VL Deep Learning for Natural Language Processing

1. Organization & Introduction

Prof. Dr. Ralf Krestel

AG Information Profiling and Retrieval

Lerning Goals for this Chapter

- Answering the question: am I right here?
- Explain and define deep learning
- Position deep learning with regards to machine learning
- Understand the historical development of the area of ML

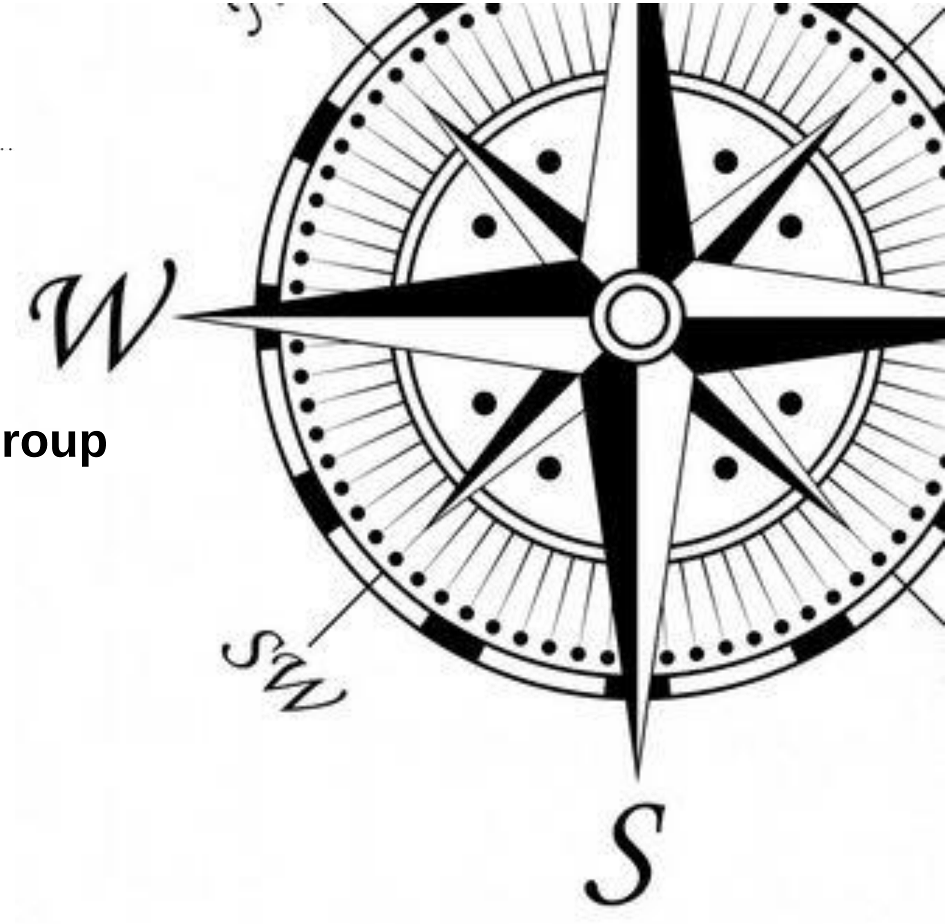
- Relevant chapters:
  – P2

20 Deep Learning Applications You Need to Know

- Fraud detection
- Customer relationship management systems
- Computer vision
- Agriculture
- Vocal AI
- Natural language processing
- Data refining
- Virtual Assistants
- Autonomous vehicles
- Supercomputers
- Investment modeling
- Climate Change
- E-commerce
- Emotional intelligence
- Entertainment
- Deep Dreaming
- Advertising
- Manufacturing
- Healthcare
- Sports

https://builtin.com/artificial-intelligence/deep-learning-applications

Topics Today



1. **Organization**
   a. **Information Profiling & Retrieval Group**
   b. Course Organization
   c. Schedule for the Semester
2. Introduction to Deep Learning
3. Brief History of Machine Learning
4. Summary

Information Profiling & Retrieval (IPR) Group

Who are we?

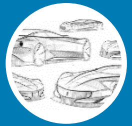
- Prof. Dr. Ralf Krestel
- In Kiel:
  - Lakshmi Rajendram-Bashyam
    - Phd student working at ZBW, Hamburg
  - Nobel Jacob-Varghese
    - PhD student working at ZBW, Kiel
  - Aftab Anjum
    - PhD student working at CAU, Kiel
    - aftab.anjum@email.uni-kiel.de
- In Potsdam:
  - Alejandro Sierra
    - PhD student working at HPI, Potsdam

Leibniz Gemeinschaft

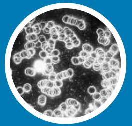
Information Profiling and Retrieval (IPR)

Focus on understanding of text


Extraction

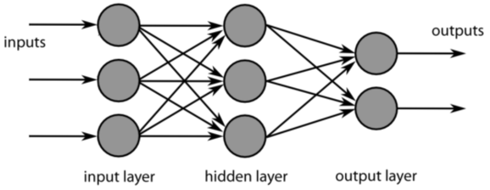

Representation


Analysis
Search
Recommendation


Visualization

AI methods

- Deep learning, topic modeling, knowledge graphs



Application domains

- Scientific publications, archives, libraries, web pages, social media, Wikipedia, user-generated content, patents, legal docs, news articles, political speeches, …
- **Metadata, joint analysis, multi-modal**

IPR - Teaching

- IPR regularly offers the following courses (approximately every three semesters):
  - Text Mining (in German) BS W/INF V2 U2
  - Information Retrieval (in German) BS & MS W/INF V4 U1 PU1
  - Deep Learning for Natural Language Processing (in English) MS W/INF V2 U2

