Machine Learning II

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Machine Learning for Computer Vision
TU Dresden

https://mlcv.cs.tu-dresden.de/courses/26-summer/ml2/

Summer Term 2026

Machine Learning II

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- Course consisting of
  - Lectures in APB/E023 on Mondays, 11:10–12:40
  - Exercises in APB/E023 on Tuesdays, 11:10–12:40, **starting April 21st**
  - Self-study
  - Final examination (covering lectures and exercises); form depends on module; typical is a 90-minute written examination
- Registration:
  - All participating students need to register through OPAL
  - Additional rules for enrolment may apply, depending on the study program.
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Machine Learning is an area of computer science focused on the research of mathematical models and algorithms for analyzing, understanding and interpreting data, as well as for deciding and acting based on data. It

- poses challenging problems
- builds on insights and methods in different areas, in particular
  - mathematics (esp. combinatorics, optimization, probability theory, statistics)
  - computer science (esp. algorithms, complexity, software engineering)
- provides an opportunity for applying analytical and engineering skills
- has impact on applications (scientific, medical, robotic, consumer)
- is intellectually stimulating

Machine Learning II

This specialized course is about selected, not necessarily connected topics of machine learning and its applications:

- Linear and integer optimization for machine learning
  - Simplex algorithm
  - Branch-and-bound/branch-and-cut algorithms
  - Partial optimality
- Supervised learning
  - Learning of rectified linear units
  - Learning of support vector machines
- Unsupervised learning
  - Clustering (of sets and graphs) — Application: Image segmentation
  - Ordering/Preordering — Application: Social network analysis
- Supervised structured learning
  - Graphical model inference — Application: Pixel classification
- Embedding
  - (Variational) auto-encoders — Application: Image generation
- Graph neural networks

Prerequisites:

- Mathematics
  - Linear algebra
  - Discrete mathematics (basics)
  - Multivariate calculus (basics)
- Computer Science
  - Algorithms and data structures
  - Theoretical computer science (basics of complexity theory)
  - Machine Learning (basics)

- Textbooks:
  - Kevin P. Murphy. Machine Learning: A Probabilistic Perspective. MIT Press 2012
  - Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, Jonathan Taylor. An Introduction to Statistical Learning. Springer 2023
  - Christopher M. Bishop, Hugh Bishop. Deep Learning: Foundations and Concepts. Springer 2024
  - Marc Peter Deisenroth. Mathematics for Machine Learning. Cambridge University Press 2020
- Scholarly journals (selection):
  - Journal of Machine Learning Research (JMLR)
  - Transactions on Pattern Analysis and Machine Intelligence (TPAMI)
  - Transactions on Machine Learning Research (TMLR)
- Academic conferences (selection):
  - International Conference on Machine Learning (ICML)
  - Neural Information Processing Systems (NeurIPS)
  - International Conference on Learning Representations (ICLR)

https://mlcv.cs.tu-dresden.de/teaching.html

Related courses we are offering this term:

- **Machine Learning Seminar**
  In APB/E008 on Fridays, 9:20–10:50
- **Research Projects**
  In APB/2026 on Mondays, 14:50–16:20. Kick-off meeting: April 13th
- **Team Project Machine Learning (CMS-AAI-TEA)**
  In APB/2026 on Mondays, 14:50–16:20. Kick-off meeting: April 20th

Notation:

- Considering that $0 = \varnothing$ and for any $m \in \mathbb{N}$: $m = \{0, \dots, m-1\}$, we may write $j \in m$ instead of $j \in \{0, \dots, m-1\}$.
- For any finite set A, let $|A|$ denote the number of elements of A.
- For any set A, let 2^A denote the power set of A.
- For any set A and any $m \in \mathbb{N}_0$, let $\binom{A}{m}$ denote the set of all m-elementary subsets of A, i.e. $\binom{A}{m} = \{B \in 2^A \colon |B| = m\}$.
- For any sets A, B, let B^A denote the set of all maps from A to B. Moreover, let AB be shorthand for the ordered pair (A, B).
- For any $f \in B^A$, any $a \in A$ and any $b \in B$, we may write $b = f(a)$ or $b = f_a$ instead of $(a, b) \in f$.
- For any $f \in B^A$ and any $U \subseteq A$, let $f|_U := f \cap (U \times B)$.
- Given any set J and, for any $j \in J$, a set S_j, we denote by $\prod_{j \in J} S_j$ the Cartesian product of the family $\{S_j\}_{j \in J}$, i.e.

$$\prod_{j \in J} S_j = \left\{ f \colon J \to \bigcup_{j \in J} S_j \;\middle|\; \forall j \in J \colon f(j) \in S_j \right\} \quad . \tag{1}$$

Notation (contd.):

- Let $\langle \cdot, \cdot \rangle$ denote the standard inner product, and let $\| \cdot \|$ denote the l_2-norm.
- Consider any $m, n \in \mathbb{N}_0$ and any $A \in \mathbb{R}^{m \times n}$, i.e. $A \colon m \times n \to \mathbb{R}$.
  For any $J \subseteq m$ and any $K \subseteq n$, let $A|_{JK} := A|_{J \times K}$.
  For any $J \subseteq m$, let $A|_{J\cdot} := A|_{J \times n}$. For any $j \in m$, let $A_{j\cdot} := A|_{\{j\} \times n}$.
  For any $K \subseteq n$, let $A|_{\cdot K} := A|_{m \times K}$. For any $k \in n$, let $A_{\cdot k} := A|_{m \times \{k\}}$.