

Ringvorlesung AI

1: Introduction

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Summer Semester 25

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“Artificial intelligence is the science of making machines do things that would require intelligence if done by men.” – Marvin Minsky

“Artificial intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs.” – John McCarthy

“Artificial intelligence is a field of study and technology focused on creating machines and computer systems that can exhibit human-like intelligence.” – Yoshua Bengio

“I believe that deep learning will allow us to build AI systems that can understand and interact with the world in a way that is far beyond what is possible with current technology.” – Geoffrey Hinton

Intelligence

Definition (human intelligence)

mental quality that consists of the abilities to learn from experience, adapt to new situations, understand and handle abstract concepts, and use knowledge to manipulate one's environment.

Source: Britannica <https://www.britannica.com/science/human-intelligence-psychology>

Definition (artificial intelligence (AI))

the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience.

Source: Britannica <https://www.britannica.com/technology/artificial-intelligence>

Turing Test



Eliza

Welcome to

EEEEE	LL	III	ZZZZZ	AAAAA
EE	LL	II	ZZ	AA AA
EEEEE	LL	II	ZZZ	AAAAAAA
EE	LL	II	ZZ	AA AA
EEEEE	LLLLL	III	ZZZZZ	AA AA

Eliza is a mock Rogerian psychotherapist.

The original program was described by Joseph Weizenbaum in 1966.

This implementation by Norbert Landsteiner 2005.

ELIZA: Is something troubling you ?

YOU: Men are all alike.

ELIZA: What is the connection, do you suppose ?

YOU: They're always bugging us about something or other.

ELIZA: Can you think of a specific example ?

YOU: Well, my boyfriend made me come here.

ELIZA: Is it important to you that your boyfriend made you come here ?

YOU: He says I'm depressed much of the time.

ELIZA: I am sorry to hear that you are depressed.

YOU: It's true. I am unhappy.

ELIZA: Can you explain what made you unhappy ?

YOU:

Eliza built into Emacs

Try out Alt M-x doctor

Simulating Eliza with ChatGPT – I /II

- » Please simulate an Eliza session as of the 60's (Weizenbaum)
- « Sure! Here's a simulated ELIZA session in the style of the original 1960s program by Joseph Weizenbaum, which used Rogerian therapy techniques to reflect back and encourage users to elaborate.
- » ELIZA: Hello. I am ELIZA. How do you do? Please tell me your problem.
- » User: I've been feeling anxious lately.
- » ELIZA: I am sorry to hear that you are feeling anxious. Can you tell me more about it?
- » User: I just feel overwhelmed with work and life in general.
- » ELIZA: What about work and life makes you feel overwhelmed?
- » User: There's just so much to do, and I don't have enough time.
- » ELIZA: You say you don't have enough time. Could you explain that further?
- » User: Well, between my job, family, and personal projects, I can't seem to keep up.
- » ELIZA: Your job, family, and personal projects seem to be important to you. How do you feel about them?
- » User: I love them, but they also stress me out.

Simulating Eliza with ChatGPT – II /II

- » OK well done, can you assume for the time being ELIZA and I do the user prompt?
- » Sure! I'll act as ELIZA, and you can be the user. Go ahead and type your response.
- » ELIZA: Hello. I am ELIZA. How do you do? Please tell me your problem.
- » You said: Men are all alike
- » ELIZA: In what way?
- » You said: They are always bugging us about something or the other
- » ELIZA: Can you think of a specific example?
- » You said: Well, my boyfriend made me come here
- » ELIZA: Your boyfriend made you come here?
- » You said: Yes
- » ELIZA: I see. Do you often let others influence your decisions?
- » You said: Sometimes, Do you think it's bad?
- » ELIZA: I am not here to judge. How do you feel about it?
- » You said: My boyfriend says I am depressed much of the time
- » ELIZA: I am sorry to hear that you are feeling depressed. Do you think your boyfriend's observation is accurate?
- » You said: Yes I am unhappy
- » ELIZA: I am sorry to hear that you are unhappy. What do you think is causing this unhappiness?

Data, Information, Knowledge

*We are drowning in information but starved for knowledge.
John Naisbit, “Megatrends” (1982)*

Data

Definition (Data)

Data refers to raw, unprocessed facts and figures without any context or interpretation. It is the basic building block from which information and knowledge are derived.

Examples:

- Numbers, text, symbols, images, and measurements
- A list of temperatures recorded by a weather station
- A database of customer transactions

Characteristics:

- Unprocessed and unorganized
- Needs to be processed to become meaningful
- Can be quantitative or qualitative

Information

Definition (Information)

Information is data that has been processed, organized, and structured in a way that makes it meaningful and useful. It provides context and relevance to data.

Examples:

- A weather report that interprets temperature data to provide forecasts
- A sales report that analyzes customer transaction data to identify trends
- An article that explains scientific findings based on experimental data

Characteristics:

- Processed and organized data
- Provides context and relevance
- Useful for decision-making and understanding

Knowledge

Definition (Knowledge)

Knowledge is the application of information, experience, and expertise to make decisions, solve problems, and take actions. It involves understanding and insight gained through learning and experience.