- In addition, seminars and projects are offered irregularly on the topics:
  - Recommender Systems (BA)
  - Knowledge Graphs (MA)
  - Topic Modeling (MA)
  - Large Language Models (MA)

- **Bachelor and Master theses**
  https://www.ipr.informatik.uni-kiel.de/de/abschlussarbeiten/offene-themen

Open Student Assistant Position

- Web development within the BMBF-funded CoCo project
  - https://www.coco-projekt.de/
- 20 - 40 hours/month
- 13 Euro/hour

If interested, contact me:
rkr@Informatik.uni-kiel.de

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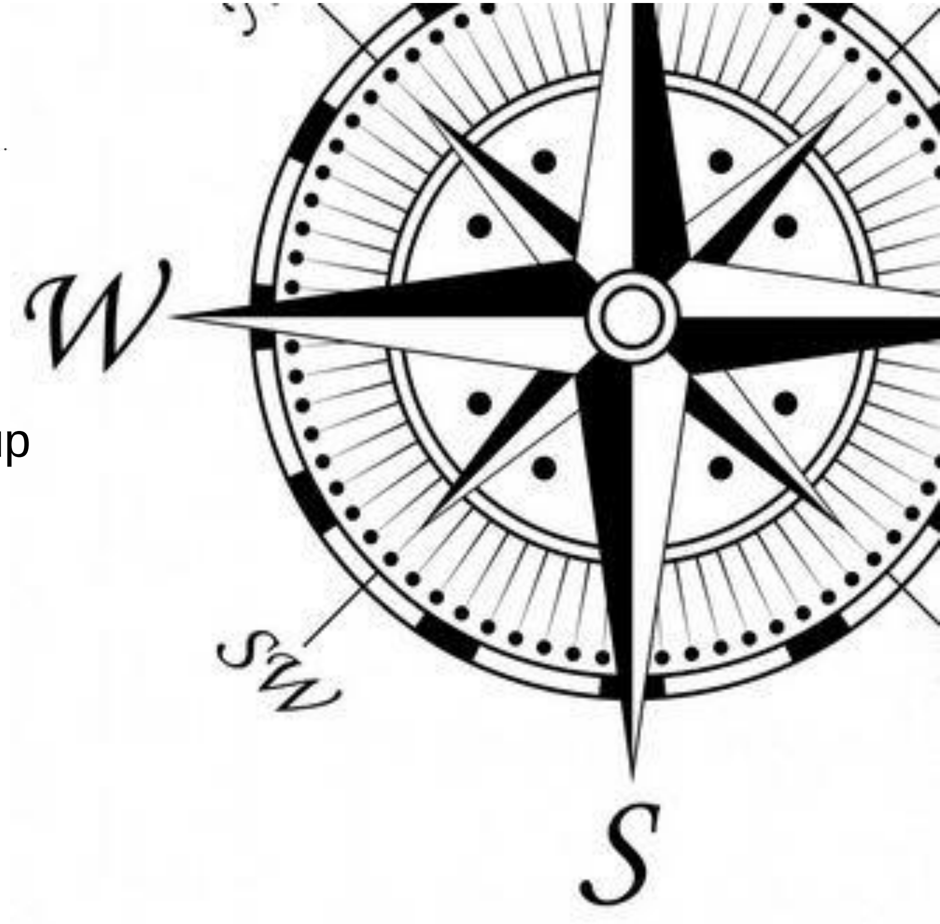


Communication & Resources

- We will use Moodle as our main platform:
  - https://elearn.informatik.uni-kiel.de/course/view.php?id=274
  - Enrolment key: Ernie&Bert
- Suggestions for improvment of
  - Use of slides/errors on slides
  - Assignments
- Questions any time!
  - During/After lecture
  - In person room CAP 901
    - Email first!
  - Email: **rkr@informatik.uni-kiel.de**

Dates

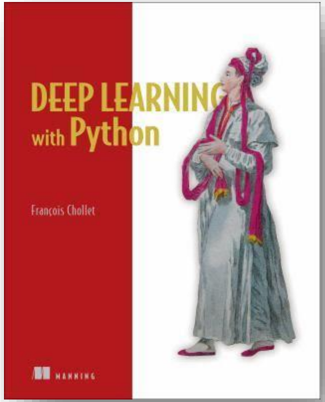
- Exercises: Monday, 16:15 - 17:45
  - LMS8 - R.EG.016
- Lecture : Thursday 10:15 – 11:45
  - LMS8 - R.EG.016
- No lectures/exercises
  - 15.4.24 Semester Start
  - 9.5.24 Holiday
  - 20.5.24 Holiday

Grading

- Exam
  - Mostly „theoretical“ questions
  - Some „practical/applied“ questions
  - No language-/library-specific programming questions
- Three homework assignments
  - **At least 50% points per assignment to be eligible for exam**
  - **For every assignment where you got more than 90% you will get one bonus point in the exam (if you pass the exam)**
  - Hand-in through Moodle

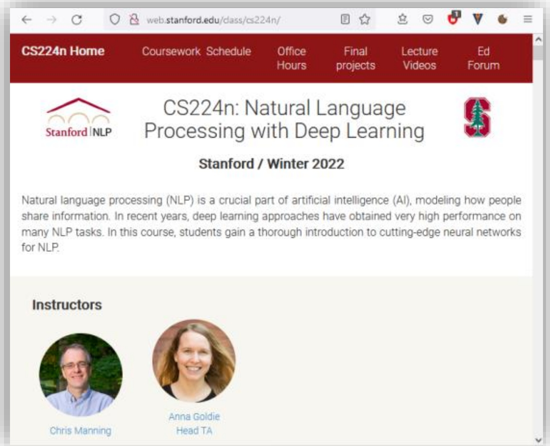
Literature

- Deep Learning with Python
  - Francois Chollet
  - Manning Publications Company



Note: the book uses Tensorflow/Keras for programming examples; we will use Pytorch!

