Introduction to Deep Learning
The Team

Lecturer

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PhDs

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What is Computer Vision?

• First defined in the 60s in artificial intelligence groups
• “Mimic the human visual system”
• Center block of robotic intelligence
Hubel and Wiesel

- David Hubel and Torsten Wiesel were neurobiologists from Harvard Medical School
- Experiment revealed several secrets of the human vision system
- Won 2 Nobel prizes
Hubel and Wiesel Experiment

• Recorded electrical activity from individual neurons in the brains of cats.

• Slide projector to show specific patterns to the cats noted specific patterns stimulated activity in specific parts of the brain.

• Results: Visual cortex cells are sensitive to the orientation of edges but insensitive to their position.
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".
A Few Decades Later…
Image Classification

Input image → Preprocessing → Features: HAAR, HOG, SIFT, SURF → Learning Algorithm → SVM, Random Forests, ANN → Label Assignment

Cat or Background

I2DL: Prof. Niessner
Image Classification

Input image

Awesome magic box

Open the box

Become magicians

Label Assignment

Cat or Background

Post 2012
Why Deep Learning?
What Has Changed?

1998 LeCun et al.
- MNIST digit recognition dataset
- $10^7$ pixels used in training

2012 Krizhevsky et al.
- ImageNet image recognition dataset
- $10^{14}$ pixels used in training
What Made this Possible?

Big Data

Models know where to learn from

Hardware

Models are trainable

Deep

Models are complex
Deep Learning Recognition

ACM Turing Award 2019 (Nobel Prize of Computing)
Yann LeCun, Geoffrey Hinton, and Yoshua Bengio
Deep Learning and Computer Vision

Deep Learning Evolution in Computer Vision

Credits: Dr. Pont-Tuset, ETH Zurich
Deep Learning and Computer Vision

Credit: Dr. Pont-Tuset, ETH Zurich
Deep Learning Today

Object Detection

hat with a wide brim

dog
Deep Learning Today

Self-driving cars
Deep Learning Today

AlphaGo

Emoticon suggestion

ever punch a cactus?

Machine translation

Deep Learning rocks

Deep Learning Felsen
Deep Learning Today
Deep Learning Today

Google Assistant (Google IO’19)
Deep Learning Today

Google LaMDA (Google IO’22)
Deep Learning Today

- Chat-GPT
Deep Learning Today

Healthcare, cancer detection
An astronaut, Teddy bears, a bowl of soup, mixing sparkling chemicals as mad scientists, shopping for groceries, working on new AI research, in the style of ukiyo-e, as a one-line drawing, in ancient Egypt.

Dall-E 2 Image generation from text
Deep Learning Today

A high tech solarpunk utopia in the Amazon rainforest

StableDiffusion Image generation from text
https://huggingface.co/spaces/stabilityai/stable-diffusion
Deep Learning Today

StableDiffusion Image Outpainting
Deep Learning Market

 [...] market research report Deep Learning Market [...] “the deep learning market is expected to be worth USD 415 Billion by 2030.
Deep Learning Job Perspective

• Excellent Job Perspectives!
  – Automation requires ML/DL -> growth!
  – Top-notch companies will gladly hire you!

• Many industries now:
  – IT-Companies
  – Cars, Logistics, Health Care, etc...
  – Manufacturing / Robotics, etc...
But: Also Challenging!

• High-level understanding is not enough
  – Need proper theory background
  – Need proper practical skillsets

• Can be competitive!
  – Many good people
  – Downloading scripts / running code not enough 😊
  – Deeper understanding often requires PhDs
Deep Learning on the Internet
Deep Learning Memes
Deep Learning Memes

Deep Learning

What society thinks I do
What my friends think I do
What other computer scientists think I do
What mathematicians think I do
What I think I do
What I actually do

from theano import *
Deep Learning Memes

ONE DOES NOT SIMPLY

LEARN DEEPLY

imgflip.com
Deep Learning Memes

Types of Headaches

- Migraine
- Hypertension
- Stress
- MATH BEHIND DL
Deep Learning at TUM
Many TUM Research Labs use DL

- Visual Computing Lab (Prof. Niessner):
  - Research in computer vision, graphics, and machine learning
- 3D AI Lab (Prof. Dai)
  - Research in 3D perception, 3D scene understanding
- Computer Vision Group (Prof. Cremers)
  - Research in computer vision and pattern recognition
- Data Mining and Analytics Lab (Prof. Günnemann)
  - Research methods for robust machine learning
- Computer Aided Medical Procedures (Prof. Navab)
  - Research in machine learning for medical applications
- And many more 😊
Our Research Lab

Visual Computing & Artificial Intelligence (Prof. Niessner):

- Website: https://niessnerlab.org/publications.html
- Twitter: https://twitter.com/MattNiessner
- Youtube: https://www.youtube.com/channel/UCXN2nYjVT0cRg61RPEzK5Q
Deep Learning at TUM

[I2DL: Prof. Niessner]

