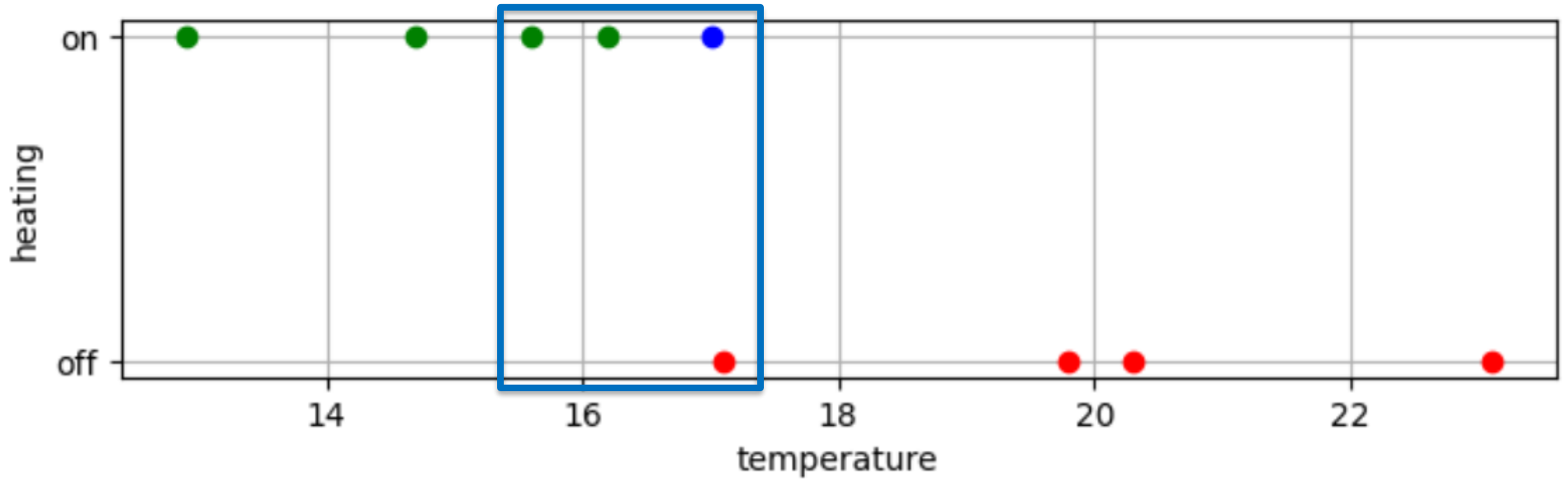
```
# plot the resulting decision tree
plot_tree(model, feature_names=['temperature'], class_names=['off', 'on']);
```



K Nearest Neighbors

```
from sklearn.neighbors import KNeighborsClassifier
model = KNeighborsClassifier(n_neighbors=3)  # instantiate with K = 3
model.fit(table[['temperature']].values, table.heating=='on')  # fit data
model.predict([[17.0]]).item()  # predict label for new temperature value
```