Examples:

- A meteorologist using weather information to predict future weather patterns
- A business analyst using sales information to develop strategies for increasing revenue
- A doctor using medical information to diagnose and treat a patient

Characteristics:

- Applied information and experience
- Involves understanding and insight
- Used for decision-making, problem-solving, and action

Data, Information, Knowledge – Summary

Summary

- Data is the raw material.
- Information is processed data that has meaning and context.
- Knowledge is the application of information, experience, and expertise to make decisions and take actions. Understanding these distinctions is crucial in fields like artificial intelligence, where data is collected, processed into information, and then used to generate knowledge that can drive decision-making and problem-solving.

Source: <https://chat.mistral.ai/chat>

AI Fields

Reasoning

- Theorem Proving
- Automated Reasoning
- Reasoning with Uncertainties

Knowledge

- Knowledge Representation
- Knowledge Graphs
- Ontologies

Planning and Decision-making

- Agents
- Games
- Markov decision processes

Perceiving

- Computer Vision
- Speech recognition

Learning

- Supervised Machine Learning
- Unsupervised Machine Learning
- Reinforcement Learning
- (Big) Data Mining

Communication

- NLP
- Speech Synthesis

Reasoning Fundamentals

- based on Logical Reasoning with Propositional and First-Order Logic
- uses Rule-Based Systems
- Fuzzy Logic and Probabilistic Reasoning incl. Bayesian Networks to deal with uncertainty

Will be (partially) covered in lectures on Symbolic AI and Semantik/Ontology

Knowledge Fundamentals

- based on also Logical Reasoning with Propositional and First-Order Logic
- captures Semantics in Semantic Networks such as Knowledge Graphs and Ontologies
- uses Case-Based Reasoning (CBR) for adapting solutions to known solutions

Will be (partially) covered in lectures on Symbolic AI and Semantik/Ontology

Perceiving Fundamentals

- Computer Vision includes techniques such as filtering, edge detection, and segmentation
- Feature Extraction with convolution networks
- Object detection
- Speech detection uses Hidden Markov Models (HMMs), N-Grams and Deep Learning

Will be (partially) covered in lectures on Gen AI, Computer Vision and CNN

Communication Fundamentals

- Natural Language Processing
- Tokenisation
- Word Embeddings
- Bag of Words
- Transformers
- and many more

Will be (partially) covered in lectures on Gen AI, NLP

Machine Learning Fundamentals

- Is firmly grounded on probability theory and statistics
- Based on Statistical Learning Theory [Vap95] (Supervised ML)
- Based on Markov Decision Processes and Bellman Equations (Reinforcement Learning)

Will be (partially) covered in this lecture and lectures on Regularisation, Bayes, Testing, and Validation, KNN, SVM, Random Forest, Trees, and NN and Reinforcement Learning

Machine Learning Fundamentals

The remainder of this (and the next) lecture will exclusively focus on
Machine Learning \ Reinforcement Learning

Remark: For a good general overview on AI please have a look into [RN10].

Machine Learning Examples

Ideas for examples of Machine Learning applications?

Example One: Mortgage Approval

- Assume we have to decide to provide mortgages to potential customers
- In this problem, given some features of clients such as age, gender, annual salary, years in job, ...
- The goal of the model is to approve a new customer or not based on his/her data.

Customer	Age	Gender	Salary	Years in Job	...
Müller	45	m	80000	23	...
Meyer	25	f	40000	2	...
Scholz	19	d	120000	0	...
...

Example Two: Handwriting Recognition

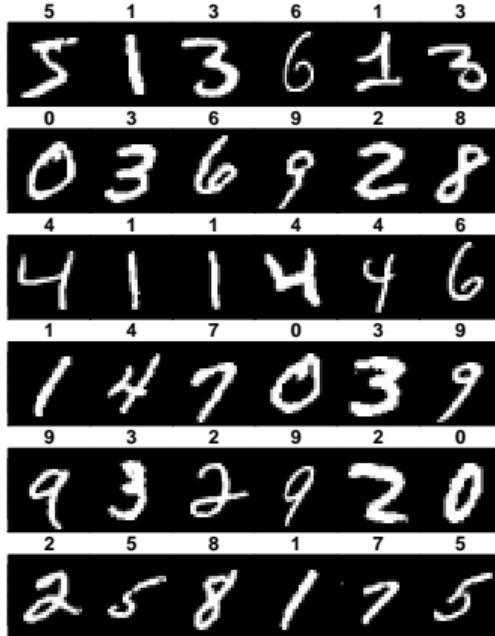


Figure: MNIST data set

Source: Suvanjanprasai, CC BY-SA 4.0, https://en.wikipedia.org/wiki/MNIST_database#/media/File:MNIST_dataset_example.png

