EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Mathematisch-Naturwissenschaftliche Fakultät

Autonomes Maschinelles Sehen

Lecture: Computer Vision

The goal of computer vision is to compute geometric and semantic properties of the three-dimensional world from digital images. Problems in this field include reconstructing the 3D shape of an object, determining how things are moving and recognizing objects or scenes. This course will provide an introduction to computer vision, with topics including image formation, camera models, camera calibration, feature detection and matching, motion estimation, geometry reconstruction, object detection and tracking, and scene understanding. Applications include building 3D maps, creating virtual avatars, image search, organizing photo collections, human computer interaction, video surveillance, self-driving cars, robotics, virtual and augmented reality, simulation, medical imaging, and mobile computer vision. Modern computer vision relies heavily on machine learning in particular deep learning and graphical models. This course therefore assumes prior knowledge of deep learning (e.g., deep learning lecture) and introduces the basic concepts of graphical models and structured prediction where needed. The tutorials will deepen the understanding of deep neural networks by implementing and applying them in Python and PyTorch. A strong emphasis of this course is on 3D vision.

This class received the CS teaching award in summer 2021

Qualification Goals

Students gain an understanding of the theoretical and practical concepts of computer vision including image formation, camera models, feature detection, multiple view geometry, 3D reconstruction, motion estimation, object recognition, scene understanding and structured prediction using deep neural networks and graphical models. A strong emphasis of this course is on 3D vision. After this course, students should be able to understand and apply the basic concepts of computer vision in practice, develop and train computer vision models, reproduce research results and conduct original research in this area.

Overview

- Course number: ML-4360
- Credits: 6 ECTS, from 2023: 9 ECTS
- Recommended for: Master, 2nd semester
- Total Workload: 270h
- This lecture is taught as **flipped classroom.** Lectures will be held asynchronously via **YouTube** (see sidebar for link). We will provide all lectures before the respective interactive live sessions for self-study. Please watch the relevant videos before participating in the interactive live sessions.
- Each week, we host **an interactive live session** where questions regarding the lecture and exercises are discussed together (see sidebar for details).
- We also offer a weekly **zoom helpdesk** where students may ask questions or share their screen to obtain individual feedback and support for solving the exercises (see sidebar for details).
- **Exercises** will not be graded. Instead, we will discuss the solution together.
- Students may obtain **bonus points** for the exam by answering questions about the lectures and exercises in weekly quizzes. The questions also serve as a measure for self-assessment and self-motivation. All quizzes are provided via our **Lecture Quiz Server** (see sidebar for details).

Prerequisites

- Basic **Computer Science** skills: Variables, functions, loops, classes, algorithms
- Basic **Python** and **PyTorch** coding skills
- Basic **Math** skills: Linear algebra, probability and information theory (eg., Math for ML lecture https://www.tml.cs.uni-tuebingen.de/teaching/2020_maths_for_ml/index.php)
  As a refresher we recommend reading Chapters 1-4 of: http://www.deeplearningbook.org
- Experience with **Deep Learning** (eg., through participation our Deep Learning lecture)

Registration

- To **participate in this lecture**, you must enroll via **ILIAS** (see sidebar for link)
- Registration via **ILIAS will open** on 30.03. at 12:00
- Information about **exam registration** can be found here

Exercises

The exercises play an essential role in understanding the content of the course. There will be 6 assignments in total. The assignments contain pen and paper questions as well as programming problems. For some of the exercises, the students will use **PyTorch**, a state-of-the-art deep learning framework which features GPU support and auto-differentiation. If you have **questions** regarding the exercises or the lecture, please ask them during the interactive sessions, at the zoom helpdesk or in our ILIAS forum.

Further Readings

- Richard Szeliski: Computer Vision: Algorithms and Applications
- Hartley and Zisserman: Multiple View Geometry in Computer Vision
- Nowozin and Lampert: Structured Learning and Prediction in Computer Vision
- Goodfellow, Bengio and Courville: Deep Learning
- Deisenroth, Faisal and Ong: Mathematics for Machine Learning
- Computer Vision Lecture Notes written by students in summer 2021
- Articles and papers mentioned in the lecture slides

