Introduction to Deep Learning

The Team

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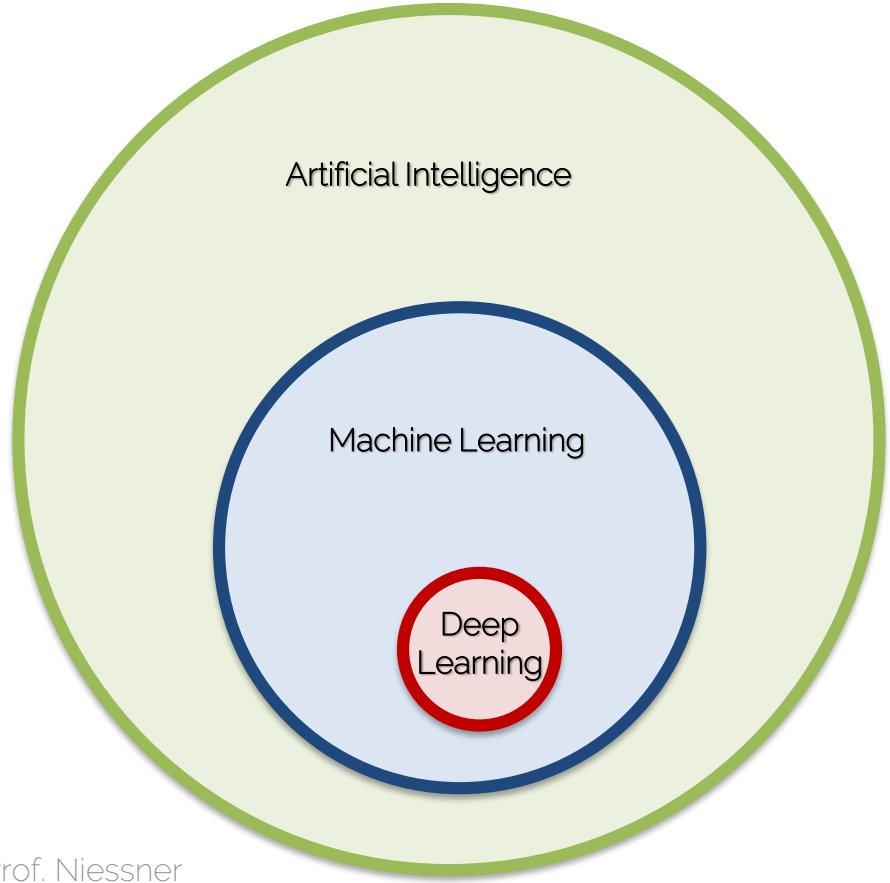
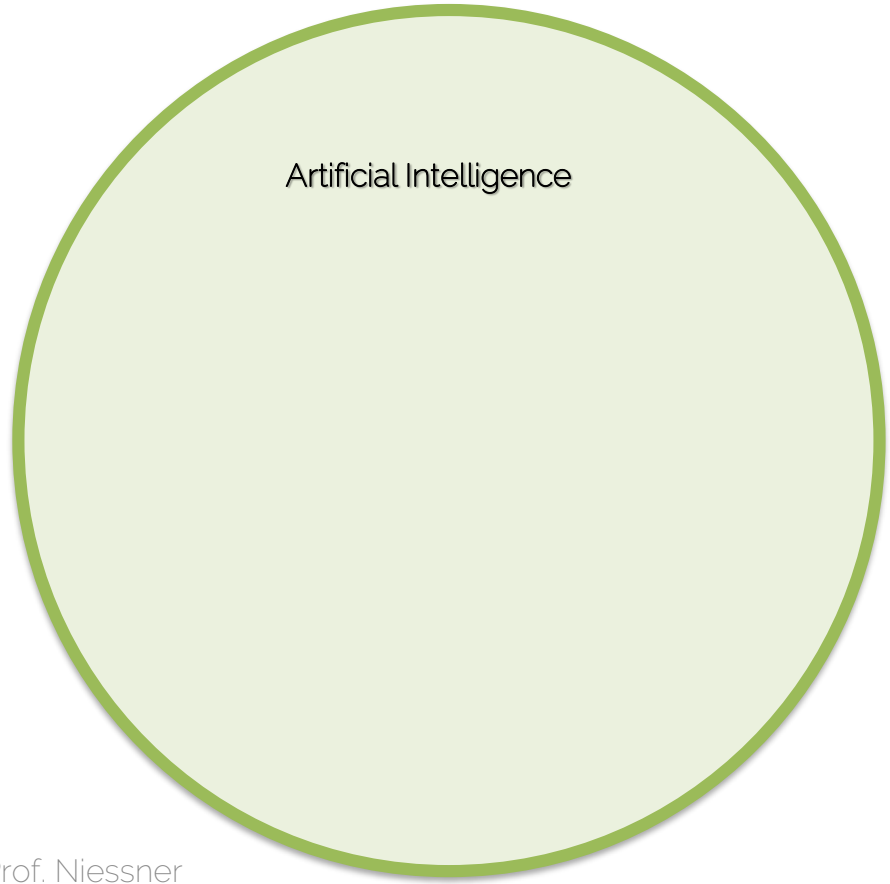
What is this lecture about?



What is this lecture about?

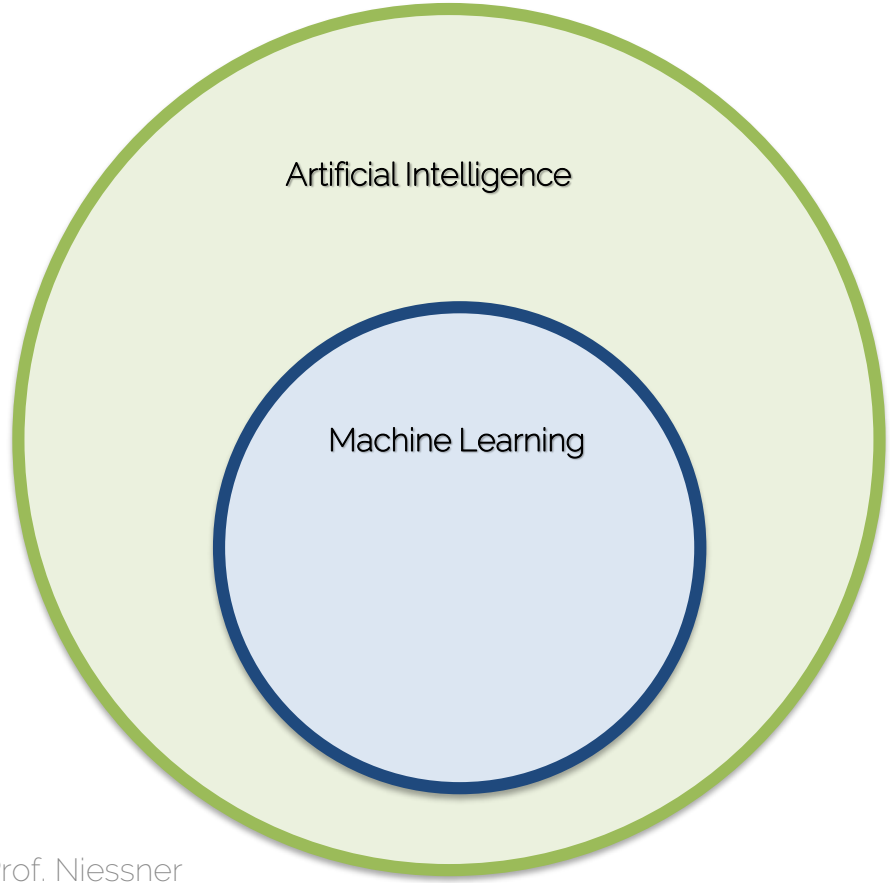


- AI Methods
  - Broad definition!
    - "if" statements"

      if (cold)