Example Three: Fashion Classification

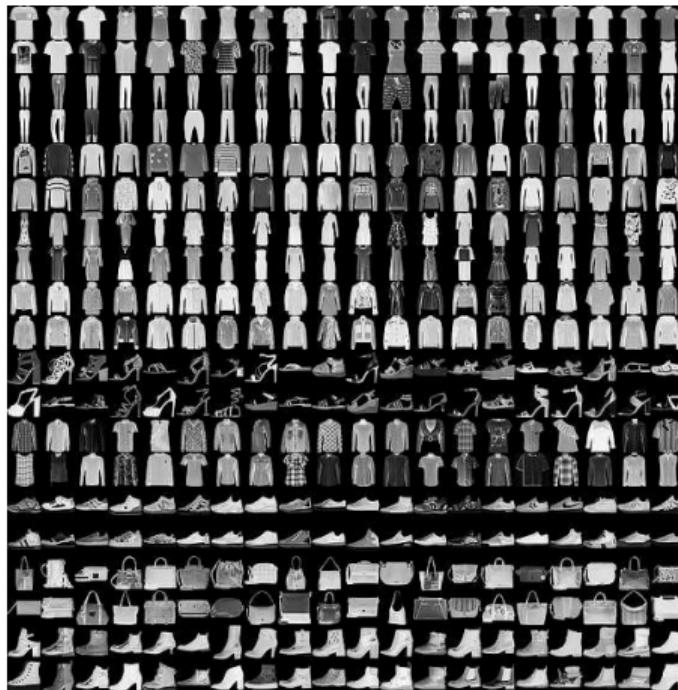


Figure: MNIST Fashion data set

Example Four: Image Classification

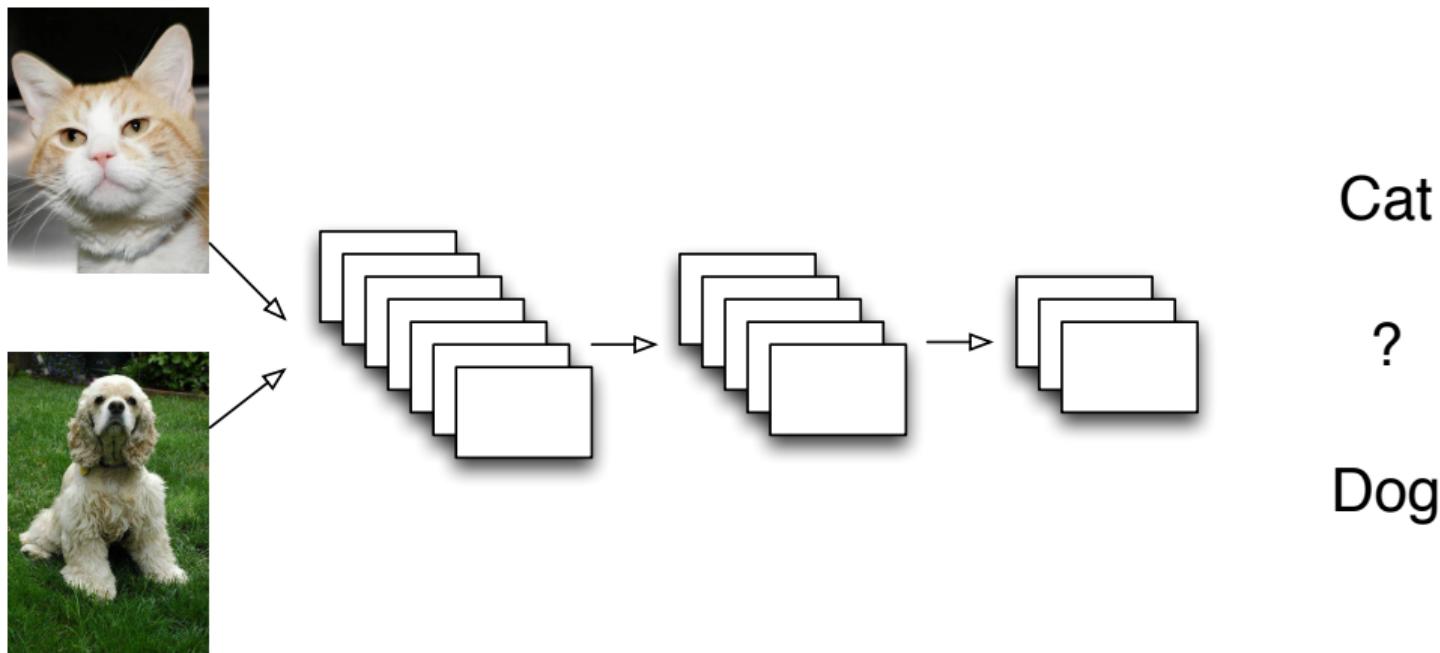


Figure: Cats or Dogs

Example Five: Image Labeling



Figure: Grace Hopper

```
bazel-bin/tensorflow/examples/label_image/label_image
59.026866: examples/label_image/main.cc:250] military uniform (653): 0.834306
59.026906: examples/label_image/main.cc:250] mortarboard (668): 0.0218692
59.026920: examples/label_image/main.cc:250] academic gown (401): 0.0103579
59.026933: examples/label_image/main.cc:250] pickelhaube (716): 0.00800814
59.026944: examples/label_image/main.cc:250] bulletproof vest (466): 0.00535088
```