[Caelles et al., CVPR’ 17] One-Shot Video Object Segmentation
Deep Learning at TUM

FlowNet
P. Fischer,
A. Dosovitskiy,
E. Ilg,
P. Häusser,
C. Hazirbas,
V. Golkov,
P. v.d. Smagt,
D. Cremers,
T. Brox

FlowNet
FlowNetS
FlowNetC

[Dosovitskiy et al., ICCV’15] FlowNet

I2DL: Prof. Niessner
Deep Learning at TUM

• Multiple object tracking with graph neural networks

[Brasó and Leal-Taixé, CVPR 2020] Learning a Neural Solver for Multiple Object Tracking.
Deep Learning at TUM

[Yang et al., ECCV’18] Deep Virtual Stereo Odometry
Our method generates temporally coherent volumetric data with a trained CNN generator.
Deep Learning at TUM

Animation Synthesis

Source Actor

Target UV-Map

Target Background

Output

[Thies et al., Siggraph'19]: Neural Textures
Deep Learning at TUM

Animation Synthesis

Source Actor

Target UV-Map

Target Background

a time to look ahead

Output

[Thies et al., Siggraph'19]: Neural Textures
Deep Learning at TUM

[Grassal et al., CVPR’22]: Neural Head Avatars
Deep Learning at TUM

Single RGB Image $\rightarrow$ Scene Reconstruction

Only single-view training samples
Deep Learning at TUM

[Božić et al., NeurIPS'21]: TransformerFusion
ScanNet Stats:
- Kinect-style RGB-D sensors
- 1513 scans of 3D environments
- 2.5 Mio RGB-D frames
- Dense 3D, crowd-source MTurk labels
- Annotations projected to 2D frames
Deep Learning at TUM

[Hou et al., CVPR’19] 3D Semantic Instance Segmentation
Deep Learning at TUM

Input Scan
Deep Learning at TUM

Input Scan

[Dai et al., CVPR'21] SPSG
Deep Learning at TUM

Texturify

Generate Textures

[Siddiqui et al., ECCV’22] Texturify
Deep Learning at TUM

Depth Input (lateral view)

IPNet [Bhatnagar et al. 2020]

NPMs* [Palafox et al. 2021]

SPAM (Ours)

Ground Truth

I2DL: Prof. Niessner

[Palafox et al., CVPR'22] SPAMs
Deep Learning at TUM
Context of Other Lectures at TUM
Introduction to Deep Learning

Optimization

Machine Learning basics

Introduction to NN

Back-propagation

CNN

RNN
Deep Learning at TUM

- Intro to Deep Learning
- ADL for Vision (Niessner)
- DL for Medical Applicat. (Navab)
- Machine Learning (Günnemann)
- ML for 3D Geom. (Dai)
- DL in Robotics (Bäuml)
- DL for Physics (Thuerey)
- I2DL: Prof. Niessner
Why is I2DL so Important?

• Many of the other lectures / practical require it!
  – Often only limited spots are available (e.g., in the Advanced Deep Learning for Computer Vision Class)

• Solid preparation for guided research / IDP
  – Most topics require it
  – For career in AI/DL these are the best ways to get into
Introduction to Deep Learning

Logistics
About the Lecture

• Theory lectures
• Lectures are online and will be released every Monday, 14:00
  https://niessner.github.io/I2DL/
  There are old recordings from 2 years, but everything will be re-recorded

Practical exercises (see later slides)
  – Released every Thursday, 10:00
  – Tutorial: Online videos (uploaded to live.rgb.tum.de)
  – Programming exercises

• Guest lecture!
Lecture 1: Introduction to the lecture, Deep Learning, Machine Learning.
Lecture 2: Machine Learning Basics, Linear regression, Maximum Likelihood
Lecture 3: Introduction to Neural Networks, Computational Graphs
Lecture 4: Optimization and Backpropagation
Lecture 5: Scaling Optimization to large Data, Stochastic Gradient Descent
Lecture 6: Training Neural Networks I
Lecture 7: Training Neural Networks II
Lecture 8: Training Neural Networks III
Lecture 9: Introduction to CNNs
Lecture 10: CNNs architectures;
Lecture 11: Recurrent Neural Networks (RNNs)
Lecture 12: Advanced Deep Learning architectures
Guest Lecture

I2DL: Prof. Niessner
Moodle ➔ Piazza

• Announcements via Piazza - **IMPORTANT!**
  – Sign up online for access: [http://piazza.com/tum.de](http://piazza.com/tum.de)
    • Select “**Summer 2023**” term, search for IN2346
    • Use your @mytum.de email address
  – We will share common information (e.g., regarding exam)

• Forum
  – Ask and discuss questions
    • Tutors will monitor and answer questions
    • You are very welcome to actively participate
  – Please do not post solutions of the exercises
  – You can post private question visible only to the staff
Email

• Email list:
  
  i2dl@vc.in.tum.de

• Do NOT email us personally!
  – Cannot handle so many emails / hence will be ignored