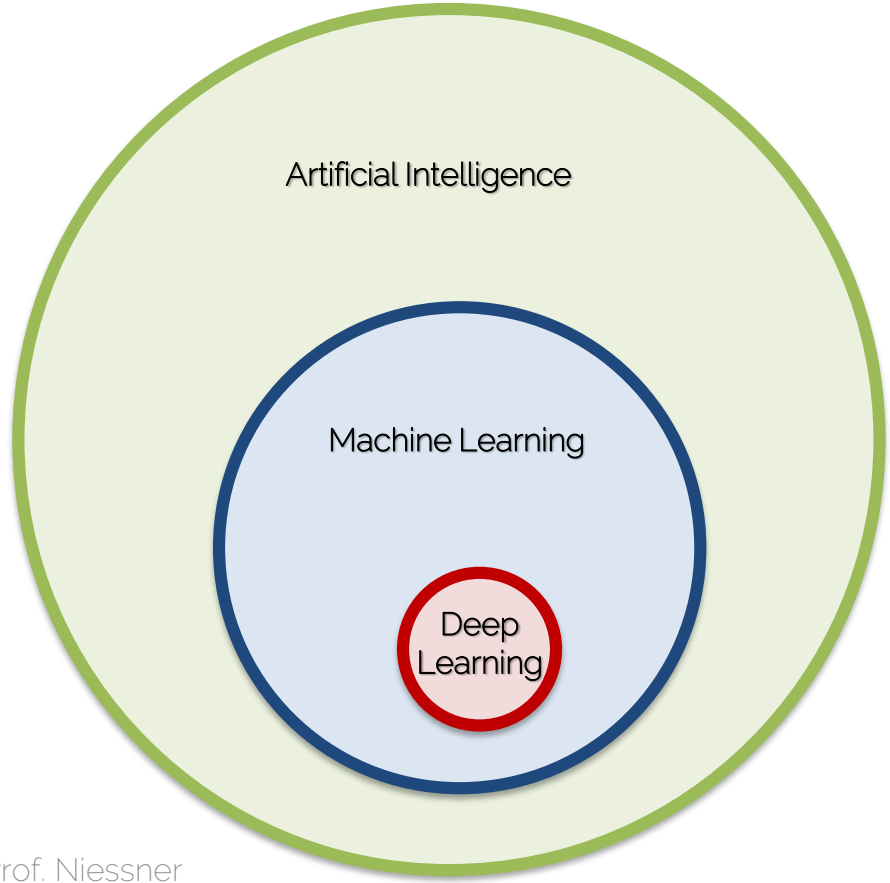
      turn_up_heat();
    - Binary Search
    - Dijkstra, A*, …
    - Prime, Kurskal, …
    - Logic algorithms, etc.
  - ….

What is this lecture about?



- ML Methods
  - Linear/logistic regression
  - Support Vector Machines
  - Random Decision Trees, Forests, Jungles, …
  - …

What is this lecture about?

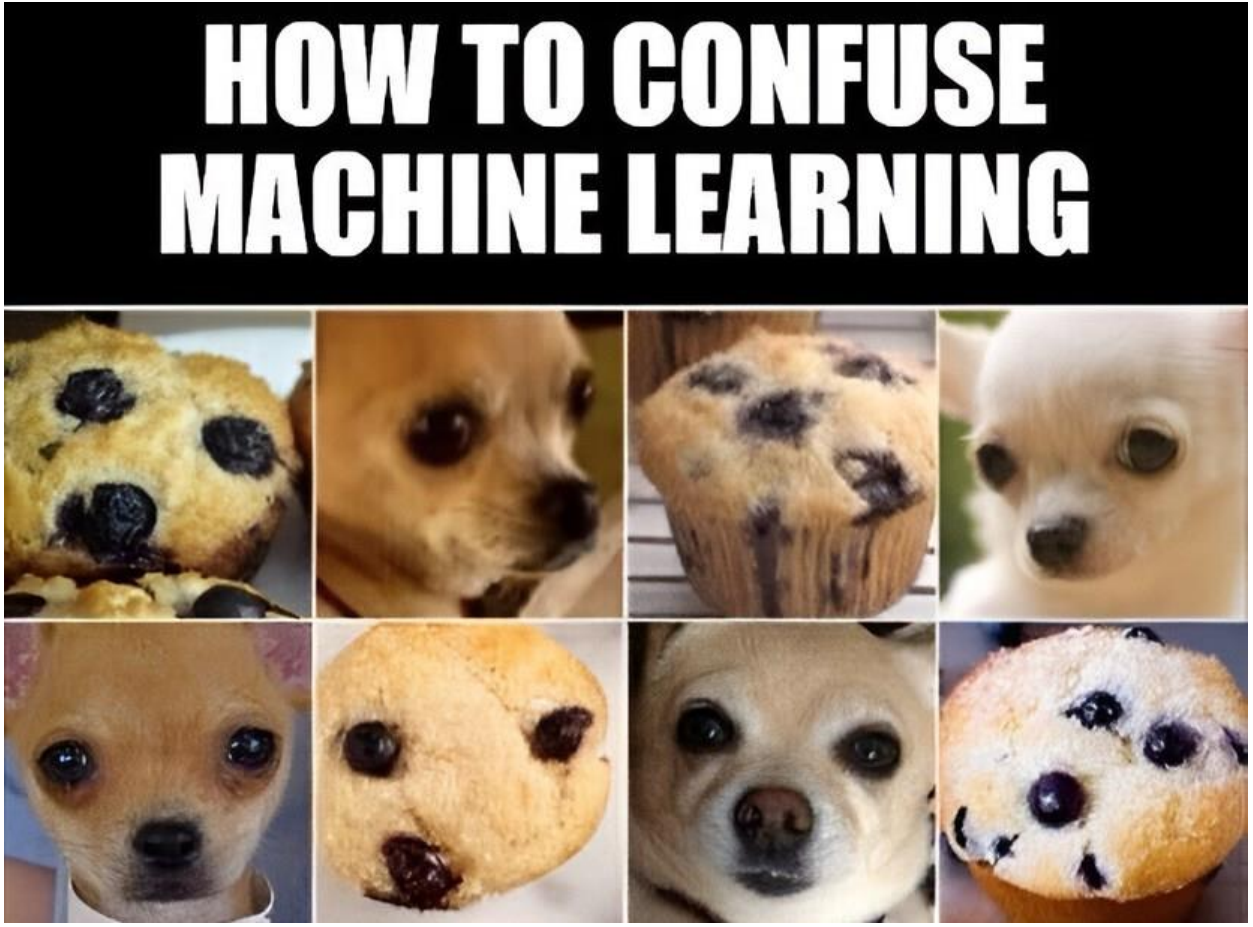


- Deep Learning
  - ML-methods leveraging neural networks
    - Multi-layer perceptrons
    - Convolutional neural networks
    - Recurrent neural networks
    - Transformers
    - Generative models, etc…

What do you see?

Wikimedia Commons

What does a machine see?



What does a machine see?

Q: Is the door of the truck cab open?

Q: In this image, how many eyes can you see on the animal?

Q: How many wheels can you see in the image?

GPT-4V; Credit: https://tsb0601.github.io/mmvp_blog/

What is Computer Vision?

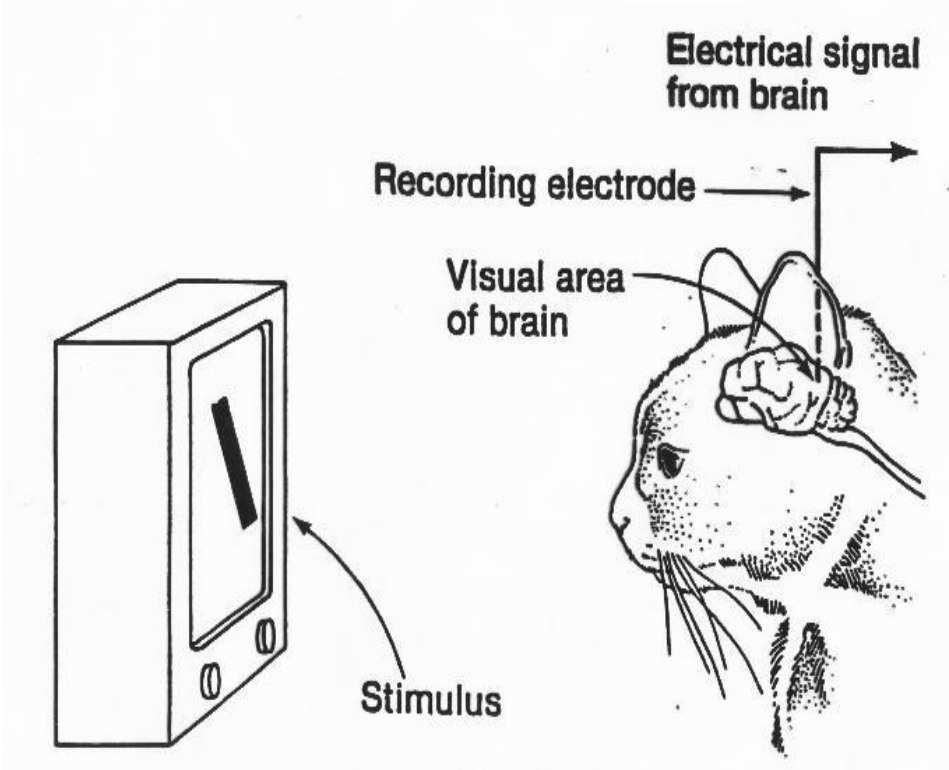
- First defined in the 60s in artificial intelligence groups
- “Mimic the human visual system”
- Center block of robotic intelligence