Source: James S. Davis - Naval History and Heritage Command https://de.wikipedia.org/wiki/Grace_Hopper#/media/Datei:Grace_Hopper.jpg

Example Six: Train Machines to Play Soccer



For more information, see <https://www.frankfurt-university.de/de/hochschule/fachbereich-2-informatik-und-ingenieurwissenschaften/einrichtungen-services/roboterfussball-team-fra-united/> - FRA-UAS has scored runners-up at world championship RoboCup 2017.

Example Seven: Predict (Prostate) Cancer Example

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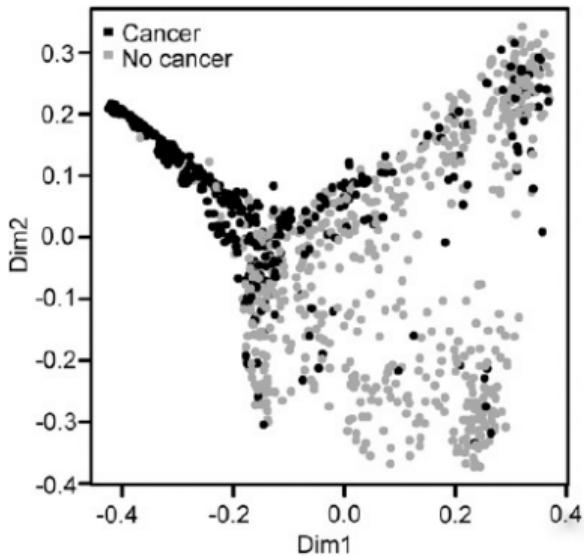


Figure: Multidimensional scaling plot of patients with prostate disease. Black dots indicate individual patients with prostate cancer; gray dots, patients with noncancerous disease.

Example Eight: Predict Breast Cancer

One can calculate ML algorithms online, see

<https://www.kaggle.com/jschae02/kernels/notebooks/new?forkParentScriptVersionId=1288066> or
<http://scikit-learn.org/stable/>.

Below an example of comparison of performance of several ML-Algorithm using the Breast Cancer Wisconsin (Diagnostic) Database, see

[https://archive.ics.uci.edu/ml/datasets/Breast+Cancer+Wisconsin+\(Diagnostic\)](https://archive.ics.uci.edu/ml/datasets/Breast+Cancer+Wisconsin+(Diagnostic)):

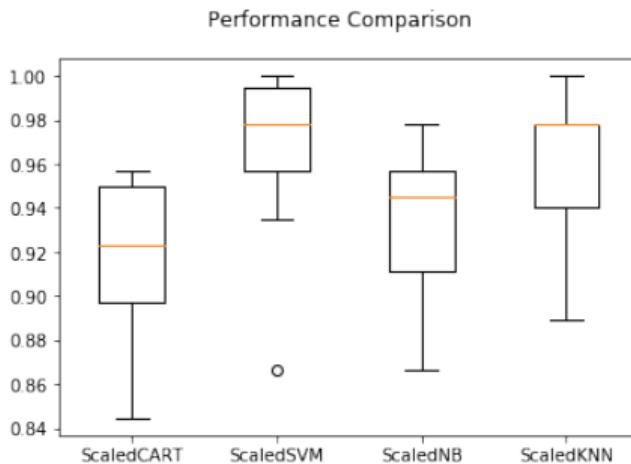


Figure: Performance of Several ML-Algorithm using the Breast Cancer Wisconsin (Diagnostic) Database

Example Nine: Autonomous Driving



Figure: Autonomous Driving

Source: Michael KR

https://de.wikipedia.org/wiki/Autonomes_Fahren#/media/File:Daimler_2014_Mercedes_Autonomes_Fahren_Magdeburg_5430.jpg

Machine Learning – Definitions

Definition

Machine learning is the science of getting computers to act without being explicitly programmed. (Andrew Ng, Stanford)

Definition

Machine learning answers the question “How can we build computer systems that automatically improve with experience, and what are the fundamental laws that govern all learning processes?” (Tom M. Mitchell, Carnegie Mellon University)

Definition

The learning process is a process of choosing an appropriate function from a given set of functions. (Vladimir N. Vapnik, Statistical Learning Theory)

Machine Learning and Statistics

Table: Glossary, Larry Wasserman

Statistics	Machine Learning
Estimation	Learning
Classifier	Hypothesis
Data Point	Example/ Instance
Regression	Supervised Learning
Classification	Supervised Learning
Covariate	Feature
Response	Label
R	Matlab ¹