- Stanford Course
  - Chris Manning
  - http://web.stanford.edu/class/cs224n



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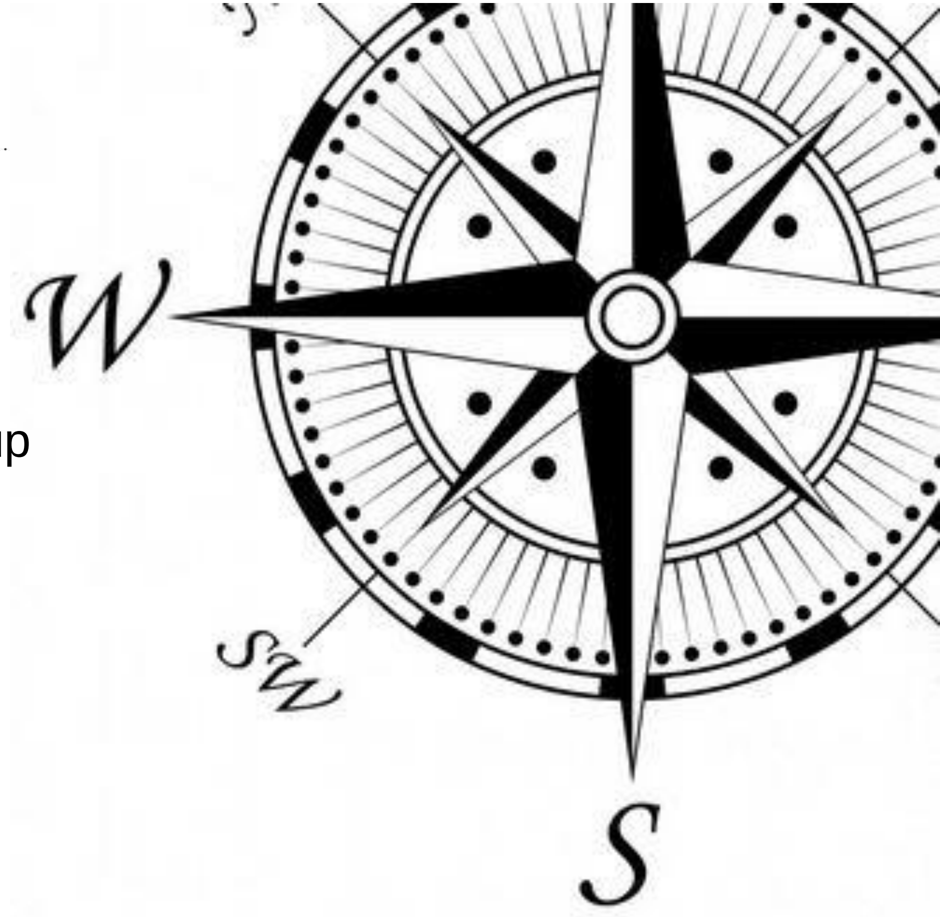

Semester Schedule

Week	Date	Exercise (Mon)	Lecture (Thu)	Assignments
1	15.4.24	No Exercise	Introduction	
2	22.4.24	Python/Pytorch/Colab	Neural Networks	Hand-out A1
3	29.4.24	Neural Network Implementation	NLP+TM	
4	6.5.24	Text Classification	Holiday	Hand-in A1
5	13.5.24	Assignment 1 Discussion	Word Embeddings I	Hand-out A2
6	20.5.24	Holiday	Word Embeddings II	
7	27.5.24	Word Embeddings Applications	Word Classifiers	
8	3.6.24	Deep Learning in Practice	Language Models	
9	10.6.24	RNNs+CNN	Recurrent Neural Networks	Hand-in A2
10	17.6.24	Assignment 2 Discussion	Sequence-to-Sequence Models	Hand-out A3
11	24.6.24	Seq2Seq & Hugging Face	Transformer Models	
12	1.7.24	Transformers	Large Language Models	Hand-in A3
13	8.7.24	Assignment 3 Discussion	Generation and Prompting	

Learning Goals

- Students will be able to…
  - Explain different neural network architectures
  - Identify application areas and tasks for deep learning
  - Select suitable network architectures for a given task
  - Explain the functions of different components of NN
  - Apply DL in Python
  - Design and implement their own applications and evaluate their performance
  - Understand the theoretical background, in particular, be able to run the backpropagation algorithm manually
  - Realize the limits of deep learning
  - get an overview of current research in the field
  - Assess societal consequences of DL and discuss them

Others?

Your Turn!

- After each topic there will be a small task which should be discussed with your neighbor for 5 minutes.
- You can use Moodle to further discuss these tasks, suggest solutions, comment, etc.

- What do you expect from this class?
  - Make a ranking of three learning goals.
  - Discuss with your neighbor.

