Introduction AI/ML

Main Areas of Artificial Intelligence

from wikipedia

- **computer vision**

data: spatial structures (e.g., images), SOTA: Convolutional Neural Networks (CNN)

- **natural language processing**

data: sequential structures (e.g., text), SOTA: transformers

- **automated decision making, robotics**

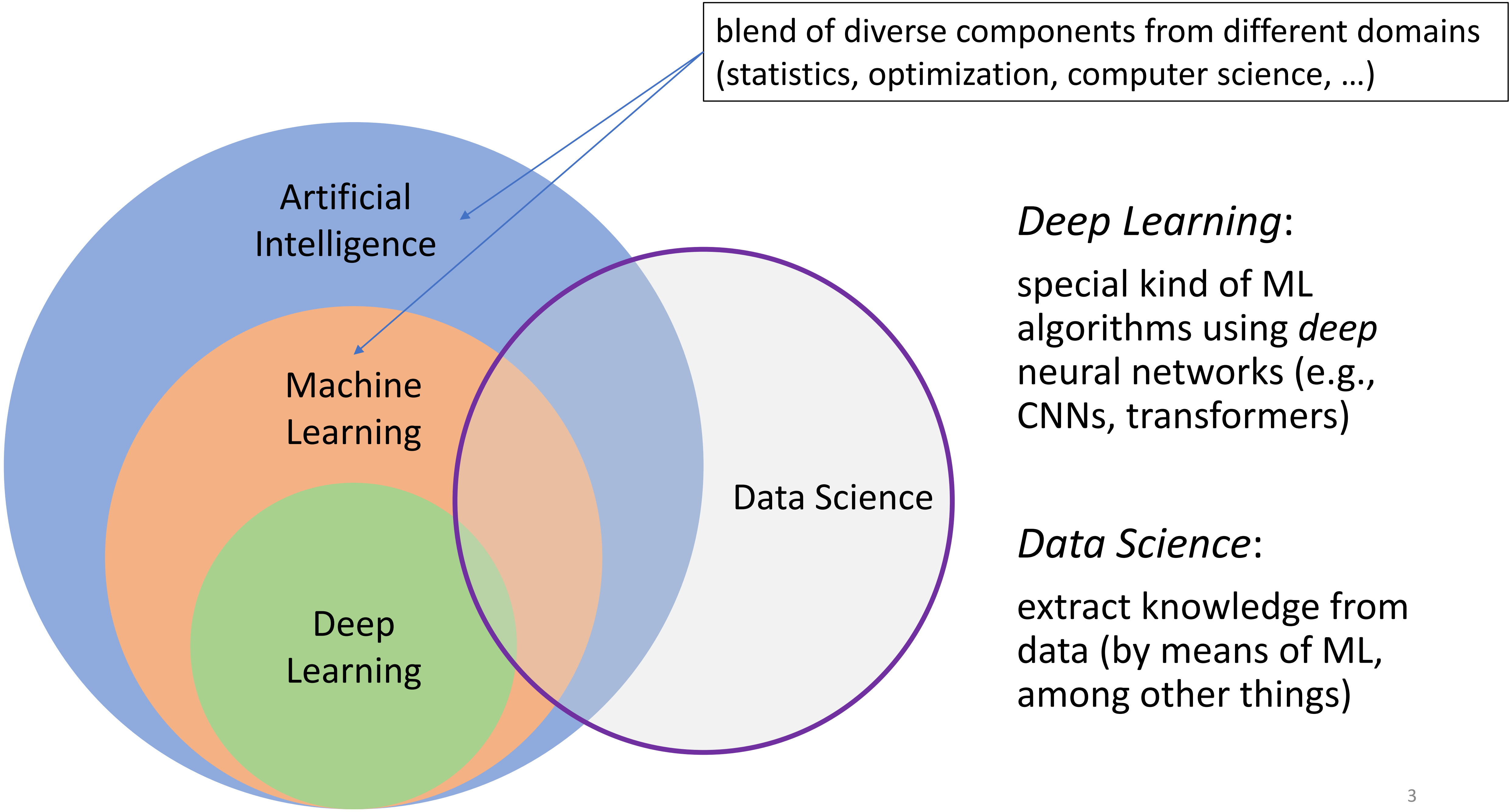
data: sequential actions (e.g., games), SOTA: reinforcement learning

agency:
perception – thought – action

All of these are enabled by one key ingredient:

learning from experience/data (**Machine Learning**)

data can also be tabular (structured): columns as features, rows as independent samples