“Machine learning is glorified statistics”, Robert Tibshirani, Stanford

¹These days python is the language of choice

Nomenclature

Machine learning approaches are categorized into

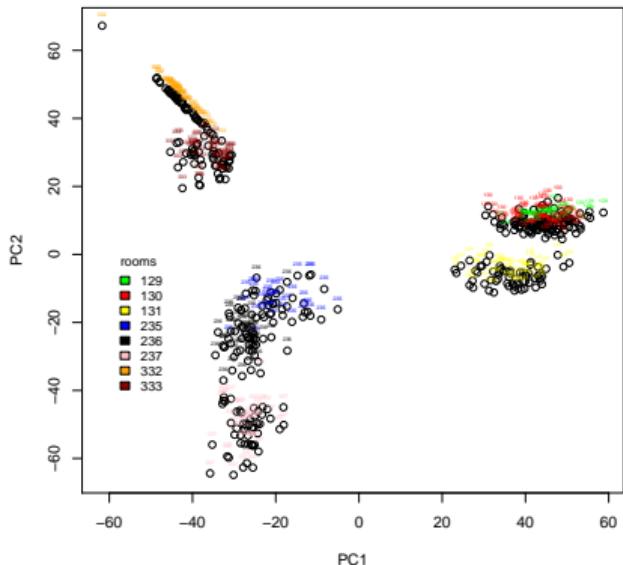
1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

based on whether there is a learning signal, teacher, expert, or feedback available to the learning system.

Supervised Learning

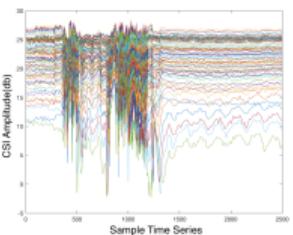
- In supervised learning we have (enough) data with correct outputs.
- These outputs can be used to train the model.
- For example, for mortgage rate approval we have data of a lot of customers with Age, Gender, Salary, Years in Job, etc. called *features* or *feature vector*. In addition, we *know* which of the customers defaults (from e.g. history).
- There are two main categories of Supervised Learning:
 1. Regression, where the output is continuous, i.e. $y \in \mathbb{R}$ or
 2. Classification, where the output is non-continuous and discrete and represented as class labels, i.e. $y \in \mathcal{L} \subset \mathbb{N}$, where \mathcal{L} is finite.

Supervised Learning Example – I/II

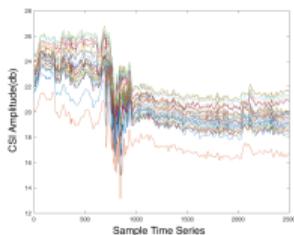


Source: [Sch14]

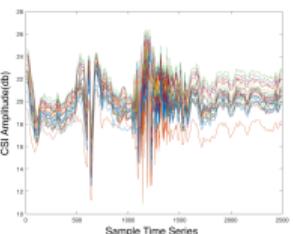
Supervised Learning Example – II/II



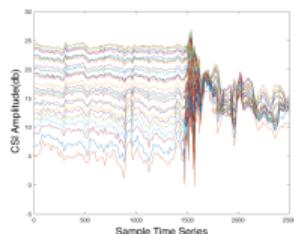
(a) Run



(b) Sit



(c) Walk



(d) Stand

Source: [DHKS20]