Hubel and Wiesel

- David Hubel and Torsten Wiesel were neurobiologists from Harvard Medical School
- Experiment revealed insights into the primate visual system
- Nobel prize 1981

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



MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

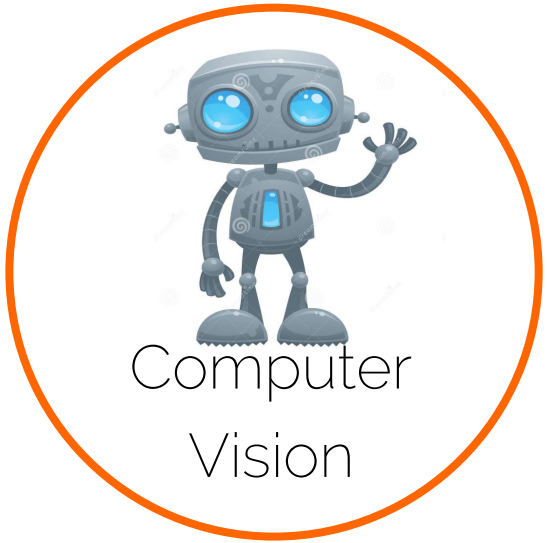
July 7, 1966

THE SUMMER VISION PROJECT

Seymour Papert

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…



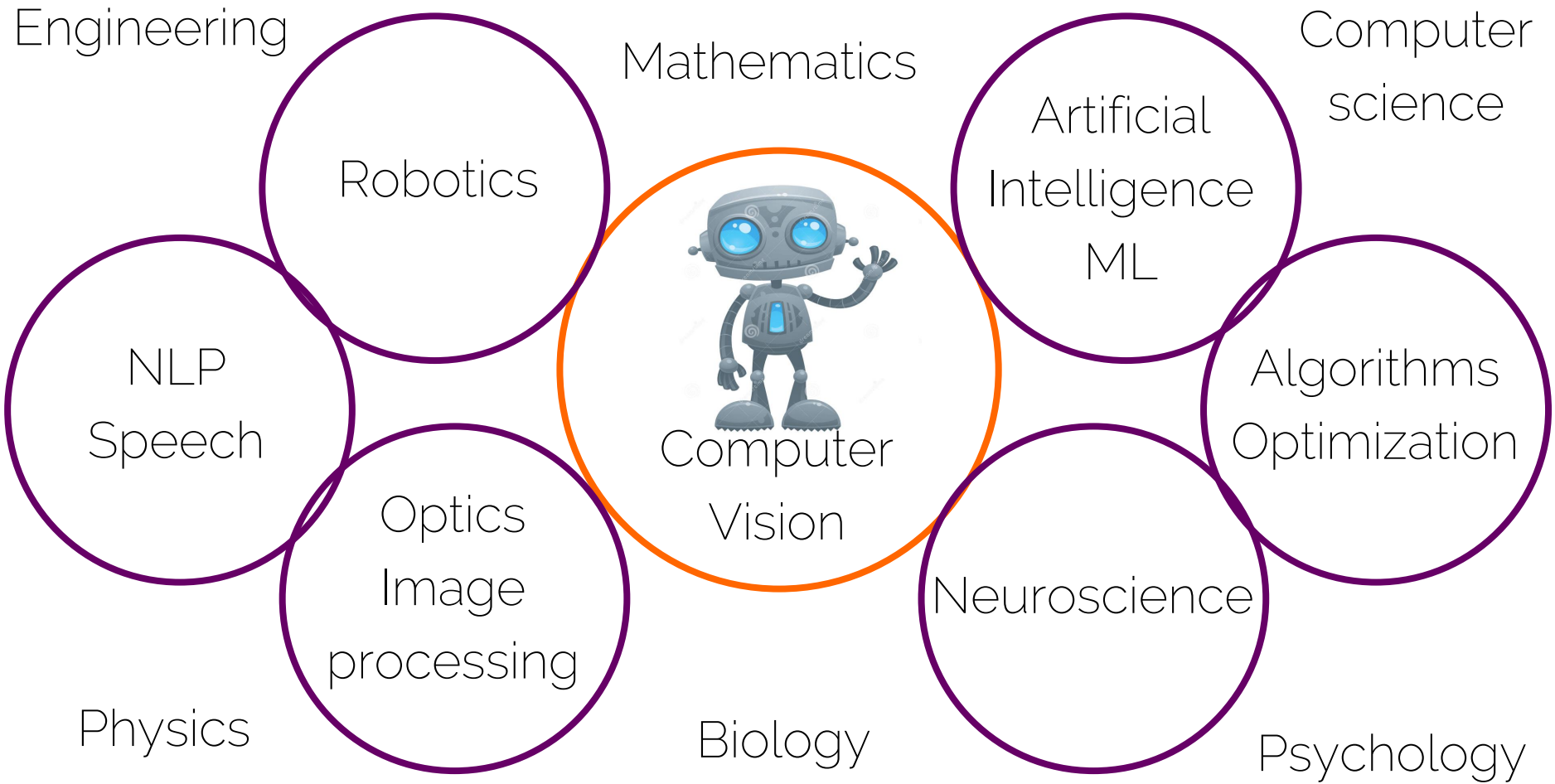
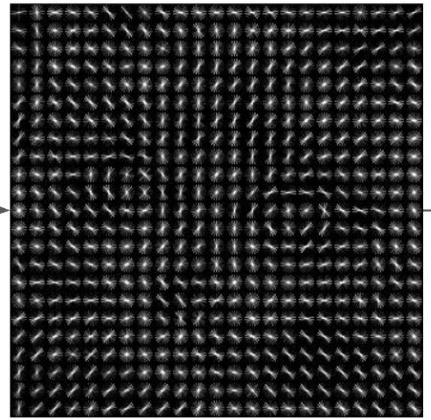

Engineering
Mathematics
Computer science
Robotics
Artificial Intelligence ML
NLP Speech
Computer Vision
Algorithms Optimization
Optics Image processing
Neuroscience
Physics
Biology
Psychology

Image Classification

Input image

Preprocessing



Features : HAAR, HOG, SIFT, SURF

Learning Algorithm

SVM, Random Forests, ANN

Label Assignment

Cat or Background

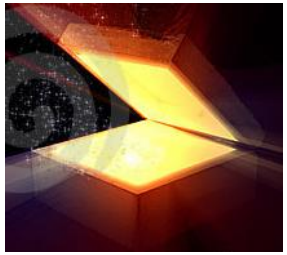
Image Classification

Input image

Awesome magic box

Label Assignment

Cat or Background



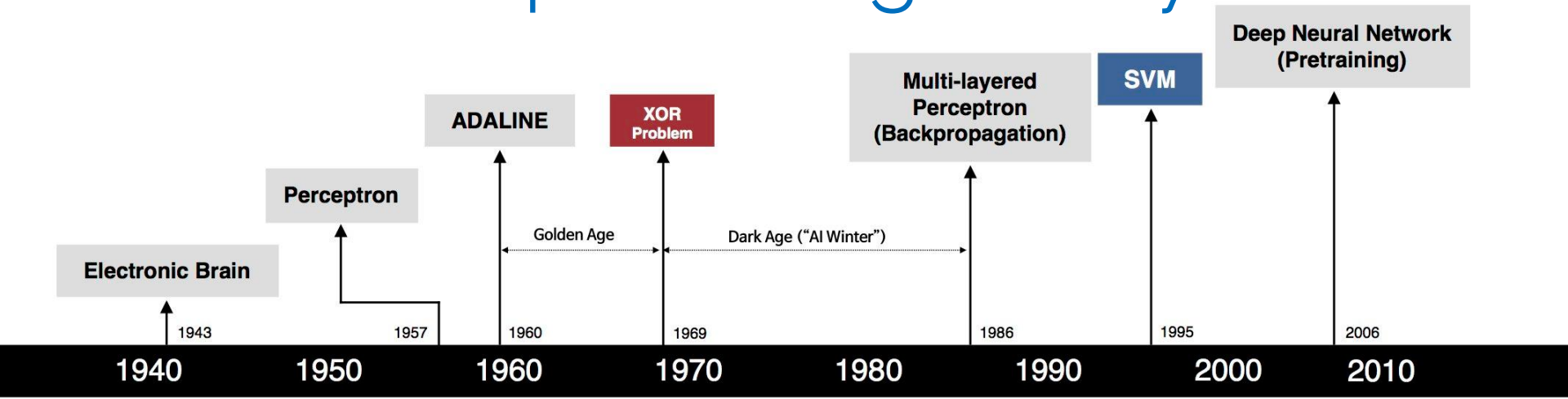
Open the box

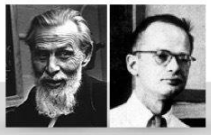
Become magicians

Post 2012

Why Deep Learning?