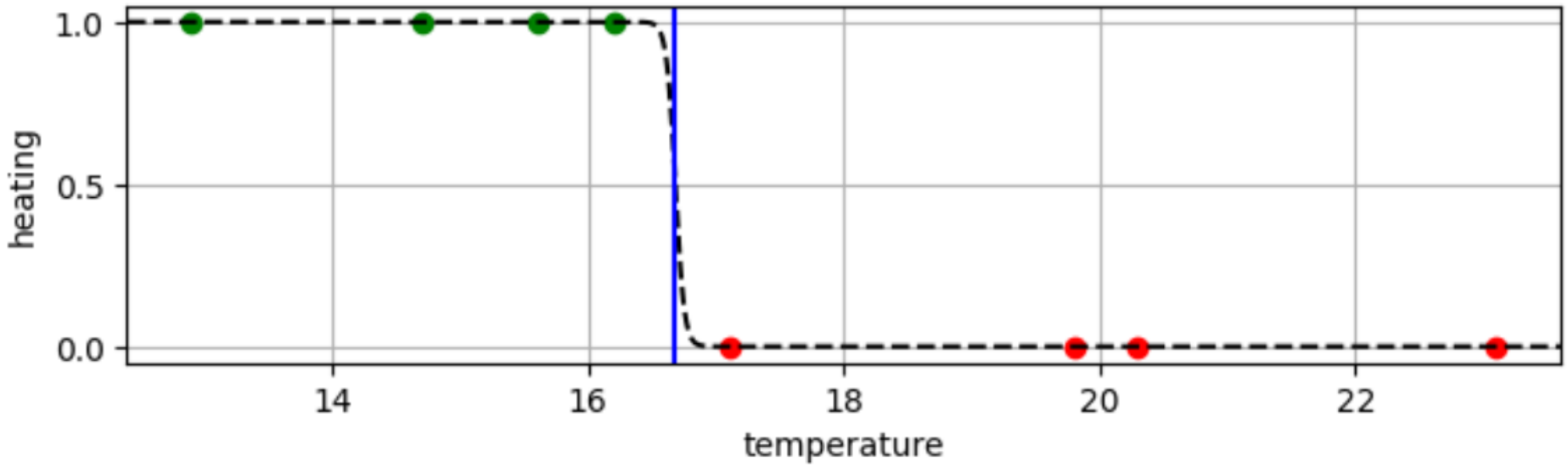
```
True
```



Logistic Regression

```
from sklearn.linear_model import LogisticRegression
model = LogisticRegression(penalty=None)  # instantiate
model.fit(table[['temperature']].values, table.heating=='on')  # fit data
threshold = -model.intercept_.item() / model.coef_.item()  # determine threshold
print(f'threshold is {threshold}°C')
model.predict([[17]]).item()  # predict label for new temperature value
```

```
threshold is 16.681991552397978°C
False
```



