Machine Learning

Section 1: Introduction

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Admin

Admin stuff (1)

Lecture	Stefan Harmeling Mon 10:30 - 12:00, 25.11 HS 5A Wed 12:30 - 14:00, 22.01 HS 5D
Feedback	after every lecture in ILIAS (for about a day)
Slides	Sciebo (also for the exercise sheets and submission)
Video	`http://mediathek.hhu.de`
Übungen	Tobias Uelwer, Maike Behrendt, Stefan Wagner, Liz Leutner, Christopher Orlowicz, Sebastian Konietzny (Mon 18:30 - 20:00, HS 5G) enfällt Thu 12:30 - 14:00, 22.01 HS 2C Fri 12:30 - 14:00, 22.21 HS 2E
Q&A session	Fri 10:30-12:00 via Zoom
Chat	RocketChat for announcements / discussion
ILIAS	for all links (and the feedback form)

Admin stuff (2)

Communication	please use RocketChat!
Exercises	weekly on sciebo, two students hand in one submission, please follow the instructions!
First sheet	available this Wed, deadline next Tue, solutions next Thu and Fri in the “Übungen”
Exam	Wed 9.2.2022 11:30-14:00 in 3D and 5F (maybe)
Admission	NEW to be admitted to the written exam you must reach at least 50% on each exercise sheet (with 2 jokers)
Grade	final grade is the grade of the exam

Some Literature

Free online:

- David J C MacKay — Cambridge, 2003
  Information Theory, Inference, and Learning Algorithms
  `http://www.inference.phy.cam.ac.uk/itprnn/book.pdf`
- David Barber — Cambridge, 2012
  Bayesian Reasoning and Machine Learning
  `http://web4.cs.ucl.ac.uk/staff/D.Barber/textbook/270212.pdf`
- Carl E Rasmussen & Christopher K I Williams — MIT, 2006
  Gaussian Processes for Machine Learning
  `http://www.gaussianprocess.org/gpml/chapters/RW.pdf`
- Kevin Murphy — MIT, 2012
  Machine Learning: a Probabilistic Perspective three nice books on:
  `https://probml.github.io/pml-book/`

Non-free:

- Judea Pearl — Morgan Kaufmann, 1988
  Probabilistic Reasoning in Intelligent Systems
- Christopher Bishop — Springer, 2007
  Pattern Recognition and Machine Learning
- Bernhard Schölkopf & Alexander J Smola — MIT, 2001
  Learning with Kernels
- Edwin T Jaynes & G Larry Bretthorst — Cambridge, 2003
  Probability Theory – the Logic of Science

Please ask your questions on rocketchat!

and you can leave feedback on ILIAS.

What is Machine Learning?

Computer programming

Simple example

input

`[17, 42, 4, 1, 5]`

unsorted sequence

program

output

`[1, 4, 5, 17, 42]`

sorted sequence

Hard example

input

image of handwritten digit

?

output

`7`

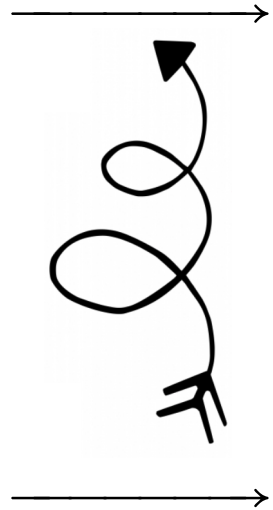
digit

What is machine learning

Difficult example

input

program



output

7

Input/output examples

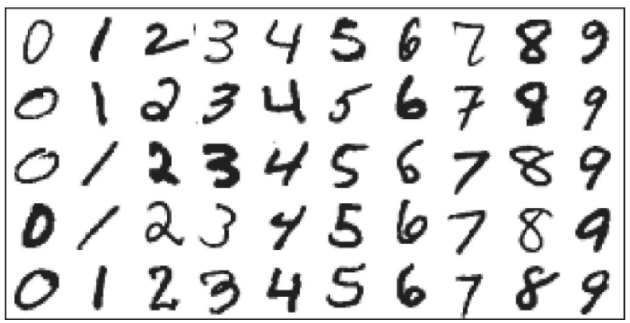


image of handwritten digit

0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9

digit

Lots of data — lots of questions

We are drowning in information and starving in knowing.
John Naisbitt

- 40 billion web pages
- 100 hours of video uploaded every minute on youtube
- 1000s of genomes sequences (each having about 3.8e9 base pairs)
- bigger telescopes generate each night terabytes of data
- ...

A great situation for Machine Learning!