Deep Learning History





S. McCulloch – W. Pitts

F. Rosenblatt

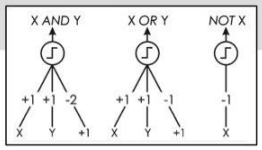
B. Widrow – M. Hoff

M. Minsky – S. Papert

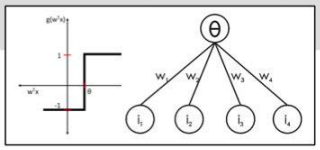
D. Rumelhart – G. Hinton – R. Wiliams

V. Vapnik – C. Cortes

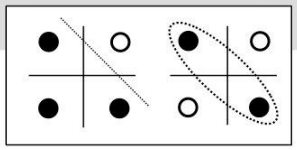
G. Hinton – S. Ruslan



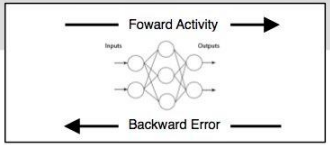
- Adjustable Weights
- Weights are not Learned



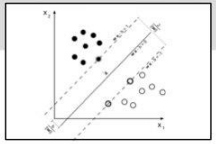
- Learnable Weights and Threshold



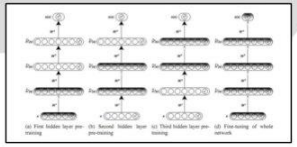
- XOR Problem



- Solution to nonlinearly separable problems
- Big computation, local optima and overfitting

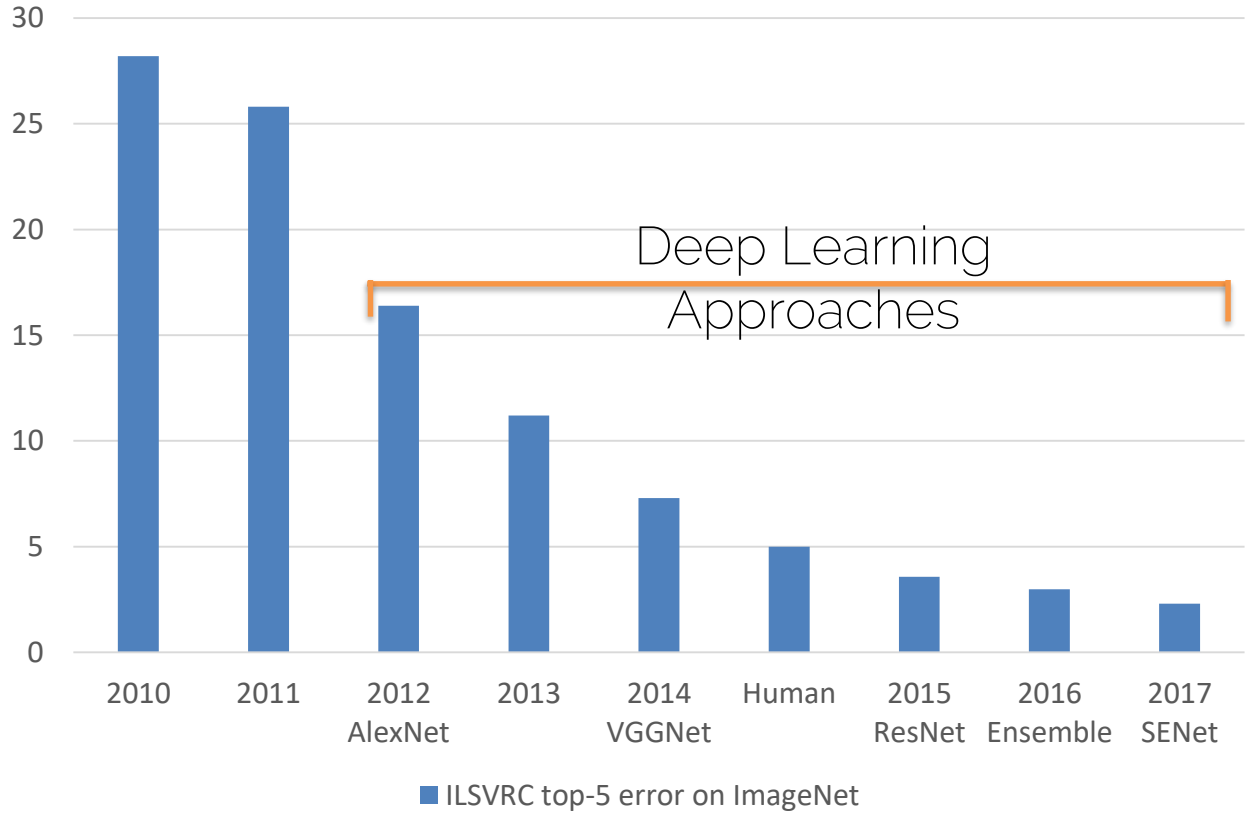


- Limitations of learning prior knowledge
- Kernel function: Human Intervention



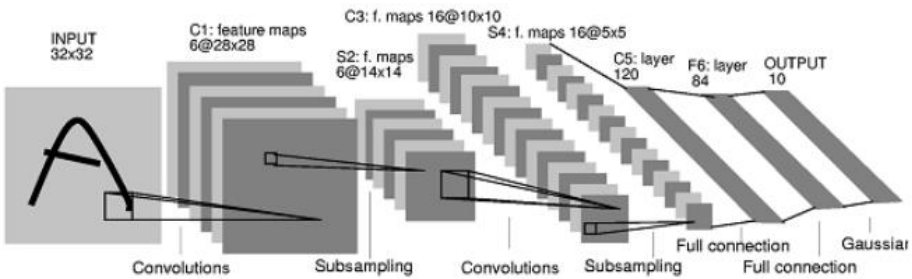
- Hierarchical feature Learning

The Empire strikes Back



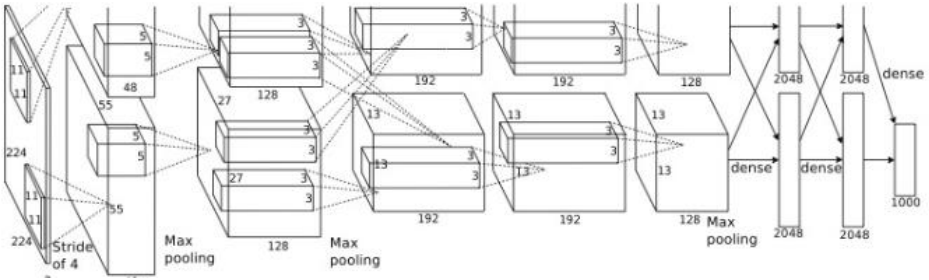
What has Changed?

1998
LeCun
et al.



- MNIST digit recognition dataset
- 10^7 pixels used in training

2012
Krizhevsky
et al.

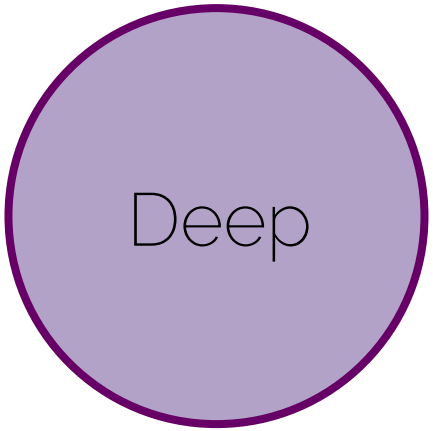


- ImageNet image recognition dataset
- 10^{14} pixels used in training

What Made this Possible?