Guest Lectures at TTK University of Applied Sciences, Tallinn, Estonia

Introduction to Machine Learning

TRAINING AND EVALUATION

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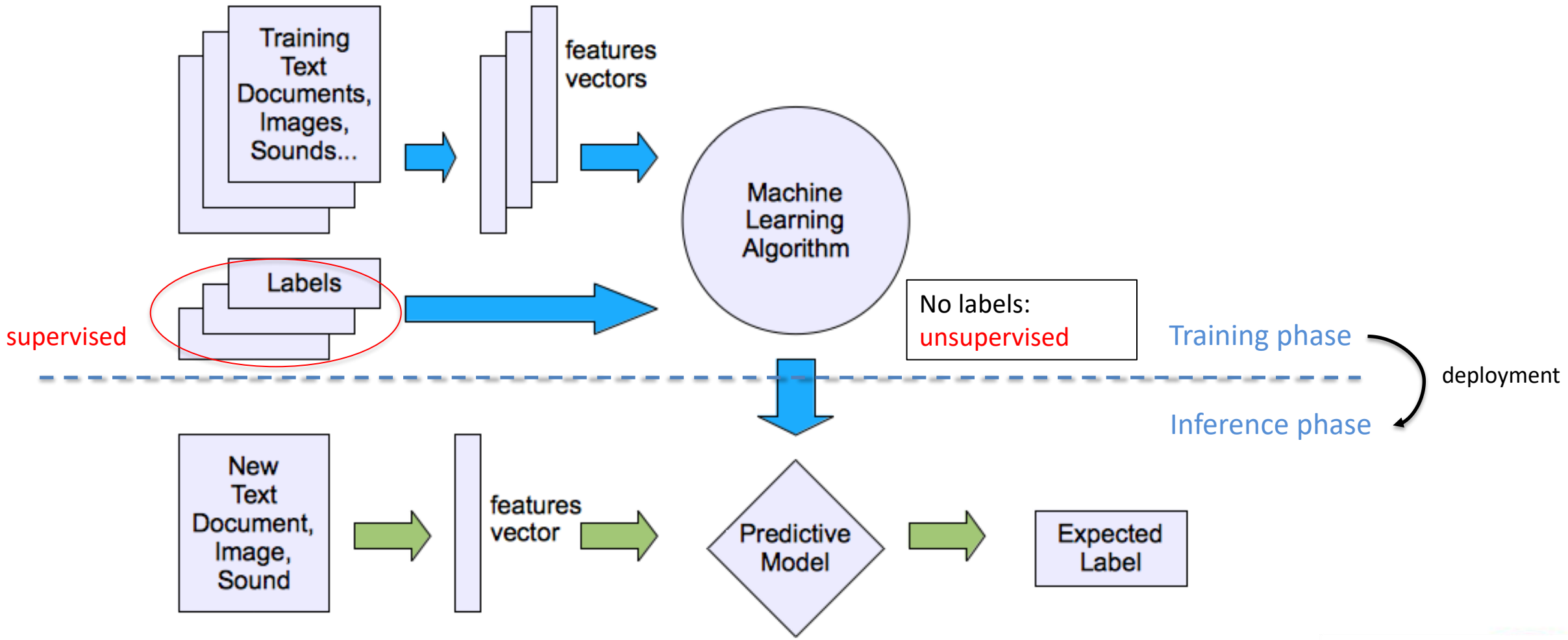
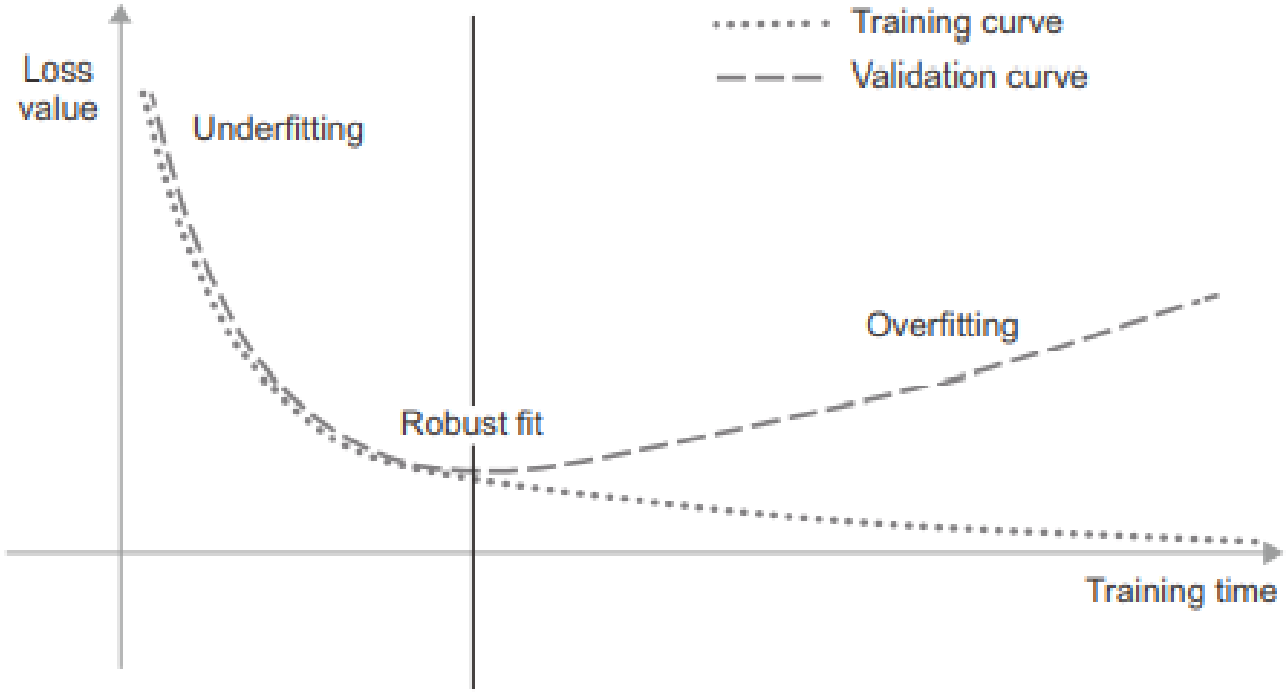
Training vs Inference



Optimization vs Generalization

- **Optimization:** fitting the data as best as possible during training
- **Generalization:** good model performance on new data during inference