Start 5 4 3 2 1 Ende

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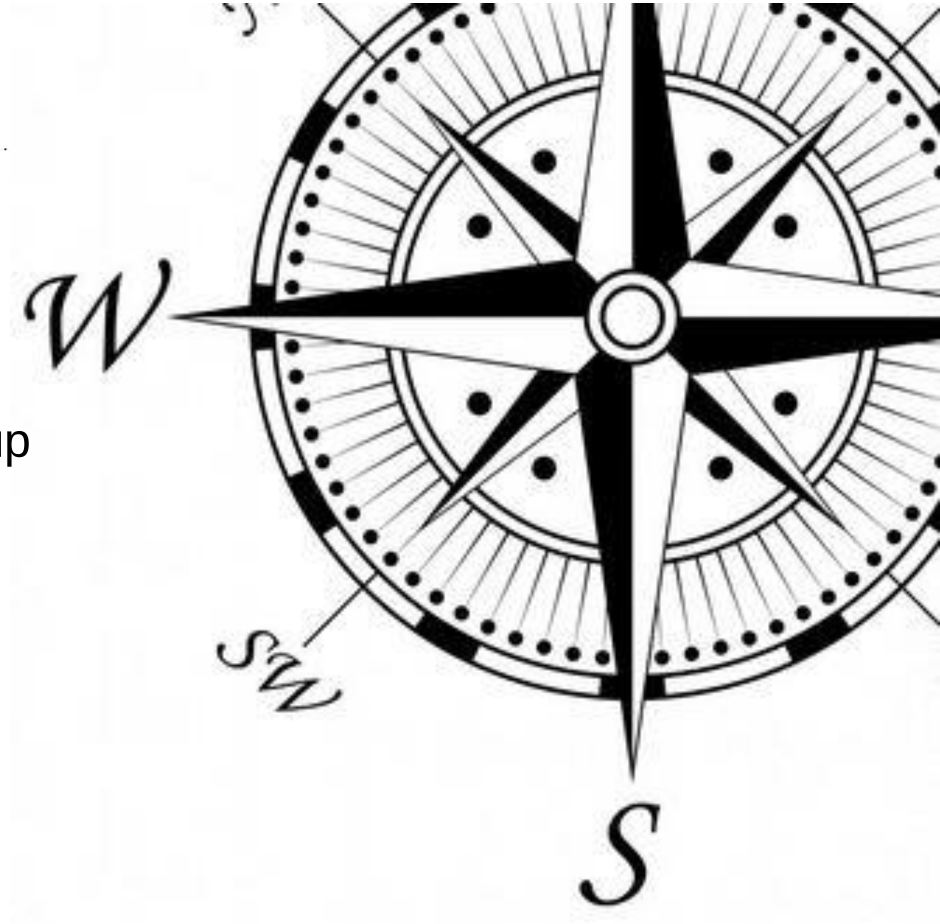
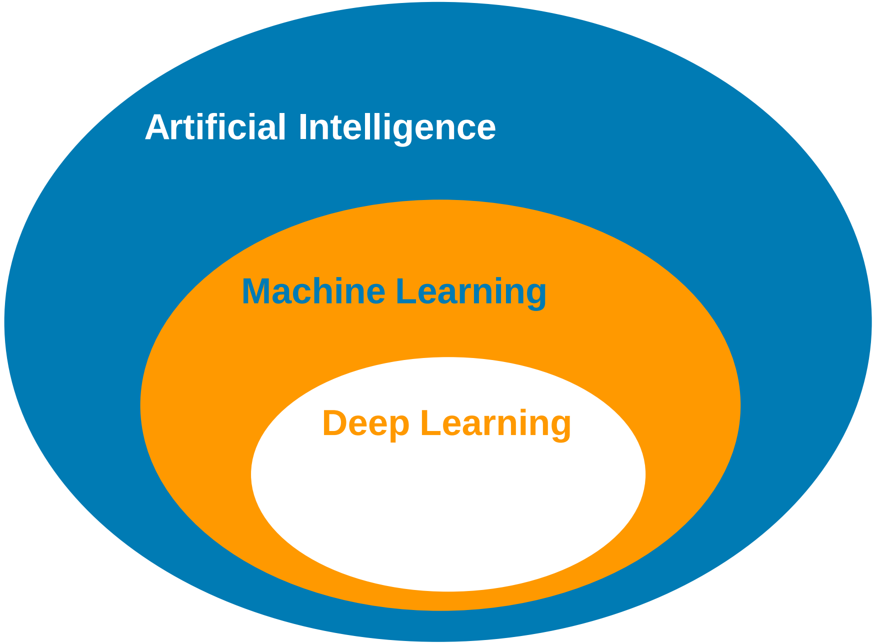


What is Deep Learning



Artificial Intelligence

- AI: „The effort to automate intellectual tasks normally performed by humans“
  - Non only machine learning but also rule-based approaches
    - **Symbolic AI**
    - Expert systems in the 80ies
    - E.g. chess computer
  - Only works for certain problems
    - Clearly defined
    - Logical problems
  - Does not work for complex, diffuse problems
    - Image classification
    - Speech recognition
    - Translation

http://illumin.usc.edu/188/deep-blue-the-history-and-engineering-behind-computer-chess/

Machine Learning

- Instead of humans coming up with rules (classical programming),

- Let computers **learn** the rules.

- A system based on machine learning (a **model**) is being trained, not programmed.
- ML is nowadays an important subfield of AI and
  - Closely connected to **statistics,**
  - Which usually deal with much **smaller** and **less complex** data.