Models know where to learn from

Models are trainable

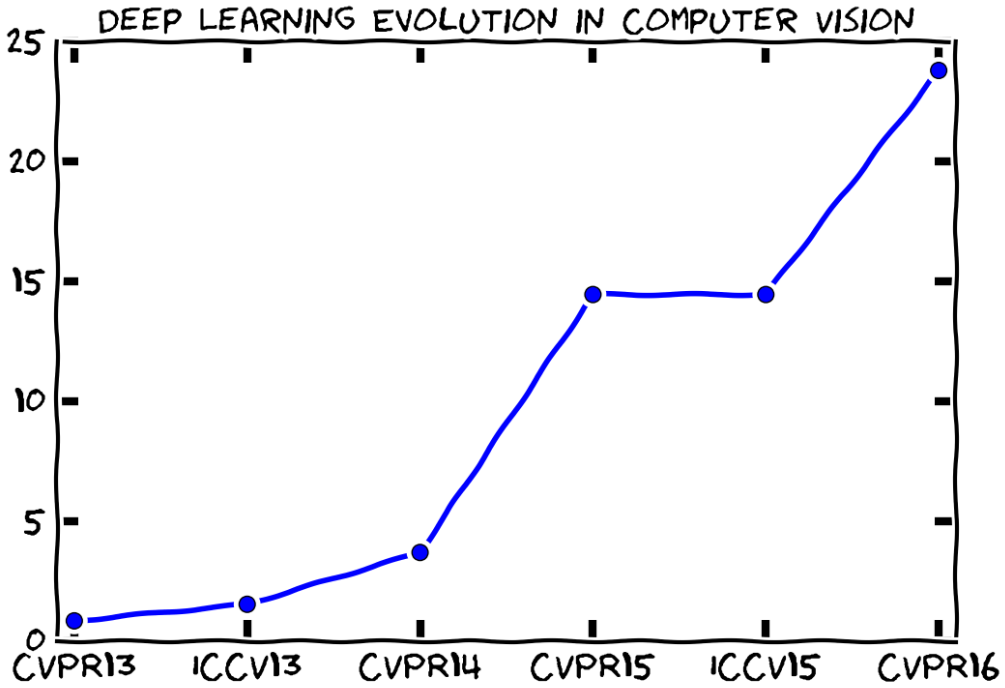


Models are complex

Deep Learning Recognition

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

Deep Learning and Computer Vision



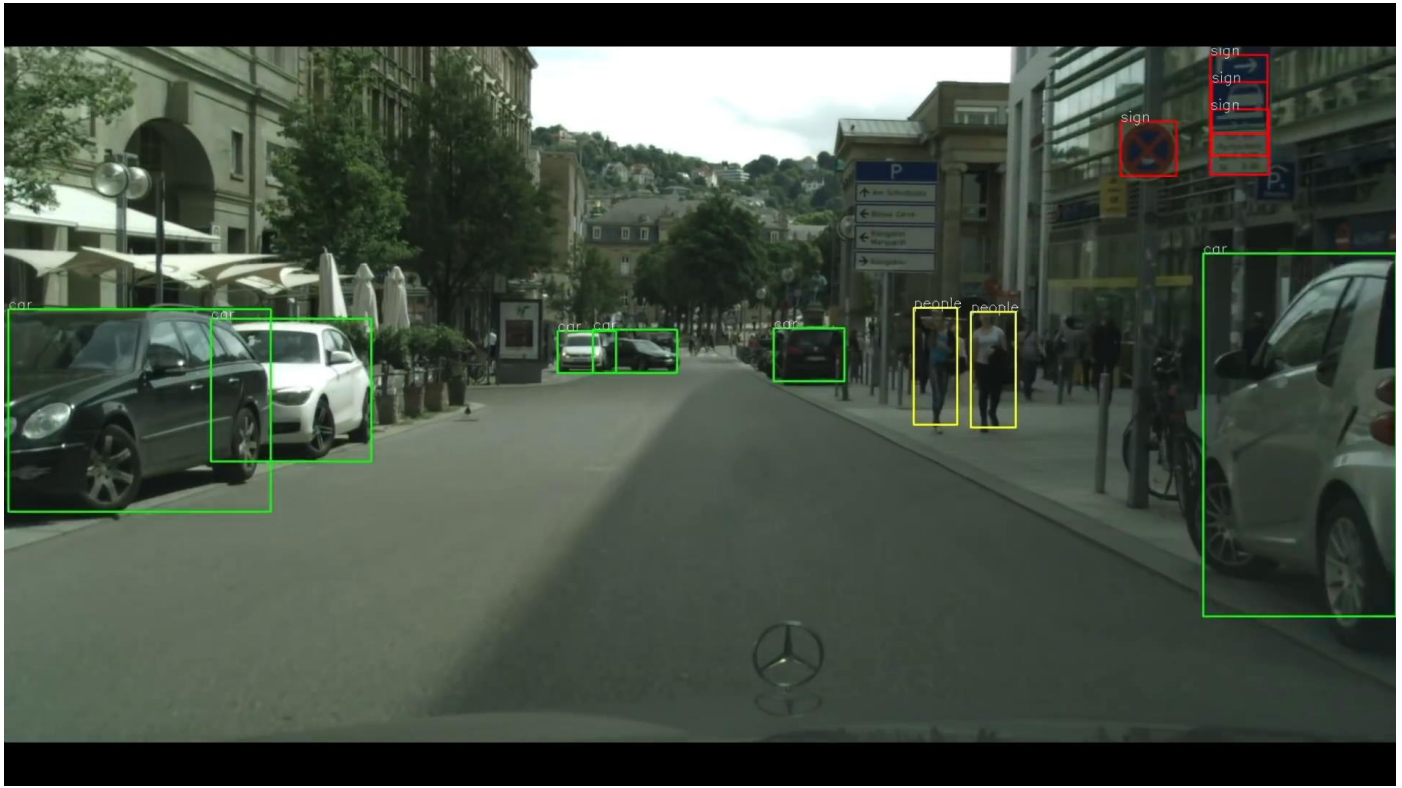
There are now >2,000 papers at almost every top-tier AI conference (CVPR/ICCV/ECCV NeurIPS/ICLR/ICML)