Underfitting vs Overfitting

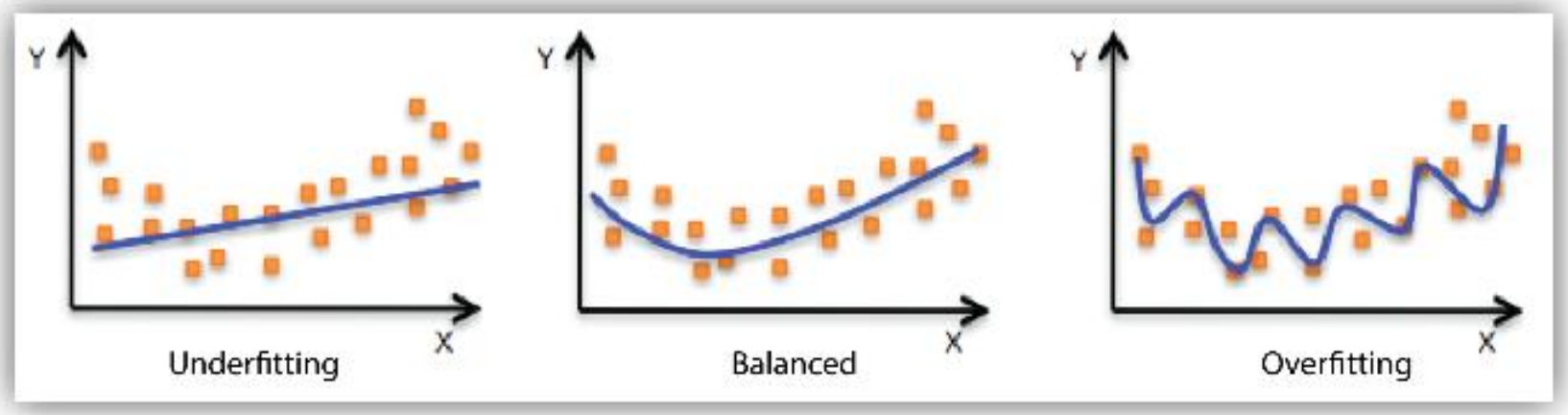
- **Underfitting:**

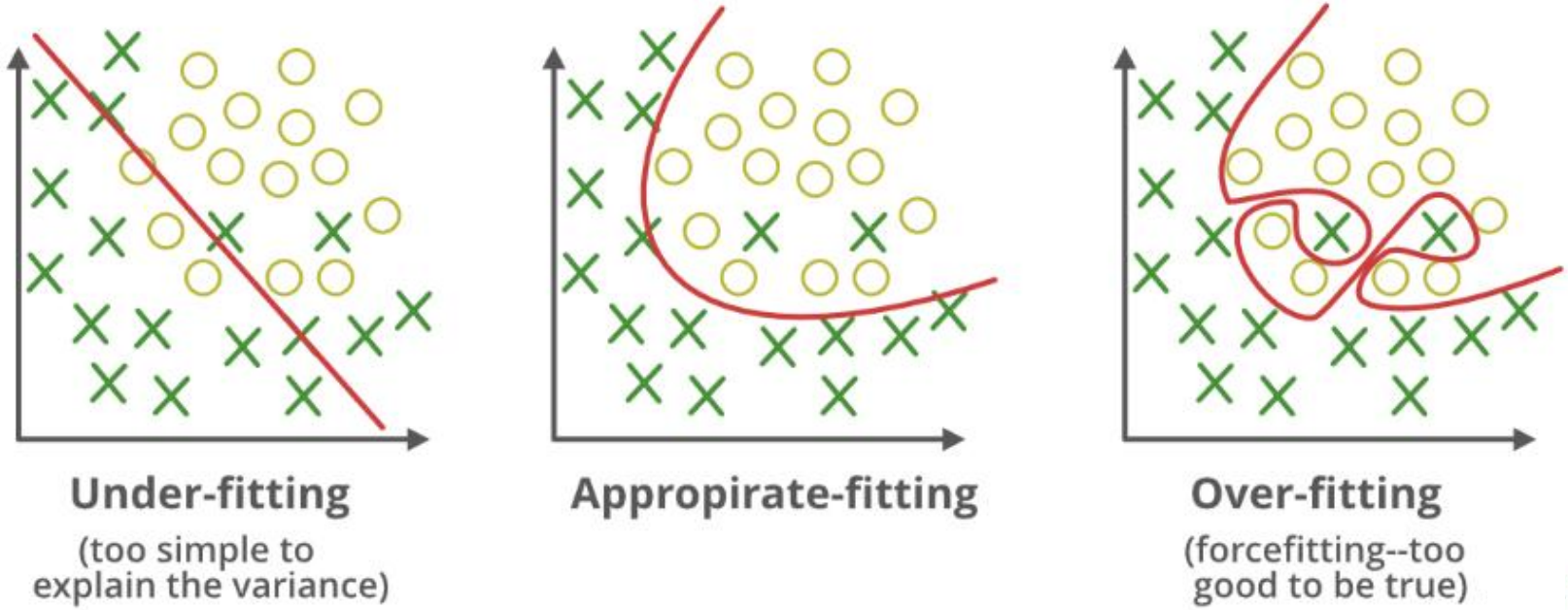
  model is too simple

- **Overfitting:**

  model is too specific