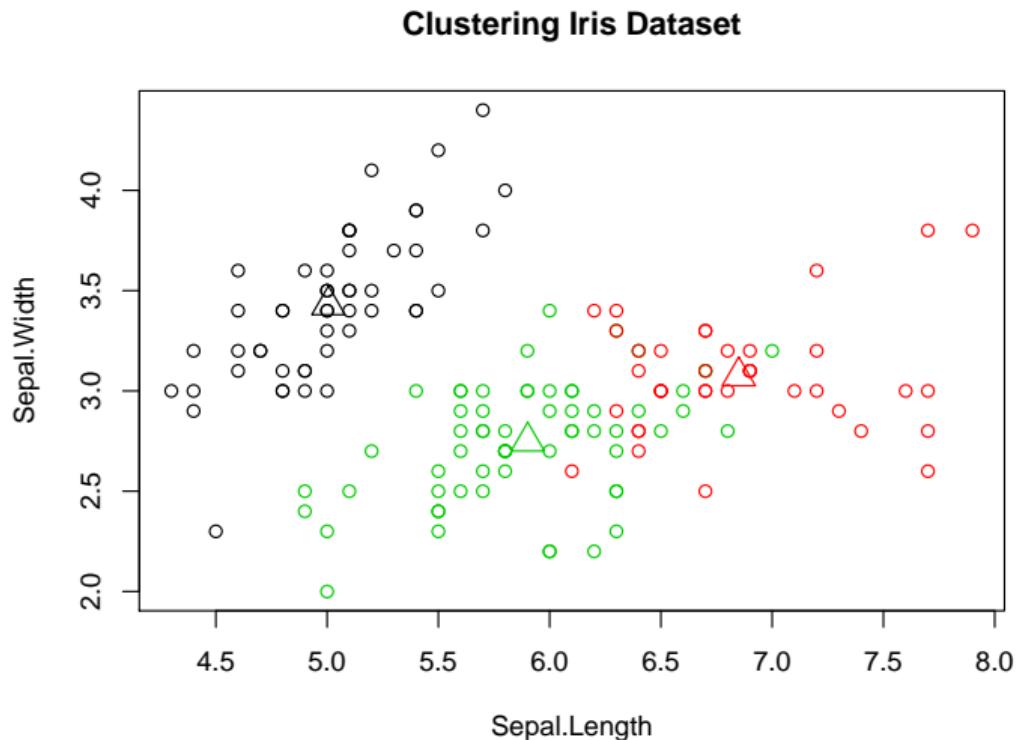
Unsupervised Learning

- In unsupervised learning we do not have data with correct outputs.
- Rather, we want the machine to learn structure by itself.

Whilst, this might seem an ill-defined problem, there are successful algorithms like e.g.

- Clustering: The goal of clustering is to group the given data automatically into groups/clusters. Each group has similar or related features
- Cocktail Party algorithm, separating sound sources, see
<https://arxiv.org/abs/1504.04658>

Unsupervised Learning Example



Reinforcement Learning

- Reinforcement learning inspired by behaviorist psychology
- Concerned with how machine should ought to take actions in a specific environment to maximize some utility function
- Similar to how we teach children by reward and punishment

Similar to supervised learning but we do not have correct / incorrect labelling but rather provide *feedback* on actions chosen.

Reinforcement Learning Example: Robot Soccer

<http://www.tgabel.de/index.php?id=publications>

More details in separate lectures later!

The (generic) Learning Model

The dataset $\mathcal{D} = (x_i, y_i)_{i=1}^N$ is known, but f is not. The goal is to learn f from the data \mathcal{D} :