Deep Learning:

special kind of ML algorithms using *deep* neural networks (e.g., CNNs, transformers)

Data Science:

extract knowledge from data (by means of ML, among other things)

ML: Learning from Experience/Data

mainly exploiting statistical dependencies with the aim of **generalization** to new (e.g., future) data (compare with human reasoning by analogies)

training (usually offline optimization):

ML algorithm + data = explicit algorithm (to be used at inference time)

→ reduction of complexity and much better generalizability compared to handcrafted algorithms

analogy: Humans do not hit the ground running (storage capacity of DNA limited) but have learning capabilities.

Ladder of Generalization

shallow learning:

representation encoded in features

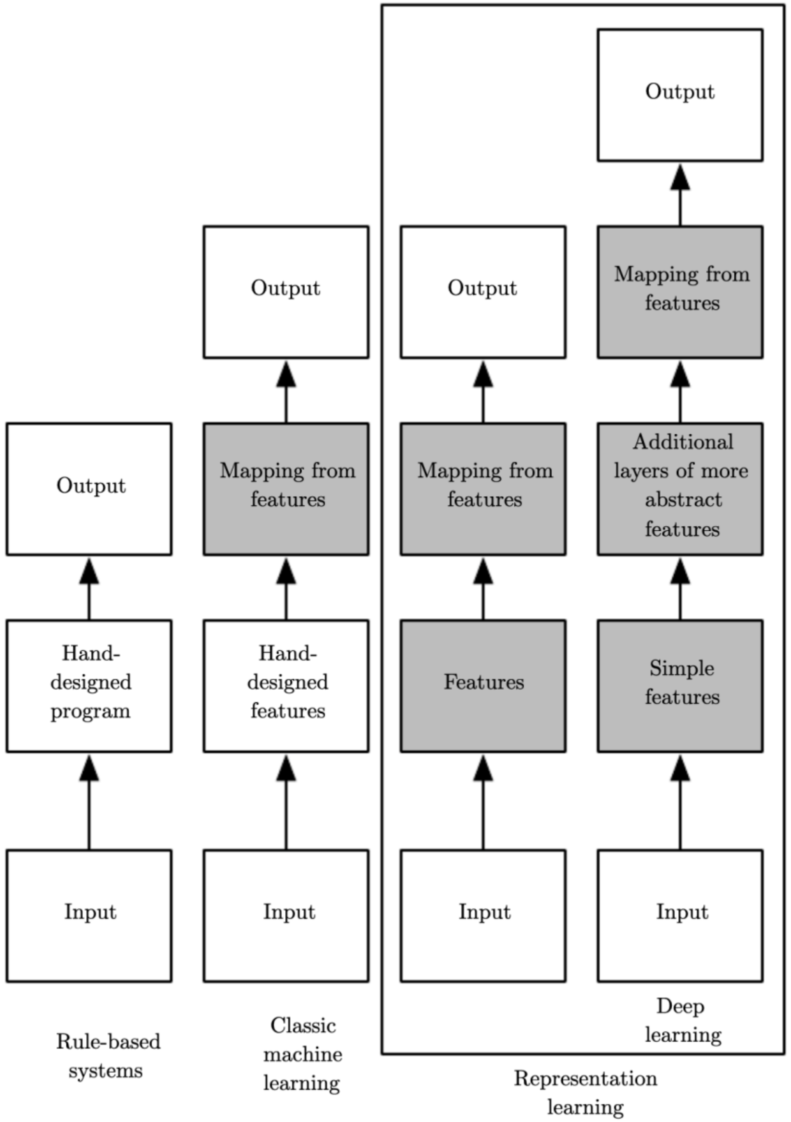
→ feature engineering

deep learning:

representation encoded in network

→ feature/representation learning

(hierarchy of concepts learned from raw data in deep graph with many layers)