  Causes:
  - Noise
  - Uncertainty
  - Rare features
  - …

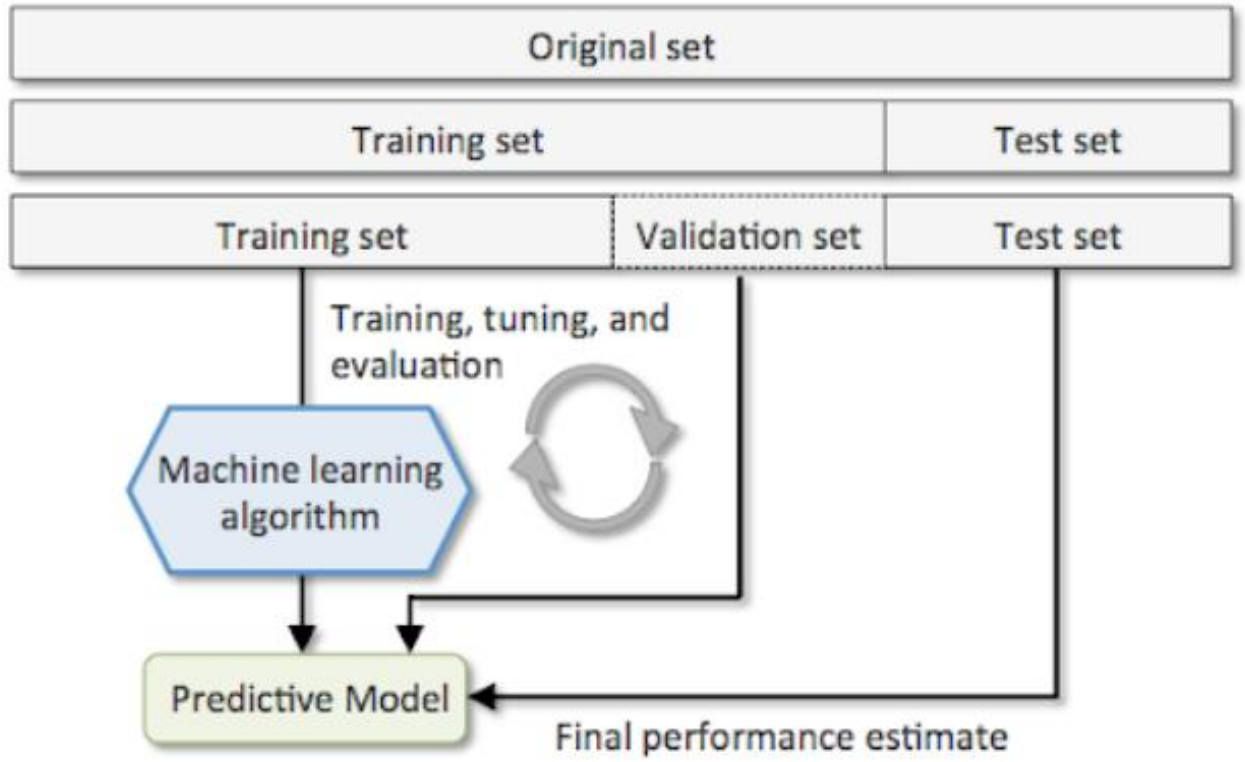




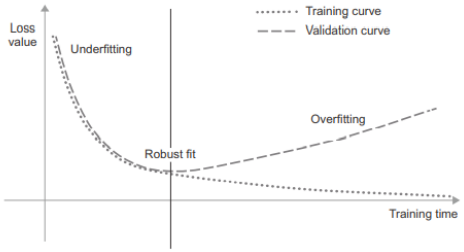
Training, Validating, and Testing

Splitting the dataset:

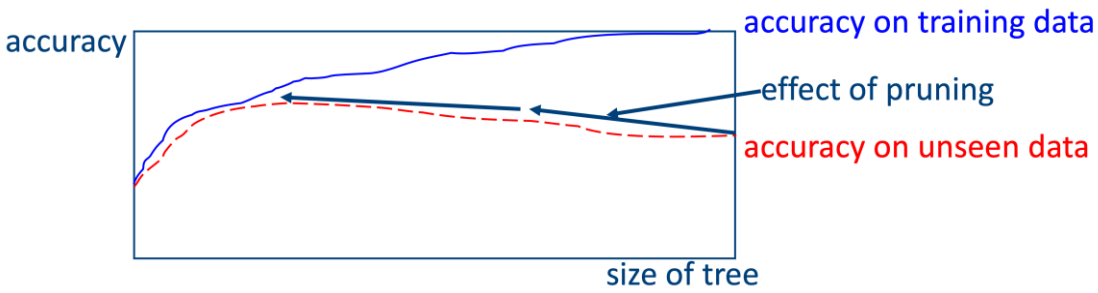
- **training**:
  - deriving the optimal model parameters
  - by the machine learning algorithm
- **validating**:
  - finding the optimal model configuration
  - tuning the hyperparameters
  - to overcome overfitting
  - by the data scientist
- **testing**:
  - final evaluation
  - by the data scientist