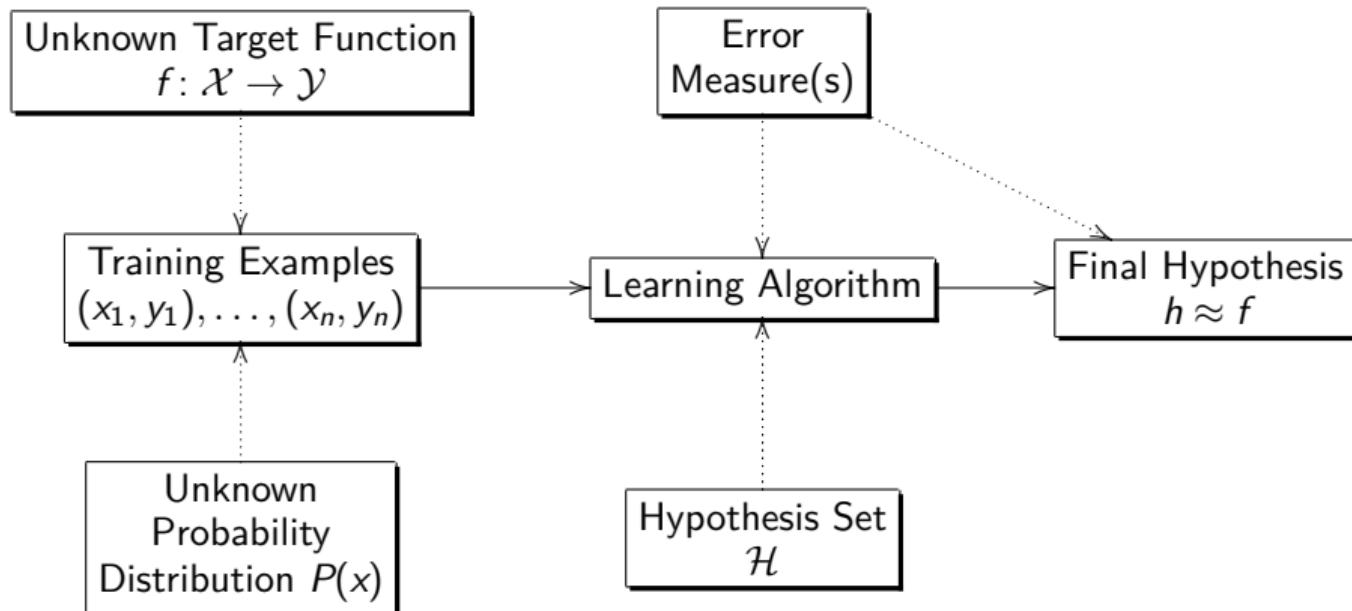


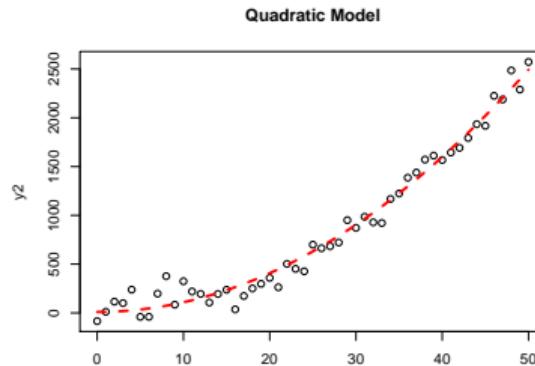
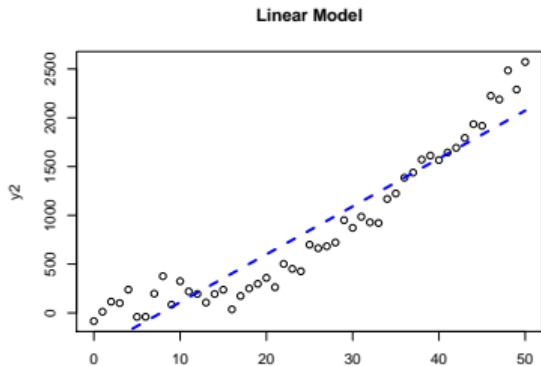
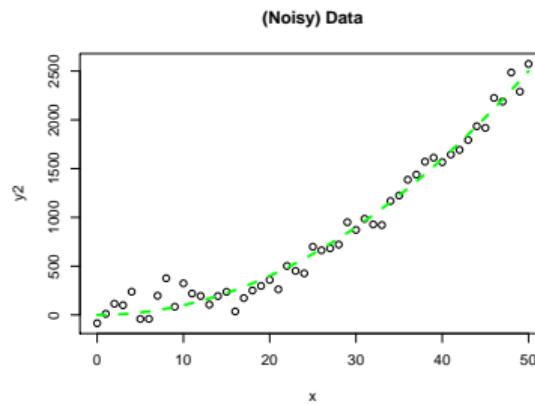
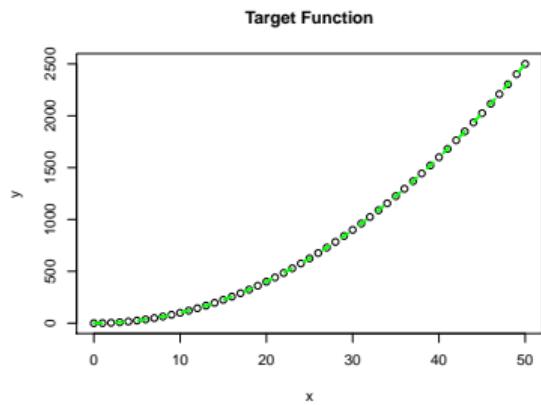
Figure: Learning Model, source: [AMMIL12]

Probability is at the Core of ML



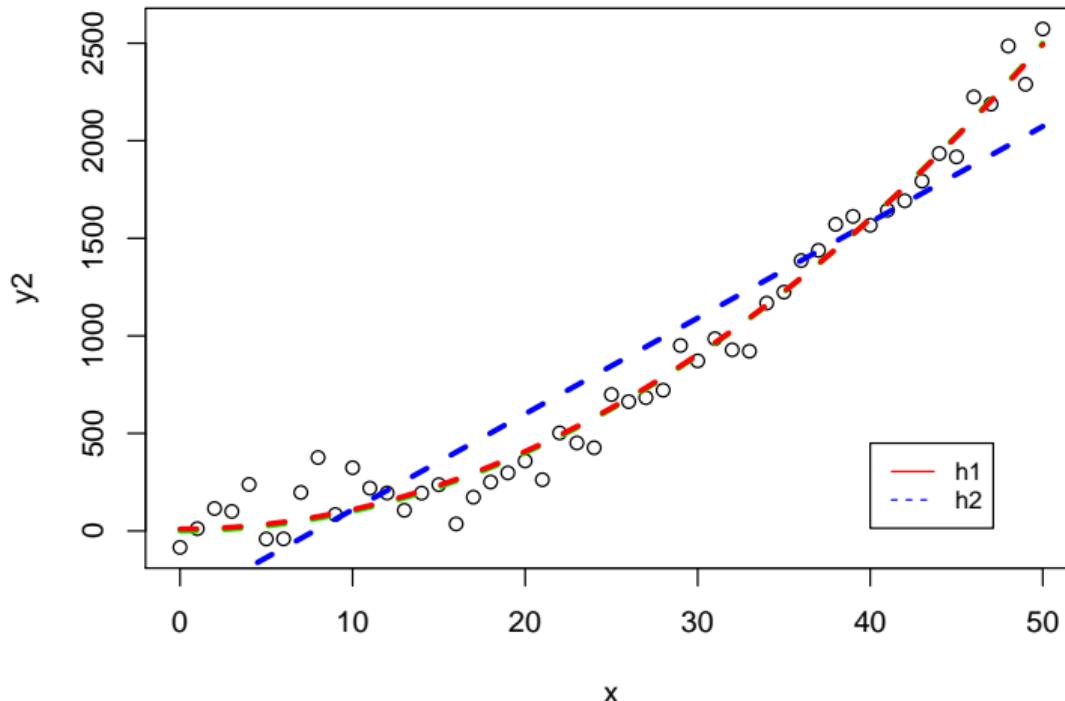
Source: Ralf Roletschek <https://commons.wikimedia.org/wiki/File:13-02-27-spielbank-wiesbaden-by-RalfR-094.jpg>