Machine Learning as Transformation

- For machine learning you need
  - **input data** and the
  - corresponding, expected **output data** and
  - a **measure** to check how well the learning works.
- **Learning** is the (stepwise) adaption of the model to **increase** the chosen **measure**.
- What is learned: a **transformation** from the input to the output data.
- The challenge of ML and DL is to find a good transformation.
  - This is easier if the input (and output) data is represented in a meaningful way.
  - Dependend on the task:
    - E.g. image pixel as RGB values or hsv values

Example: automatic speech recognition

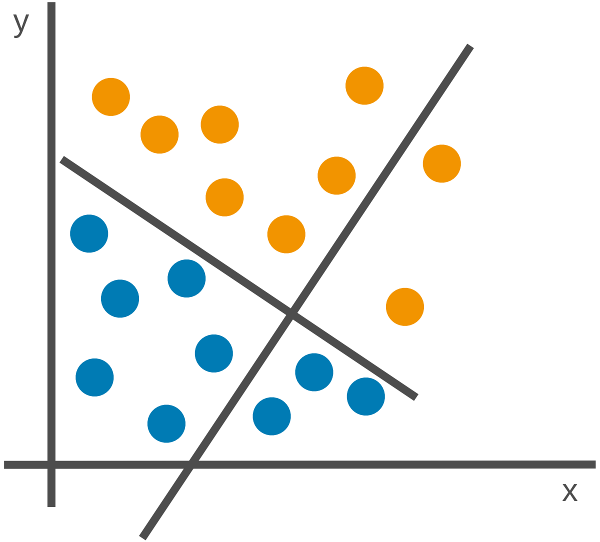
Input data: audiofiles

Output data: manually created transcripts

Measure: count of correctly recognized letters/words

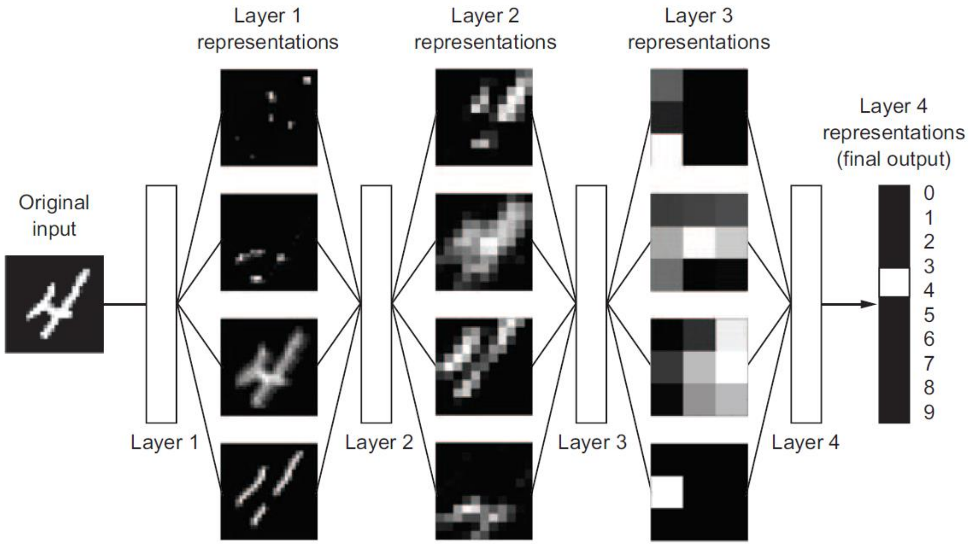
Representation Learning

- Example: classification of points into red and yellow
- Input: coordinates of the points
- Expected output: Color of points
- Measure: Proportion of correctly classified points
- New representation of the points
- Change of coordinates
- Now, classification very easy: x>0