Credits: Dr. Pont-Tuset, ETH Zurich

Deep Learning Today

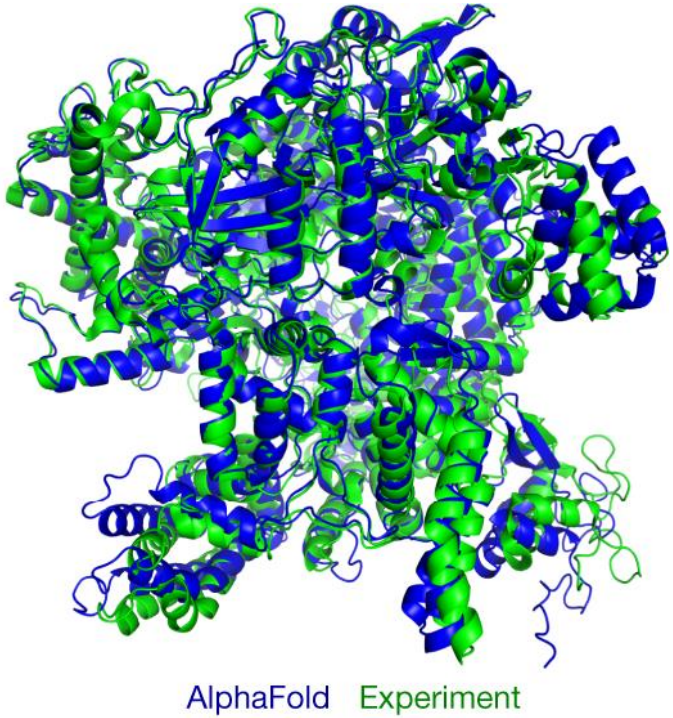
Object Detection

Deep Learning Today



Self-driving cars

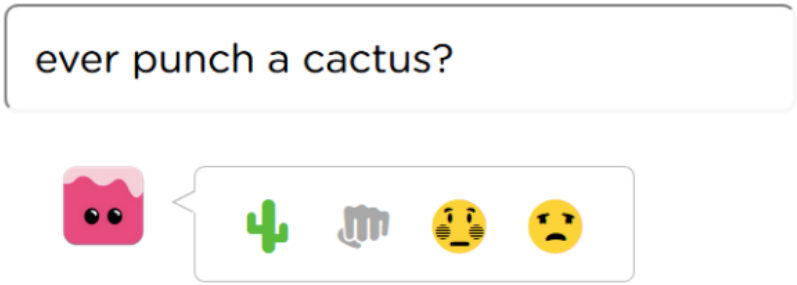
Deep Learning Today



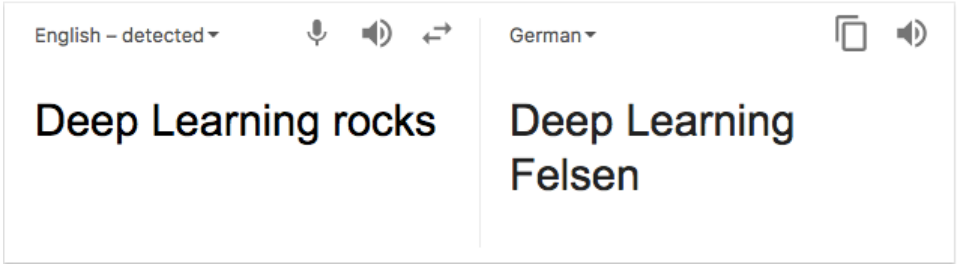
Biological research

Deep Learning Today

AlphaGo

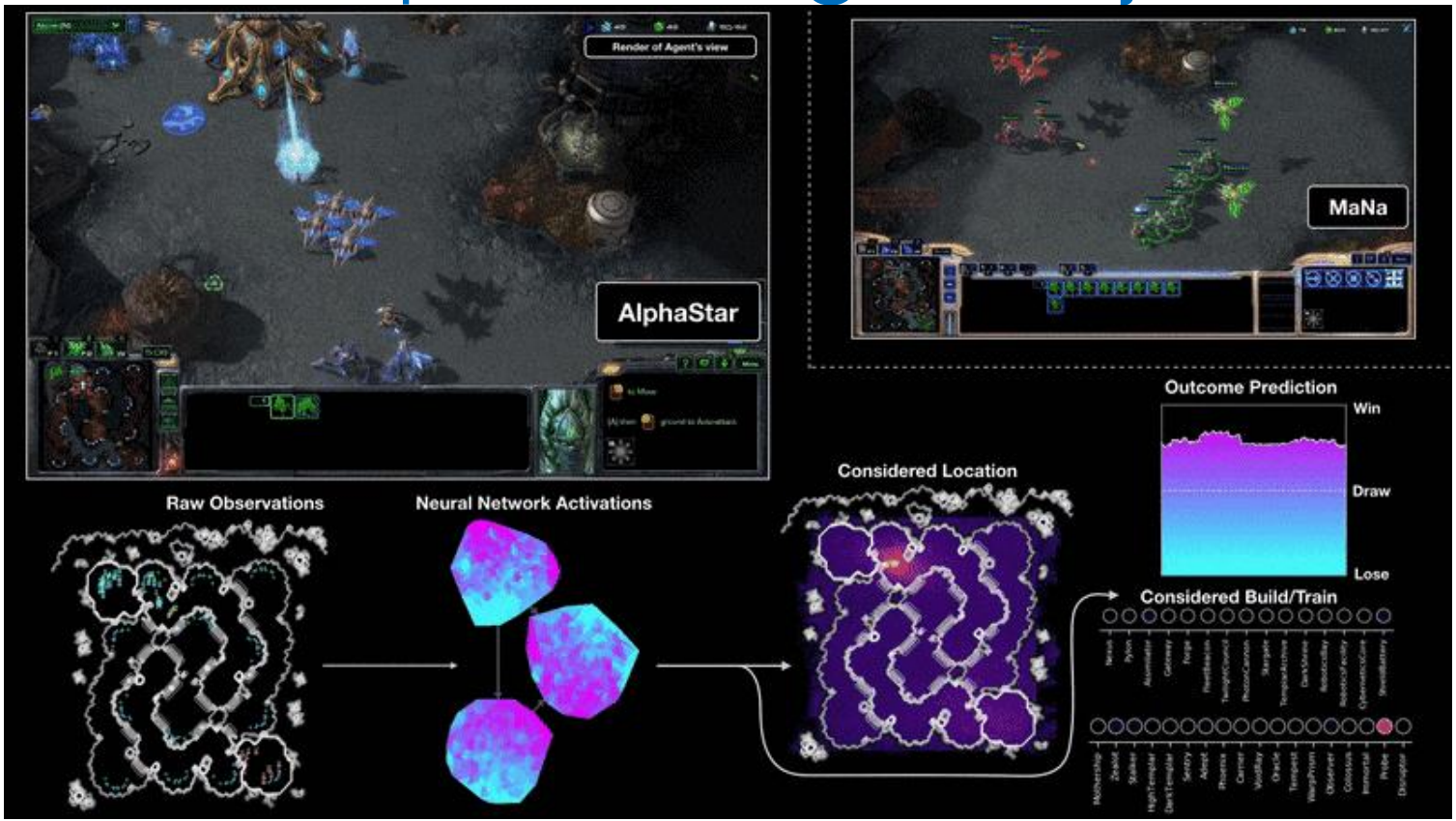


Emoticon suggestion



Machine translation

Deep Learning Today



Alpha Star

Deep Learning Today

Google LaMDA (Google IO'22)

Deep Learning Today

- Large Language Models (LLMs), e.g., Chat-GPT

NI

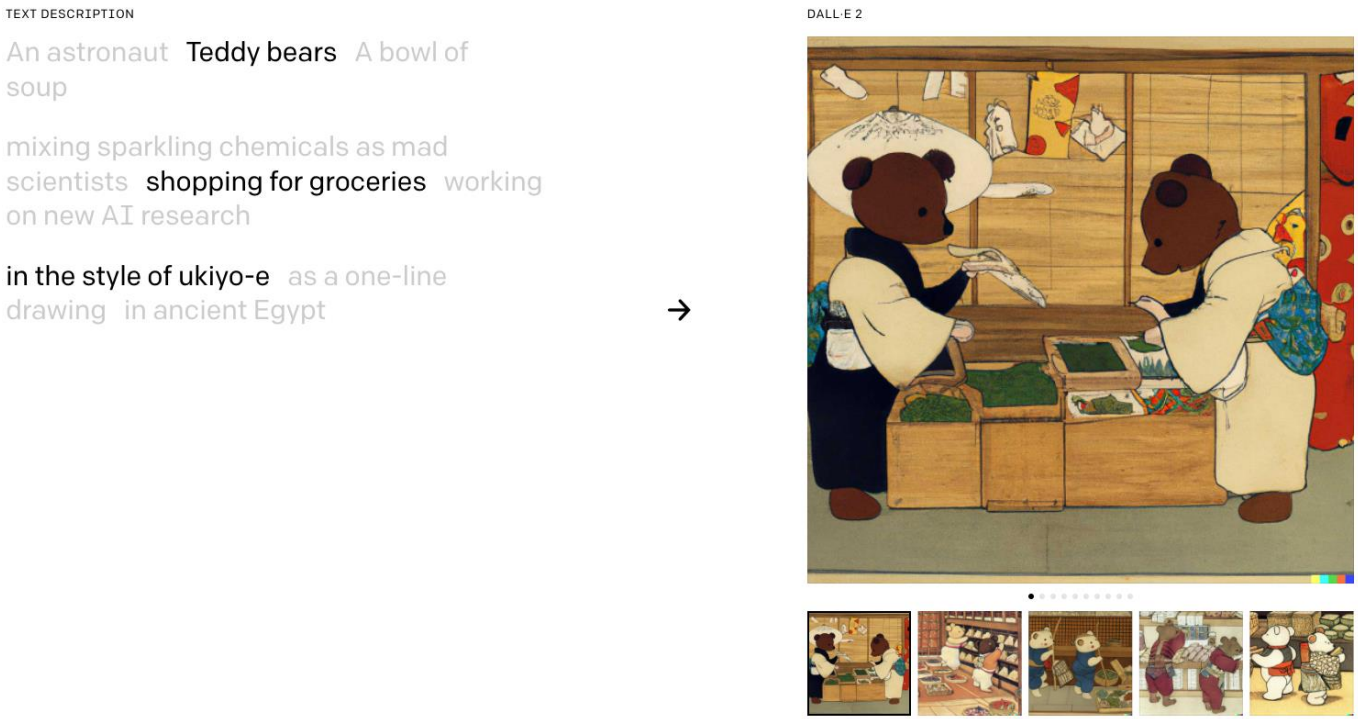
Tell me about deep learning and how I can teach it at TUM.

Deep learning is a subset of machine learning that involves training artificial neural networks to recognize patterns and make predictions or decisions based on input data. The term "deep" refers to the fact that these networks have many layers, which allows them to learn increasingly complex representations of the data as it moves through the network.

To teach deep learning at TUM, you could start with an introductory course that covers the basics of machine learning and neural networks. This could include topics such as:

1. Supervised learning: This involves training a model using labeled examples, so that it can make predictions on new, unseen data.