Small demo: Iris flower data set

Radomił Binek,Kosaciec szczecinkowaty Iris setosa, cropping by SH, CC BY-SA 4.0

D. Gordon E. Robertson, Blue Flag, Ottawa, cropping by SH, CC BY-SA 4.0

Eric Hunt, Iris virginica 2, cropping by SH, CC BY-SA 4.0

Iris setosa				*Iris versicolor*				*Iris virginica*			
Sepal length	Sepal width	Petal length	Petal width	Sepal length	Sepal width	Petal length	Petal width	Sepal length	Sepal width	Petal length	Petal width
5·1	3·5	1·4	0·2	7·0	3·2	4·7	1·4	6·3	3·3	6·0	2·5
4·9	3·0	1·4	0·2	6·4	3·2	4·5	1·5	5·8	2·7	5·1	1·9
4·7	3·2	1·3	0·2	6·9	3·1	4·9	1·5	7·1	3·0	5·9	2·1
4·6	3·1	1·5	0·2	5·5	2·3	4·0	1·3	6·3	2·9	5·6	1·8
5·0	3·6	1·4	0·2	6·5	2·8	4·6	1·5	6·5	3·0	5·8	2·2
5·4	3·9	1·7	0·4	5·7	2·8	4·5	1·3	7·6	3·0	6·6	2·1
4·6	3·4	1·4	0·3	6·3	3·3	4·7	1·6	4·9	2·5	4·5	1·7
5·0	3·4	1·5	0·2	4·9	2·4	3·3	1·0	7·3	2·9	6·3	1·8
4·4	2·9	1·4	0·2	6·6	2·9	4·6	1·3	6·7	2·5	5·8	1·8
4·9	3·1	1·5	0·1	5·2	2·7	3·9	1·4	7·2	3·6	6·1	2·5
5·4	3·7	1·5	0·2	5·0	2·0	3·5	1·0	6·5	3·2	5·1	2·0
4·8	3·4	1·6	0·2	5·9	3·0	4·2	1·5	6·4	2·7	5·3	1·9
4·8	3·0	1·4	0·1	6·0	2·2	4·0	1·0	6·8	3·0	5·5	2·1
4·3	3·0	1·1	0·1	6·1	2·9	4·7	1·4	5·7	2·5	5·0	2·0
5·8	4·0	1·2	0·2	5·6	2·9	3·6	1·3	5·8	2·8	5·1	2·4

R. A. Fisher (1936). "The use of multiple measurements in taxonomic problems"

Switch to Jupyter notebook

Types of machine learning

Supervised learning:

- discrete output: classification
- continuous output: regression
- . . . , e.g. graphs or other structures

Unsupervised learning:

- discrete output: clustering
- continuous output: dimensionality reduction

Semi-supervised learning:

- . . .

Reinforcement learning:

- (different setup). . .

Tools of machine learning

- probability theory (e.g. Bayes' rule)

$$p(B|A) = \frac{p(A|B)p(B)}{p(A)}$$

- linear algebra (e.g. vectors and matrices)

$$y = Ax + n$$

- optimization (e.g. gradient descent)

$$\begin{aligned} &\text{minimize } f(x) \\ &\text{subject to } g(x) \leq 0 \\ &\qquad\qquad h(x) = 0 \end{aligned}$$

- computer science

all the things you learned so far and more!

Tentative syllabus

2021-10-11	01	Introduction and probability as logic	01
2021-10-13	02	More on probabilities, Bayes nets	
2021-10-18	03	Continuous probabilities	02
2021-10-20	04	The Gaussian distribution	
2021-10-25	05	More on distributions, models, MAP, MLE	03
2021-10-27	06	Linear regression	
2021-11-03	07	Matrix differential calculus	04
2021-11-08	08	SVM and constrained optimization	
2021-11-10	09	Kernel trick	05
2021-11-15	10	More on kernels	
2021-11-17	11	Dimensionality reduction and PCA	06
2021-11-22	12	ISOMAP, MDS, LLE and MVU	
2021-11-24	13	kPCA, Intro to Gaussian mixture models	07
2021-11-29	14	Gaussian mixture models, k-means, EM	
2021-12-01	15	General EM, missing data, latent variables	08
2021-12-06	16	Neural networks: intro	
2021-12-08	17	Neural networks: backprop	09
2021-12-13	18	Neural networks: building blocks	
2021-12-15	19	Neural networks: tutorials about Pytorch	10
2021-12-20	20	Neural networks: tricks, unsupervised	
2021-12-22	21	Gaussian processes theory	11
2021-01-10	22	Gaussian processes / kernels	
2022-01-12	23	Gaussian processes continued again	12
2022-01-17	24	Gaussian processes / GPC	
2022-01-19	25	Sampling	13
2022-01-24	26	Statistical learning theory	
2022-01-26	27	MCMC	
2022-01-31	28	No-free-lunch theorem, biased overview and questions	
2022-02-02	29	maybe AlphaGo and AlphaGoZero	
2022-02-09	30	WRITTEN EXAM	

Summary

What is machine learning?

- Supervised learning: classification, regression
- Unsupervised learning: regression, dimensionality reduction
- ...