Schedule

Date	Lecture Slides and Videos	Live Sessions (Zoom | MvL6+Zoom)	TA Support
22.04.	**L01 - Introduction | Slides** 1.1 Organization | Video 1.2 Introduction | Video 1.3 History of Computer Vision | Video	**L01 - Lecture Organization** E01 - Exercise Introduction | Problems	Michael Niemeyer
29.04.	**L02 - Image Formation | Slides** 2.1 Primitives and Transformations | Video 2.2 Geometric Image Formation | Video 2.3 Photometric Image Formation | Video 2.4 Image Sensing Pipeline | Video	**L02 - Lecture Q&A** E01 - Exercise Q&A	Michael Niemeyer
06.05.	**L03 - Structure-from-Motion | Slides** 3.1 - Preliminaries| Video 3.2 - Two-frame Structure-from-Motion| Video 3.3 - Factorization | Video 3.4 - Bundle Adjustment | Video	**L03 - Lecture Q&A** E01 - Exercise Q&A E02 - Exercise Introduction | Problems	Michael Niemeyer
13.05.	**L04 - Stereo Reconstruction | Slides** 4.1 - Preliminaries | Video 4.2 - Block Matching | Video 4.3 - Siamese Networks | Video 4.4 - Spatial Regularization | Video 4.5 - End-to-End Learning | Video	**L04 - Lecture Q&A** E02 - Exercise Q&A	Michael Niemeyer
20.05.	**L05 - Probabilistic Graphical Models | Slides** 5.1 - Structured Prediction | Video 5.2 - Markov Random Fields | Video 5.3 - Factor Graphs | Video 5.4 - Belief Propagation | Video 5.5 - Examples | Video	**L05 - Lecture Q&A** E02 - Exercise Q&A E03 - Exercise Introduction | Problems	Michael Niemeyer Zehao Yu
27.05.	**L06 - Applications of Graphical Models | Slides** 6.1 - Stereo Reconstruction | Video 6.2 - Multi-View Reconstruction | Video 6.3 - Optical Flow | Video	**No Lecture Q&A This Week** E03 - Exercise Q&A	Zehao Yu
03.06.	**L07 - Learning in Graphical Models | Slides** 7.1 - Conditional Random Fields | Video 7.2 - Parameter Estimation | Video 7.3 - Deep Structured Models | Video	**L07 - Lecture Q&A** E03 - Exercise Q&A E04 - Exercise Introduction | Problems	Zehao Yu
10.06.	No Lecture (Pfingstpause)	No Exercise (Pfingstpause)	

17.06.	**L08 - Shape-from-X | Slides** 8.1 - Shape-from-Shading | Video 8.2 - Photometric Stereo | Video 8.3 - Shape-from-X | Video 8.4 - Volumetric Fusion | Video	**L08 - Lecture Q&A** E04 - Exercise Q&A	Zehao Yu
24.06.	No Lecture	No Exercise	
01.07.	**L09 - Coordinate-based Networks | Slides** 9.1 - Implicit Neural Representations | Video 9.2 - Differentiable Volumetric Rendering | Video 9.3 - Neural Radiance Fields | Video 9.4 - Generative Radiance Fields | Video	**L09 - Lecture Q&A** E04 - Exercise Q&A E05 - Exercise Introduction | Problems	Zehao Yu Markus Flicke
08.07.	**L10 - Recognition | Slides** 10.1 - Image Classification | Video 10.2 - Semantic Segmentation | Video 10.3 - Object Detection and Segmentation | Video	**L10 - Lecture Q&A** E05 - Exercise Q&A	Markus Flicke
15.07.	**L11 - Self-Supervised Learning | Slides** 11.1 - Preliminaries | Video 11.2 - Task-specific Models | Video 11.3 - Pretext Tasks | Video 11.4 - Contrastive Learning | Video	**L11 - Lecture Q&A** E05 - Exercise Q&A E06 - Exercise Introduction | Problems	Markus Flicke
22.07.	No Lecture	No Exercise	
29.07.	**L12 - Diverse Topics in Computer Vision | Slides** 12.1 - Input Optimization | Video 12.2 - Compositional Models | Video 12.3 - Human Body Models | Video 12.4 - Deepfakes | Video	**L12 - Lecture Q&A** E06 - Exercise Q&A	Markus Flicke

Lecturer
Prof. Dr. Andreas Geiger

TAs
Michael Niemeyer (lead)
Zehao Yu
Markus Flicke

Summer 2022

- **Live Sessions:**
  Fri, 10:15-12:00
  (until 27.5. via Zoom,
  from 3.6. on Hybrid:
  MvL6 + Zoom)
- **Individual Sessions:**
  Fri, 9:15-10:00
  Fri, 11:15-12:00
  Fri, 12:15-13:00
- **Important Links:**
  YouTube Lectures
  Slides / Exercises
  ILIAS / Zoom / Quiz

Exam

- Date: 02.08.2022
- Time: 8:00-9:30
- Rooms: HS 25 (Kupferbau)
- Mode: Written
- Exam registration

Make-up Exam

- Date: 10.10.2022
- Time: 10:00-11:30
- Room: HS 25 (Kupferbau)
- Mode: Written
- Exam registration