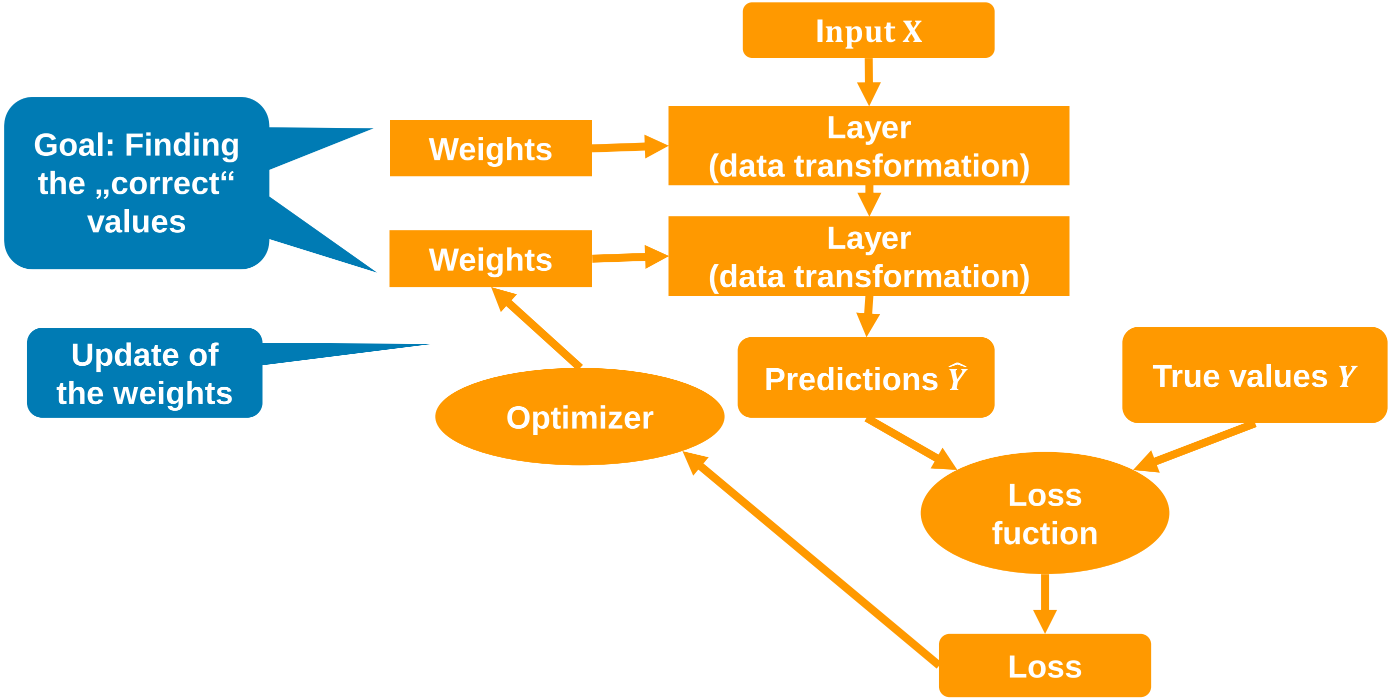


- ML: Systematic search for good representation
  - Learning=Search for **better representation**
    - Coordinate change, linear projection, non-linear operations, …
  - ML-Algorithms are not very creative
    - Simple search of the **hypothesis space**

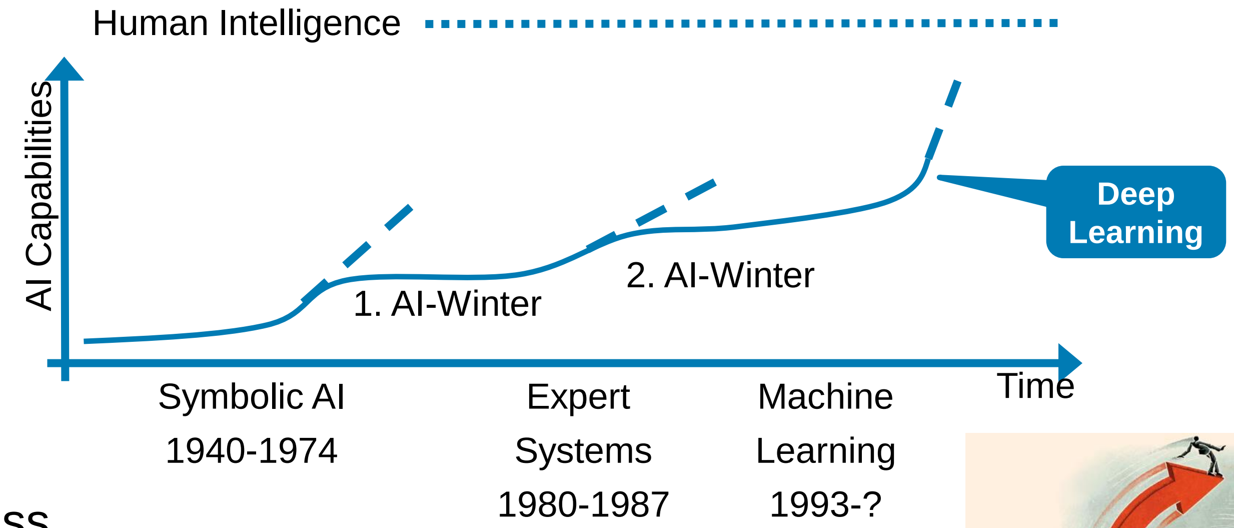
„Deep“ Learning



Deep Learning Architecture



Deep Learning Hype



1. First sucess
2. Hopes/Expectations (too high)
3. Disappointment
4. Less research funding

Deep Learning Tasks

- Which kind of problems can be solved with DL?
  - Name examples of task.

- Which type of problems DL cannot solve as well, if at all?
  - What are the reasons?

- How likely do you think is a third AI winter?
  - How to avoid a third AI winter?

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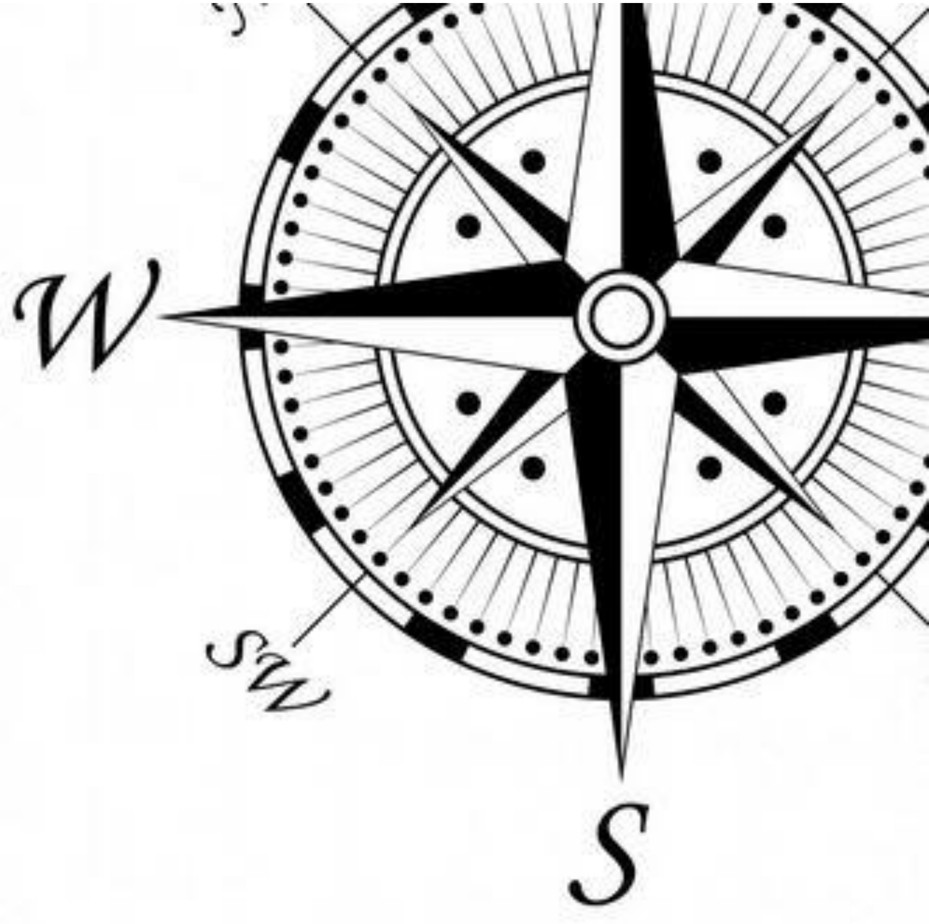
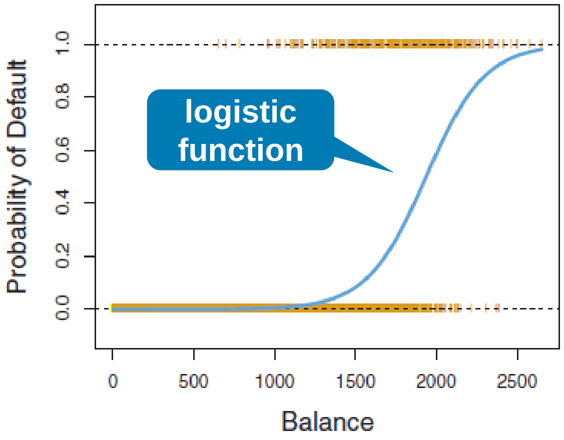