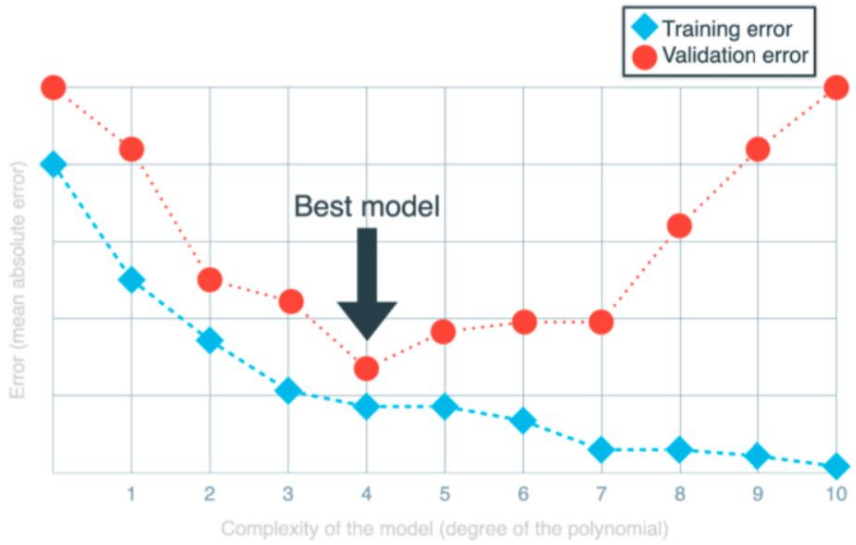
Training vs Validation Performance



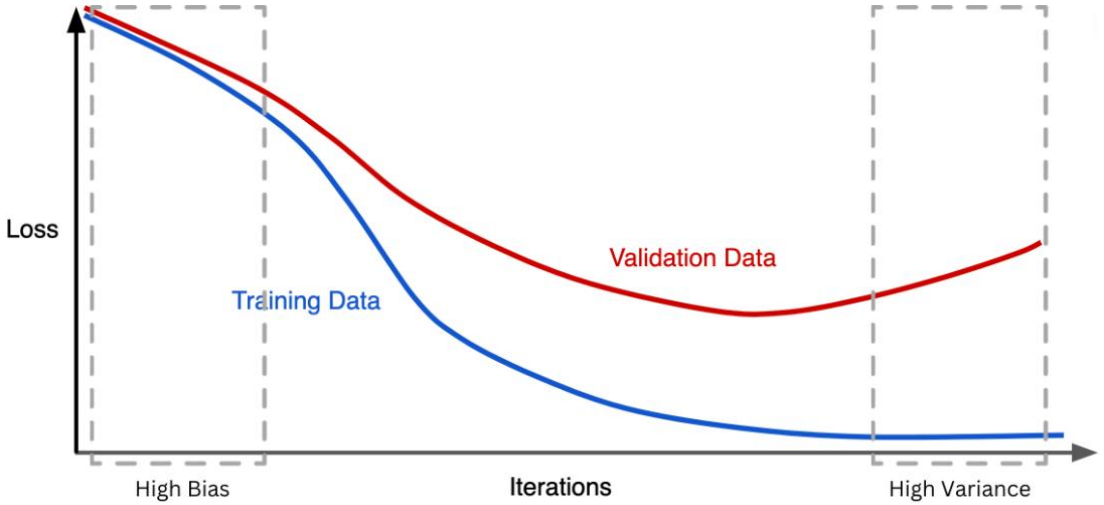
- **Decision Trees**



- **Polynomial Regression**



- **Artificial Neural Networks**



(source: https://www.dataquest.io/blog/regularization-in-machine-learning)

Model Evaluation

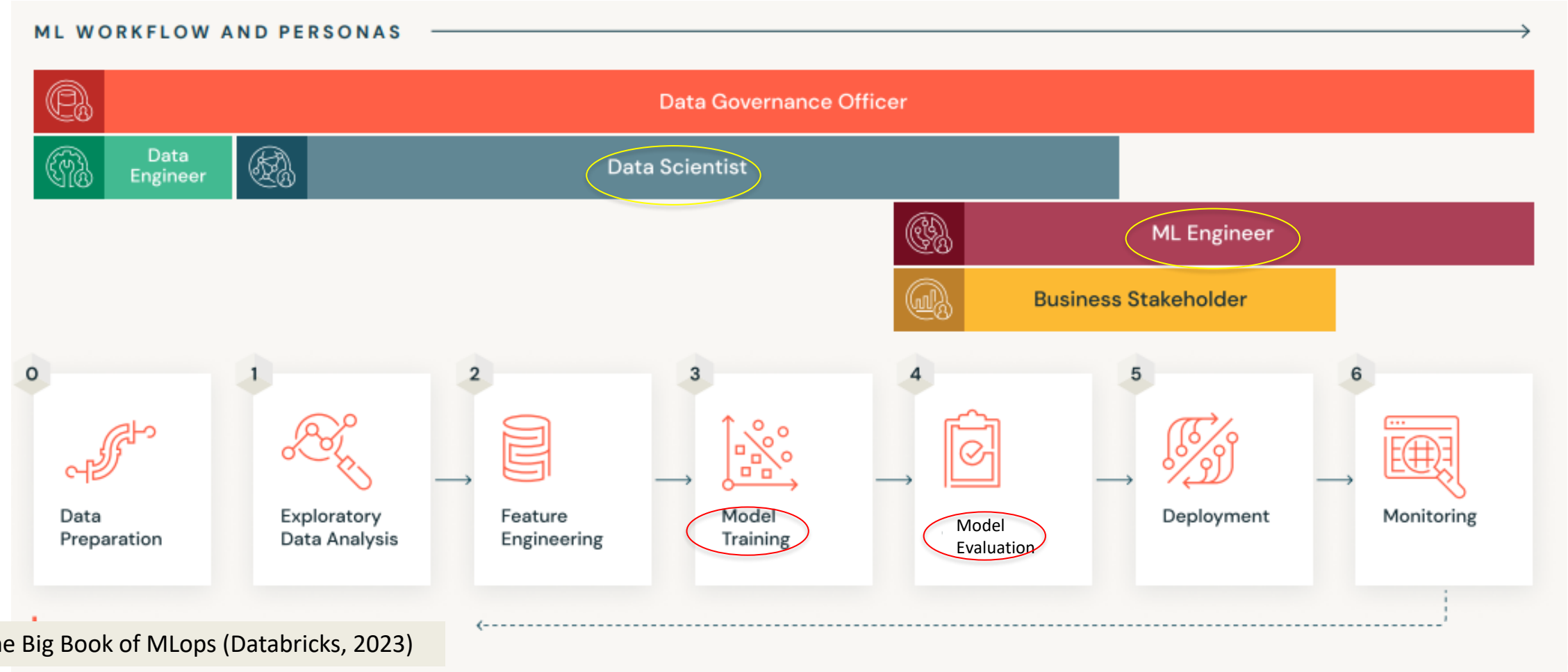
- **Loss functions:**
  - Compare predictions and true target values
  - Minimized by machine learning algorithms to obtain the best fit of the data
  - Should be mathematically convenient