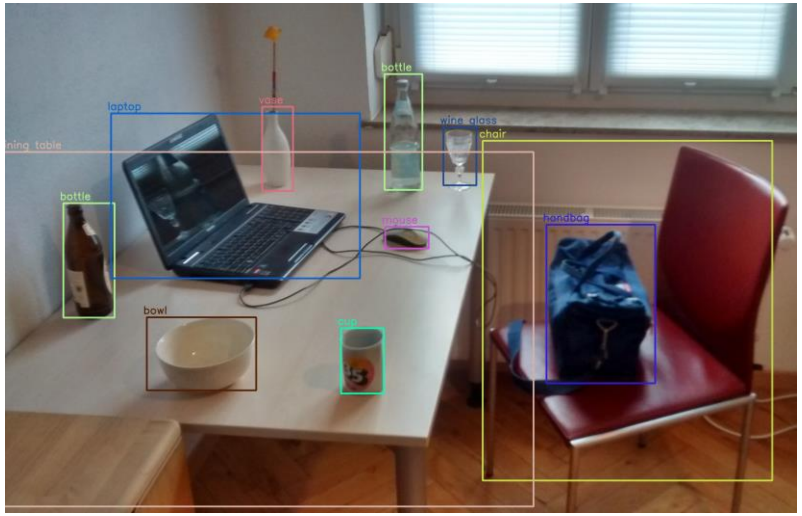


source

When to Use ML (= Learning from Data)

automation

too complex for rules



from wikipedia

object recognition, chat bot, …

complexity / uncertainty

too complex for humans

AlphaFold

protein structure predictions, demand forecasting, …

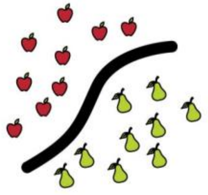
more scientific use cases: medicine (imaging, diagnosis, drug design), particle physics (analysis of collider experiments), material science (material properties and design of new materials), …

MACHINE LEARNING

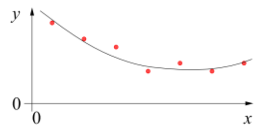
training target available (labeled or past data)

SUPERVISED

CLASSIFICATION



REGRESSION



data not labeled in any way

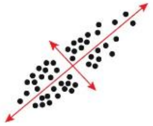
UNSUPERVISED

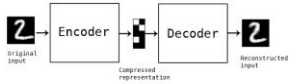
CLUSTERING

ASSOCIATION

GENERATIVE MODELS

DIMENSIONALITY REDUCTION





no supervision, but goal-based interaction with environment

REINFORCEMENT LEARNING

LEARN STATE OR ACTION VALUES

LEARN POLICY DIRECTLY

learning by teacher
(high-dimensional curve fitting)

learning by observation
(pattern recognition)

learning by trial-and-error
(sequential decision making)

unsupervised and reinforcement learning can both be cast as supervised-learning setup

Supervised Learning

learning by teacher → usually rather narrow tasks (passive approach)

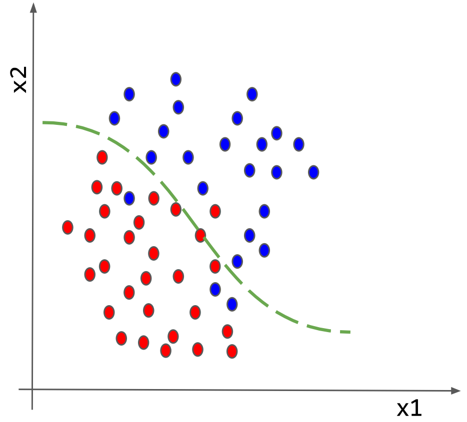
Target Quantity

- **known in training**: labeled samples or observations from past
- to be **predicted** for unknown cases (e.g., future values)

Features

input information that is

- correlated to target quantity
- known at prediction time



Example: Spam Filtering

Classify emails as spam or no spam

*use accordingly **labeled emails as training set***

use information like **occurrence of specific words** or **email length** as **features**

features x1 and x2

spam, no spam

But Before: Data Processing

environment:

[WSL](), [Python](), [virtualenv](), [pip]()

scientific Python stack:

[NumPy](), [pandas](), [matplotlib]()

coding example: stock market data