Probabilistic Modeling

- Originated from statistics
  - Older than computers
- Naive Bayes algorithm
  - Naive: input data independent
  - Bayes: $P(c|f) = \frac{P(f|c)\,P(c)}{P(f)}$

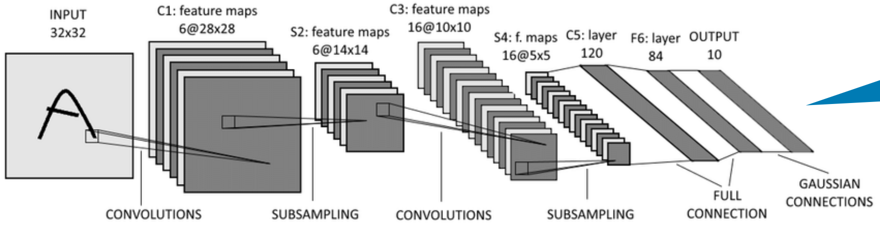
Bayes theorem

- Logistic regression
  - Classification, **not regression**!



Early Neural Networks

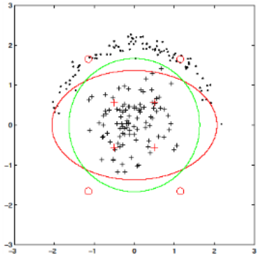
- First idea in the 1950s
- Problem back then: Not possible to train large networks
  - Only toy examples, no useful applications
- Mid of the 1980s
  - Rediscovery of the backpropagation algorithm
    - Training of large nets using gradient descent
- In 1989, first practial application of neural Nets
  - LeCun (Bell Labs): LeNet, hand writing recognition
  - Convolutional neural network (CNN) & backpropagation



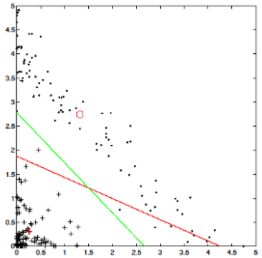
LeNet-5: In the 1990s used by USPS to recognize zipcodes automatically

Kernel Methods

- Group of classification algorithms
- Developed in the 1990s; still very popular
- Best-known algorithm: Support Vector Machines (SVM) [CV95]
  1. Data is being projected into an high-dimensional space.
  2. In this space, classes can be easily seperated by a hyperplane.
  3. Hyperplane is chosen to maximize the margins of points and hyperplane.

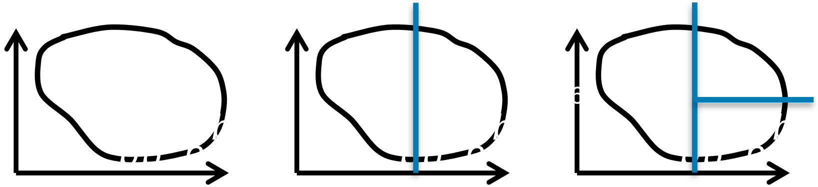


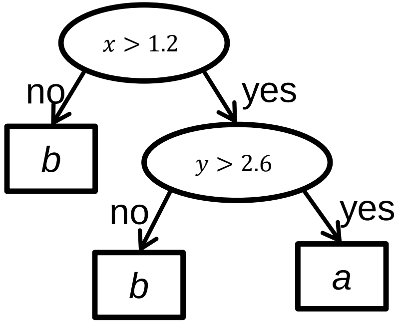
- Actual projection too costly, thus apply the **kernel trick**
  – Only calculate the distances in the high-dimensional space using a kernel function
    - Kernel function is not learnt but manually specified
    - Input data needs to be represented in a suitable way since this is a **shallow** (vs. deep) methods.