- **Evaluation metrics:**
  - Also compare predictions and true target values
  - Used by machine learning engineers to evaluate the model performance
  - Easier to interpret by humans

Common Loss Functions and Metrics

Task	Loss	Metric
Regression	**Mean Squared Error (MSE)** = mean of the squared differences between predictions and targets	**Root Mean Squared Error (RMSE)** = square root of MSE
	Mean Absolute Error (MAE) = mean of the absolute differences between predictions and targets	**Coefficient of Determination (R^2)** = number between 0 and 1 expressing the goodness of fit where 1 indicates a perfect fit
Classification	**Cross-Entropy or Log Loss** quantifies the difference between the predicted probabilities and the true labels	**Accuracy** = the number of correct predictions divided by the total number of samples

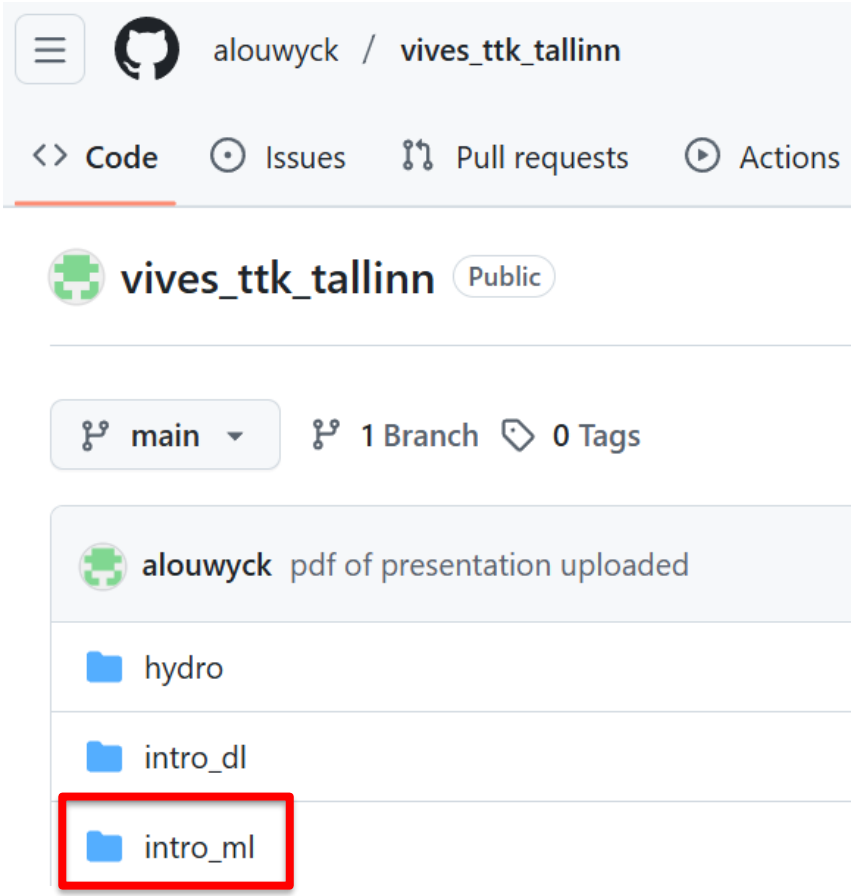
Machine Learning Workflow



The Big Book of MLops (Databricks, 2023)

GitHub Repo

https://github.com/alouwyck/vives_ttk_tallinn



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Sources

- Many slides are based on the book “Grokking Machine Learning” by Luis G Serrano (2021)
- Other slides are inspired by the book “Deep Learning with Python (2nd edition)” by François Chollet (2021)
- Some slides are adopted from the presentation on machine learning that was part of the course “Introduction to Artificial Intelligence” taught by Dr. Stefaan Haspeslagh at the Vives University of Applied Sciences during the academic year 2019-2020
- A few slides are taken from lectures given by Prof. Dr. Celine Vens and Prof. Dr. Hendrik Blockeel (Computer Sciences, KUL)
- Information was also obtained from Andrew Ng’s online course “AI for Everyone”: https://www.deeplearning.ai/courses/ai-for-everyone/
- Scikit-Learn’s User Guide was also consulted: https://scikit-learn.org/stable/user_guide.html
- Other sources are mentioned on the slides
- Perplexity.ai was used to generate some of the content