The Learning Model Applied



The Learning Model Applied

Two Hypothesis



The Learning Model Applied

Every learning model consists of two components:

1. The learning algorithm such as Linear or Non-linear Regression or Neural Network Backwards Propagation.
2. The hypothesis set $\mathcal{H} = \{h_1, \dots, h_n\}$.

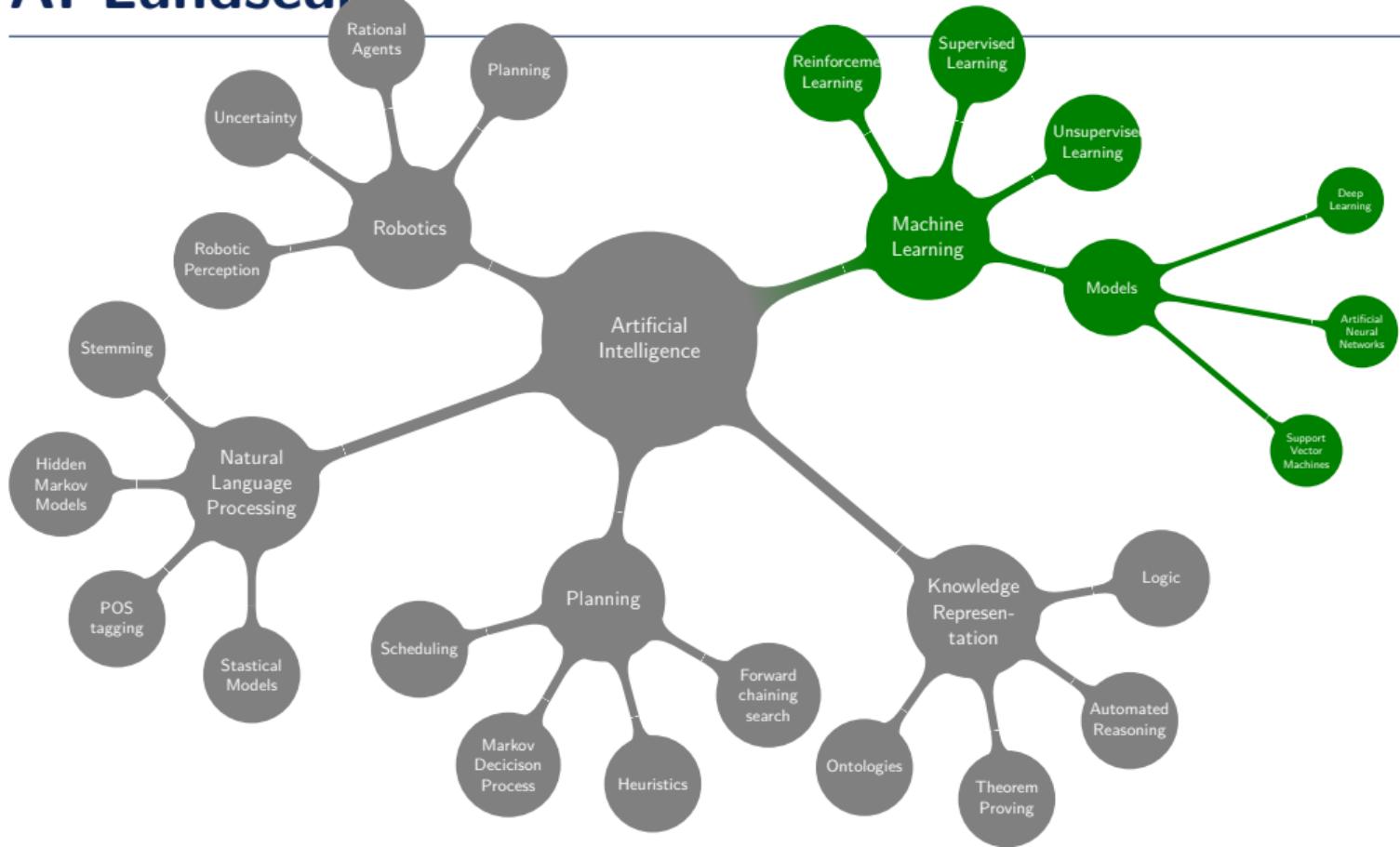
A selection of one $h_i \in \mathcal{H}$ is often called the trained model.

We want to select an $h_i \approx f$ in a certain sense.

Question: Is this even possible?

Answer: We will see in the next lecture (bear with me!).

AI Landscape



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