Decision Trees, Random Forest, GBM

- Decision Trees:
  - Heyday between 2000 and 2010
  - Easy to understand/interpret/visualize





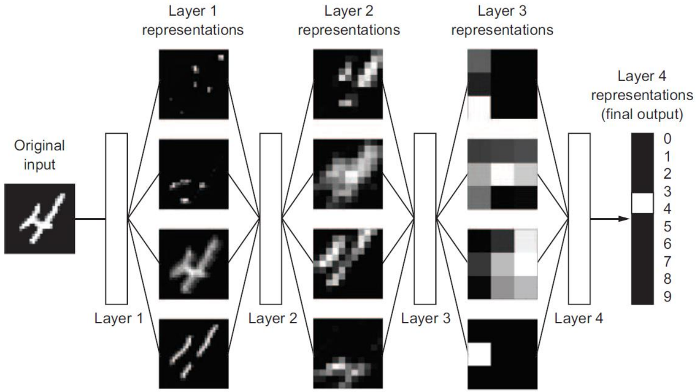
- Random Forest
  - Many small decision trees whose results are combined
  - Very successful in practice (http://kaggle.com)
- Gradient Boosting Maschines (GBM), since 2014 top choice at Kaggle
  - Similar to Random Forest
    - Improvement by focusing during training iterations on previously wrongly classified instances
  - Best algorithm for „non-perceptual" problems

Deep Neural Nets

- 2010 important research results for Deep Neural Nets
  - Hinton, U Toronto; Bengio, U Montreal; LeCun, NYU
- 2011 first success at image classification using GPU-trained DNNs
- 2012 breakthrough at image classification challenge ImageNet
  - 1.4 millionen training images, 1000 classes
    - 2011 without DL: 74,3% accuracy
    - 2012 Hinton‘s group: 83,6%
    - 2015 problem solved (96,4%)
- Since then, CNNs (convnets) de facto standard in the area of computer vision.
- Many task also in the area of Natural Language Processing (NLP)
- In case of many available training examples, DL has superseded SVMs and decision trees for many tasks.
  - E.g. at CERN for analyzing ATLAS detector data of the LHC

ML Today

- Deep Learning is not only superior based on **better results** for certain tasks, but also because there is no need for **feature engineering** any more.



For shallow problems:
GBM: XGBoost library
For perceptual problems:
DL: Keras/Pytorch library

- Shallow methods (SVM, decision trees) transform input data at most one to two times; for many complex input data this is not enough.
- In deep learning, representations are not learned in isolation, layer-by-layer, but jointly.
  - This leads to more complex representations in each layer.

Machine Learning

- Why was DL not already successful during the 1950ies?
- How about chaining five SVMs together, one after the other? Would this be a deep SVM giving good results?
- What are the weaknesses/disadvantages of DL?
- Where and why are SVMs and decision trees still in work, although DL is so successful?

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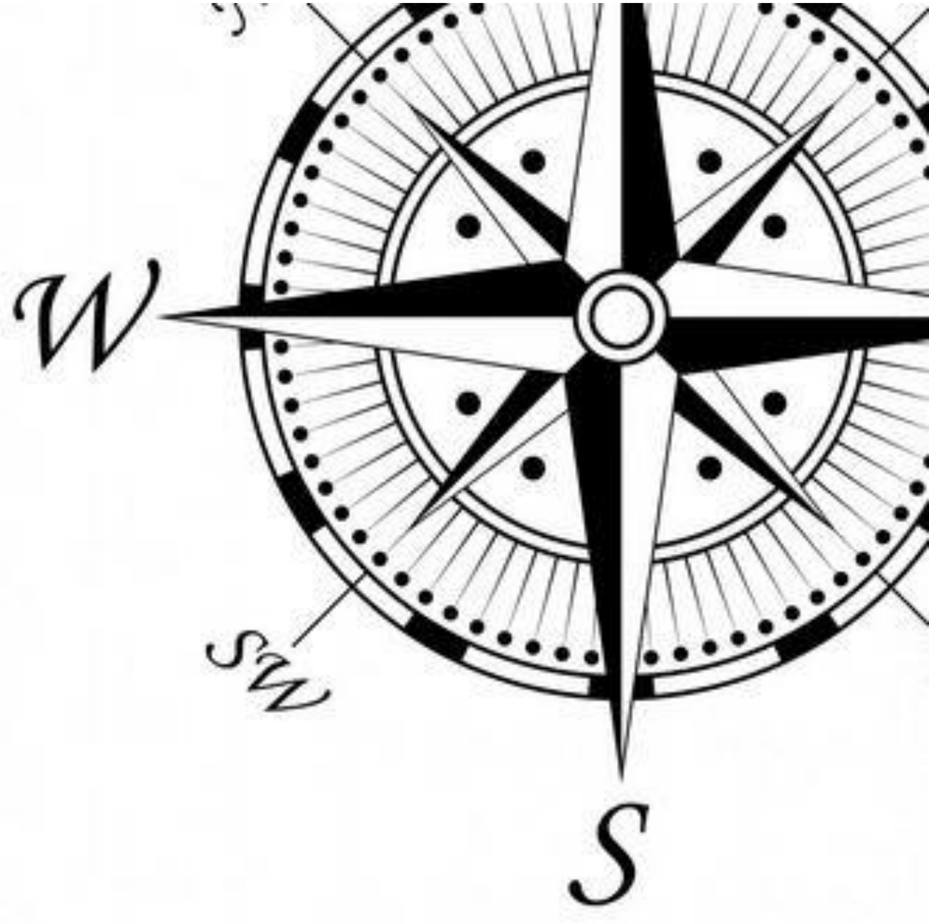

Summary

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References

- [CV95] Cortes, C. and Vapnik, V., 1995. Support-vector networks. *Machine learning*, *20*(3), pp.273-297.