• Email list for organizational questions only!
  – Content questions -> Piazza or Office Hours
  – Or post the question/issue in a private thread on Piazza
(Virtual) Office Hours

- We will have dedicated office hours regarding
  - Theoretical help (e.g., specific lecture questions)
  - Help on exercises

- More info in the first tutorial session
- Zoom links will be posted on Piazza
Website

- Links and slides will be shared on website

https://niessner.github.io/I2DL/
Exam FAQ

• **Final Exam:** TBA
• **Content:** Lecture & exercises
• **Important:** No retake exam (I2DL is taught every semester)

• **Grade Bonus:**
  – Solve 8 out of 9 “non-optional” practical exercises
  – Bonus 0.3 on a **passed** final exam
  – Bonus is transferable from previous and future semesters
Other Administrative

• “External” students welcome (LMU, TUM PhD)
  – Fill out registration form and we will add you to the course
  – Will get Certificate / Schein at the end

• Again:
  – Check announcements on piazza
  – Check content on website:
    https://niessner.github.io/I2DL/
Practical Exercises
Exercise – Goal

• Hands-on programming experience (Learning by Doing)
• Reimplementations basic building blocks
• Introduction to common libraries
• (Get grade bonus)
• Ultimately: Gather enough experience to start your own individual (research) deep learning project
Exercise – Format

• Tutorial:
  – Video only
    Posted on live.rbg.tum.de
    Slides uploaded to piazza & website
  – Video length
    Ex02: Full lecture with written exercise
    Ex03-11: Short (~30min) video and coding exercises

• Programming:
  Interactive coding notebooks (~4h each)

Start time: Thursdays 10:00 *
Working Time: 1 week
Deadline: Wednesdays, 15:59

Except for exercise 1:
- No video → this lecture
- Starting time: Today
- Working time: 2 weeks
Exercises – Tech Stack

• **Python**
  Jupiter notebooks
  Numpy

• **Deep Learning library**
  Pytorch

• **Hardware requirements**
  – Minimum: CPU
  – Preferred: Nvidia GPU
  – Alternative: Google Colab
Why Python?

– Very easy to write development code thanks to an intuitive syntax
– Biggest language used in deep learning research
Exercises – Content

- **Intro**
  - Exercise 01: Organization
  - Exercise 02: Math Recap

- **Numpy (Reinvent the wheel)**
  - Exercise 03: Dataset and Dataloader
  - Exercise 04: Solver and Linear Regression
  - Exercise 05: Neural Networks
  - Exercise 06: Hyperparameter Tuning

- **Pytorch/Tensorboard**
  - Exercise 07: Introduction to Pytorch
  - Exercise 08: Autoencoder

- **Applications (Hands-off)**
  - Exercise 09: Convolutional Neural Networks
  - Exercise 10: Semantic Segmentation
  - Exercise 11: Recurrent Neural Networks
Exercises – 9 Submissions

Intro
- Exercise 01: Organization
- Exercise 02: Math Recap

Numpy (Reinvent the wheel)
- Exercise 03: Dataset and Dataloader
- Exercise 04: Solver and Linear Regression
- Exercise 05: Neural Networks
- Exercise 06: Hyperparameter Tuning

Pytorch/Tensorboard
- Exercise 07: Introduction to Pytorch
  - Exercise 08: Autoencoder

Applications (Hands-off)
- Exercise 09: Convolutional Neural Networks
- Exercise 10: Semantic Segmentation
- Exercise 11: Recurrent Neural Networks
1: Register with your enrolled Matriculation Number
2: Login with your credentials you get via email

https://i2dl.vc.in.tum.de/
Within the working time you can submit as often as you want!
Submission System

Bonus

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<thead>
<tr>
<th>Exercise 1</th>
<th>Exercise 3</th>
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This table gives an overview over your current status regarding the grade bonus. For each exercise only the best submission is displayed.

To be eligible for the grade bonus of 0.3 (on an already passed exam), you need to pass 8 of the 9 non-optional submissions.

Leaderboard

The leaderboard shows for each exercise the highest scoring submission from each user. Only valid submissions are displayed.

<table>
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<tr>
<th>#</th>
<th>User</th>
<th>Exercise 1</th>
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Grade Bonus

• Solve 8 out of 9 submissions (bold ones)
  - Pass the required score

• Grade bonus:
  • 0.3 improvement on passed exam
  • Can be transferred from previous and future semesters
Exercise 01 – Overview

• **Starting time:** Today, after the lecture (16:00)
• **Deadline:** Wednesday 05/03, 15:59 (in 2 weeks)

• **Content**
  – Get familiar with the exercise structure
  – Jupyter Notebook & Python setup (local / Google Colab)
  – Introduction to the submission system
  – Submission:
    • Implement 1 line of code
Upcoming Lecture

• Next Lecture: Lecture 2: Machine Learning basics

• From today: Start of exercise 1
See you next time ☺