Deep Learning Today



Dall-E 2 Image generation from text

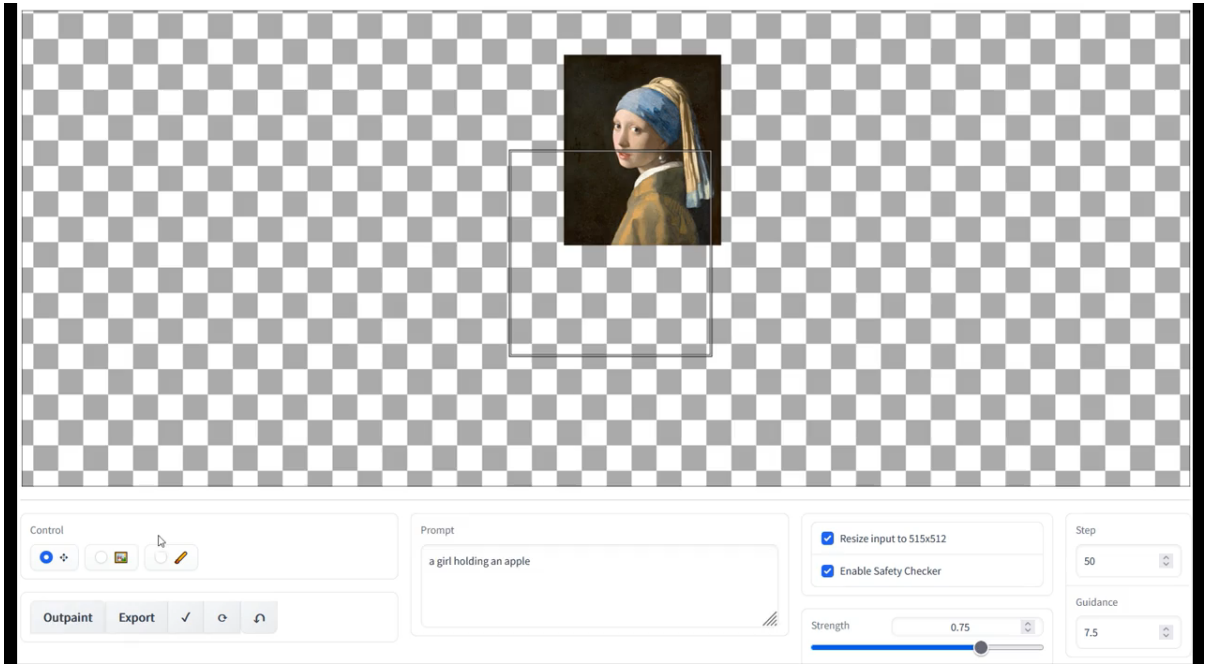
Deep Learning Today

"a robot painting a colorful sunset on a canvas in a futuristic art studio"

"a majestic dragon made of water flying through a colorful, abstract city"

https://huggingface.co/black-forest-labs/FLUX.1-dev

Deep Learning Today



StableDiffusion Image Outpainting

Deep Learning Today

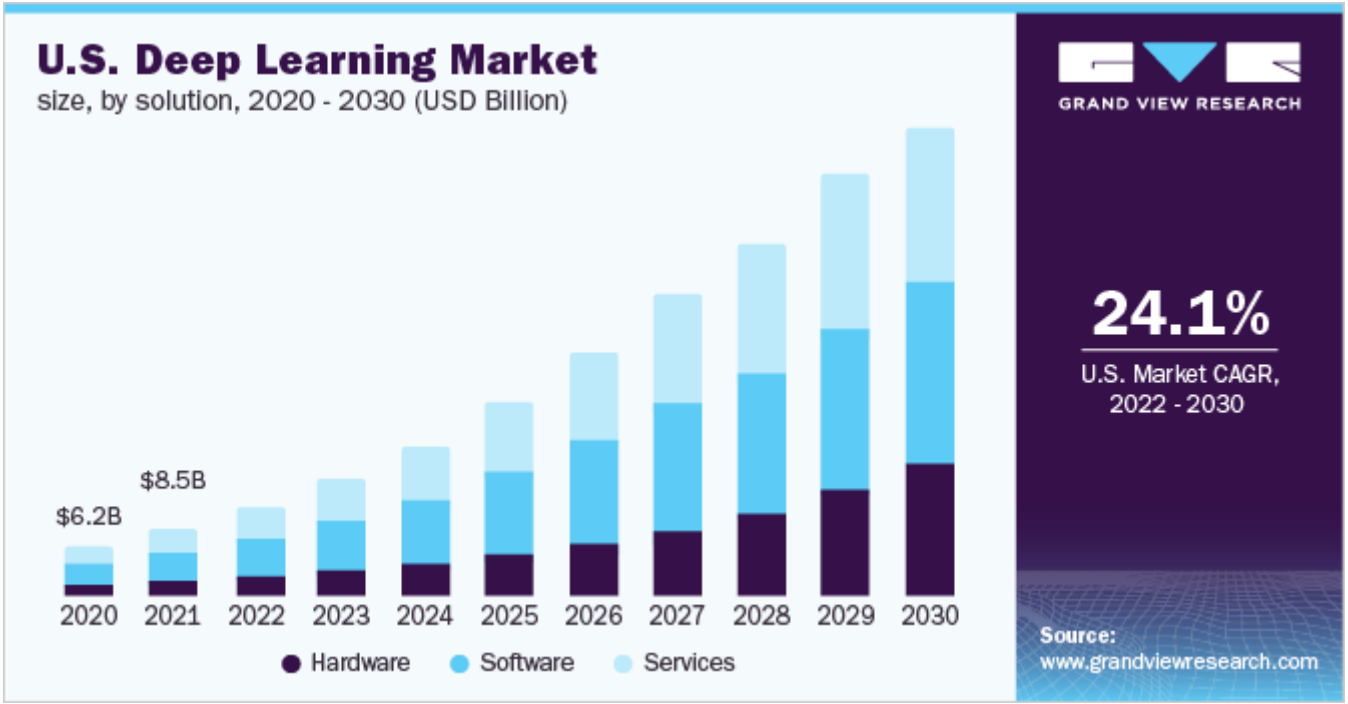
OpenAI Sora

Deep Learning Today

Deep Learning Today

Deep Learning Today

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…

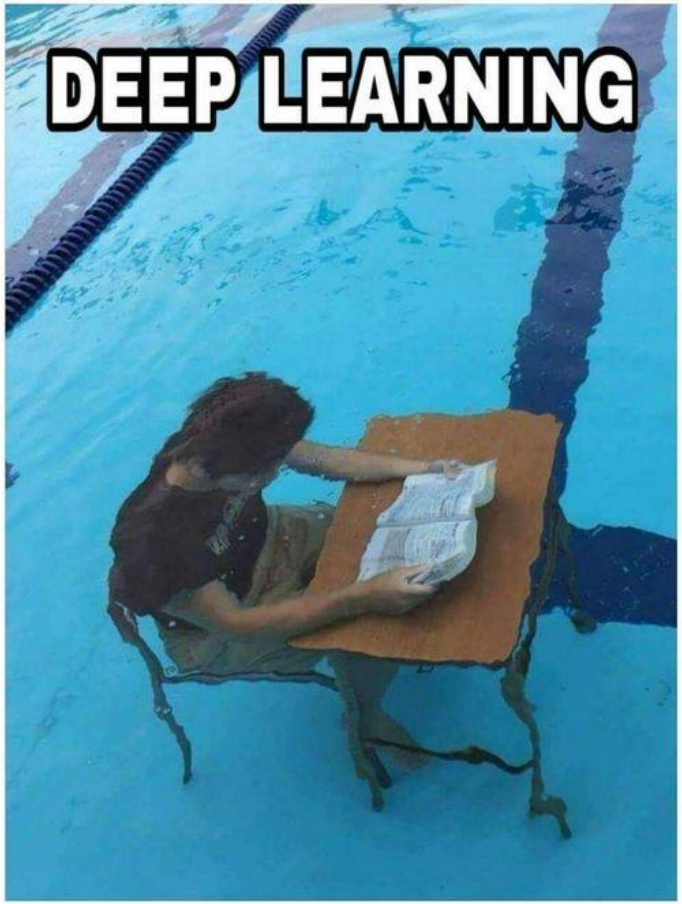
But: Also Challenging!

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

- Can be competitive!
  - Many good people
  - Education gap widens
  - Downloading scripts / running code not enough ☺
  - Deeper understanding often requires PhDs

Deep Learning on the Internet

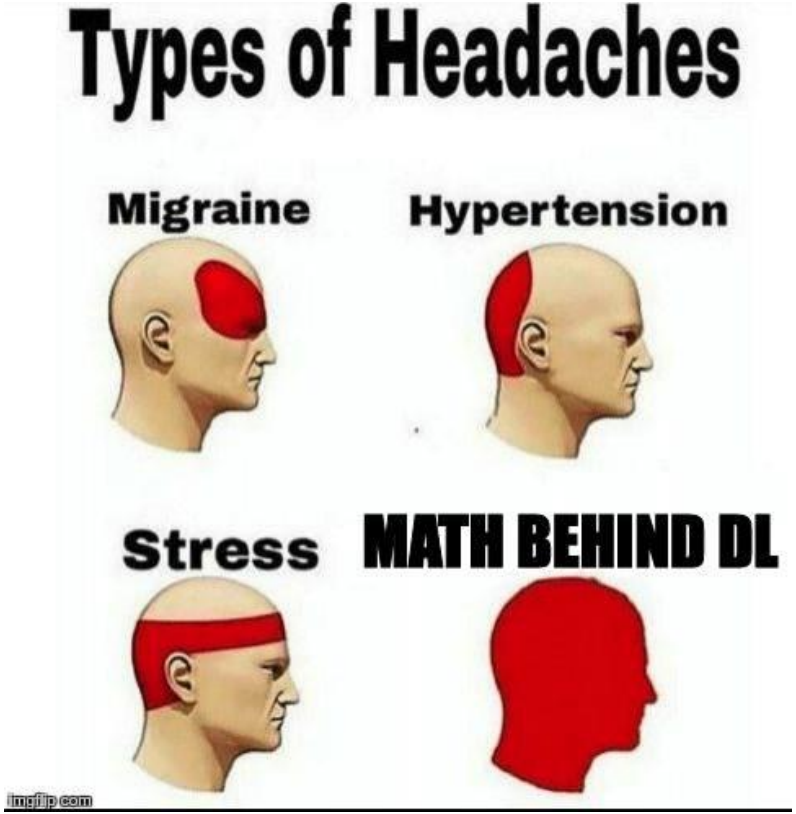
Deep Learning Memes



Deep Learning Memes

Deep Learning Memes

Deep Learning Memes



Deep Learning at TUM

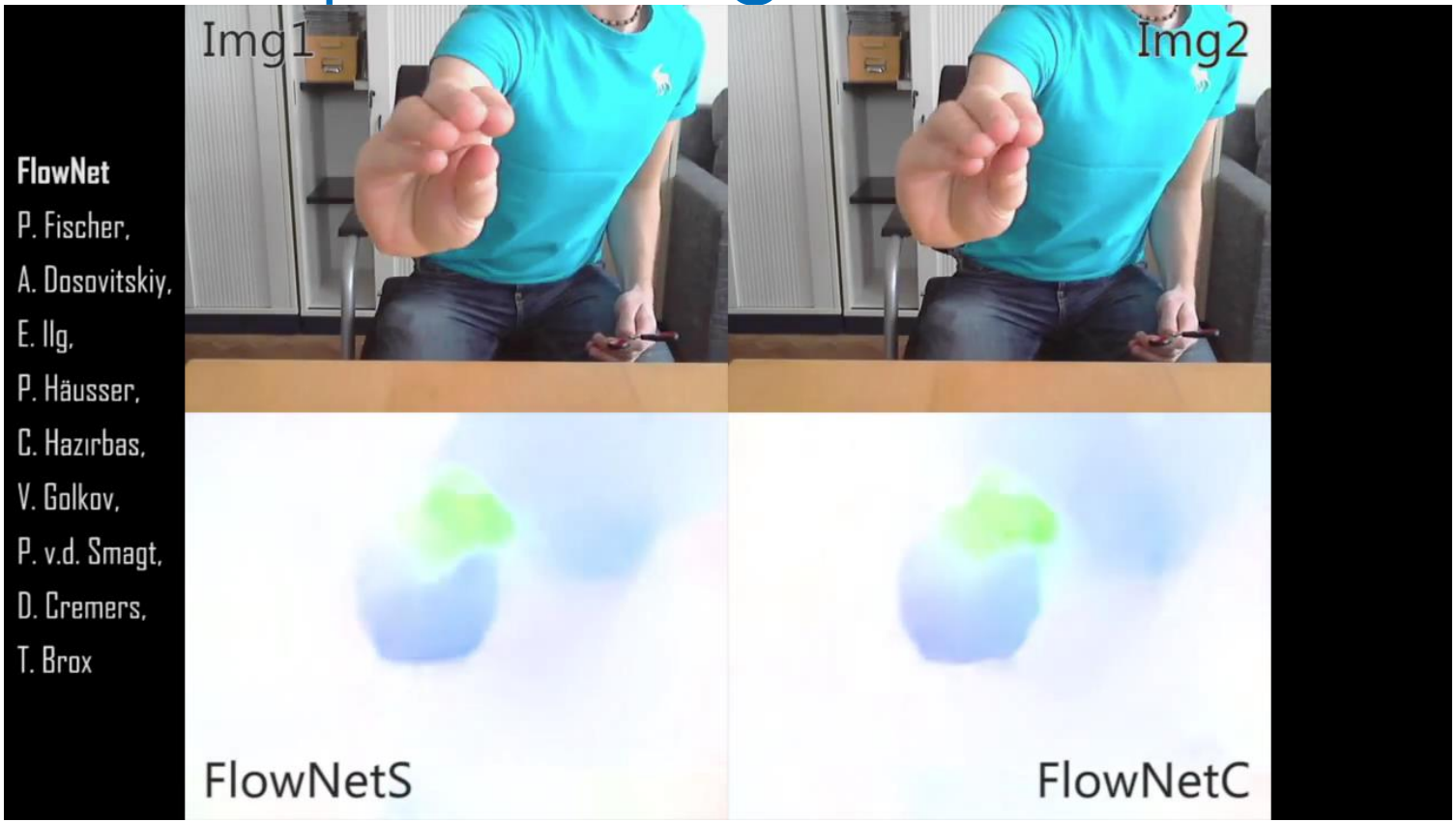
Many TUM Research Labs use DL

- 3D AI Lab (Prof. Dai)
  - Research in 3D perception, 3D scene understanding
- Visual Computing & AI (Prof. Niessner):
  - Research in computer vision, graphics, and machine learning
- Computer Vision Group (Prof. Cremers)
  - Research in computer vision, machine learning and robotics
- 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 ☺

Deep Learning at TUM

[Caelles et al., CVPR' 17] One-Shot Video Object Segmentation

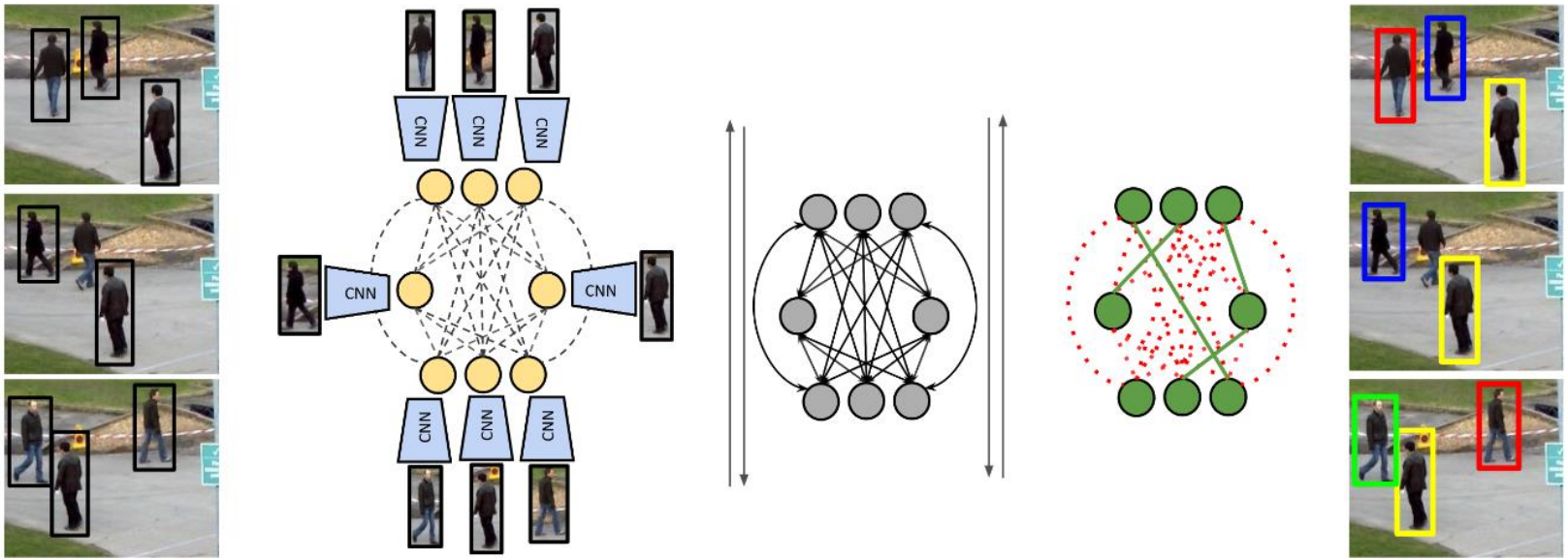
Deep Learning at TUM



[Dosovitskiy et al., ICCV' 15] FlowNet

Deep Learning at TUM

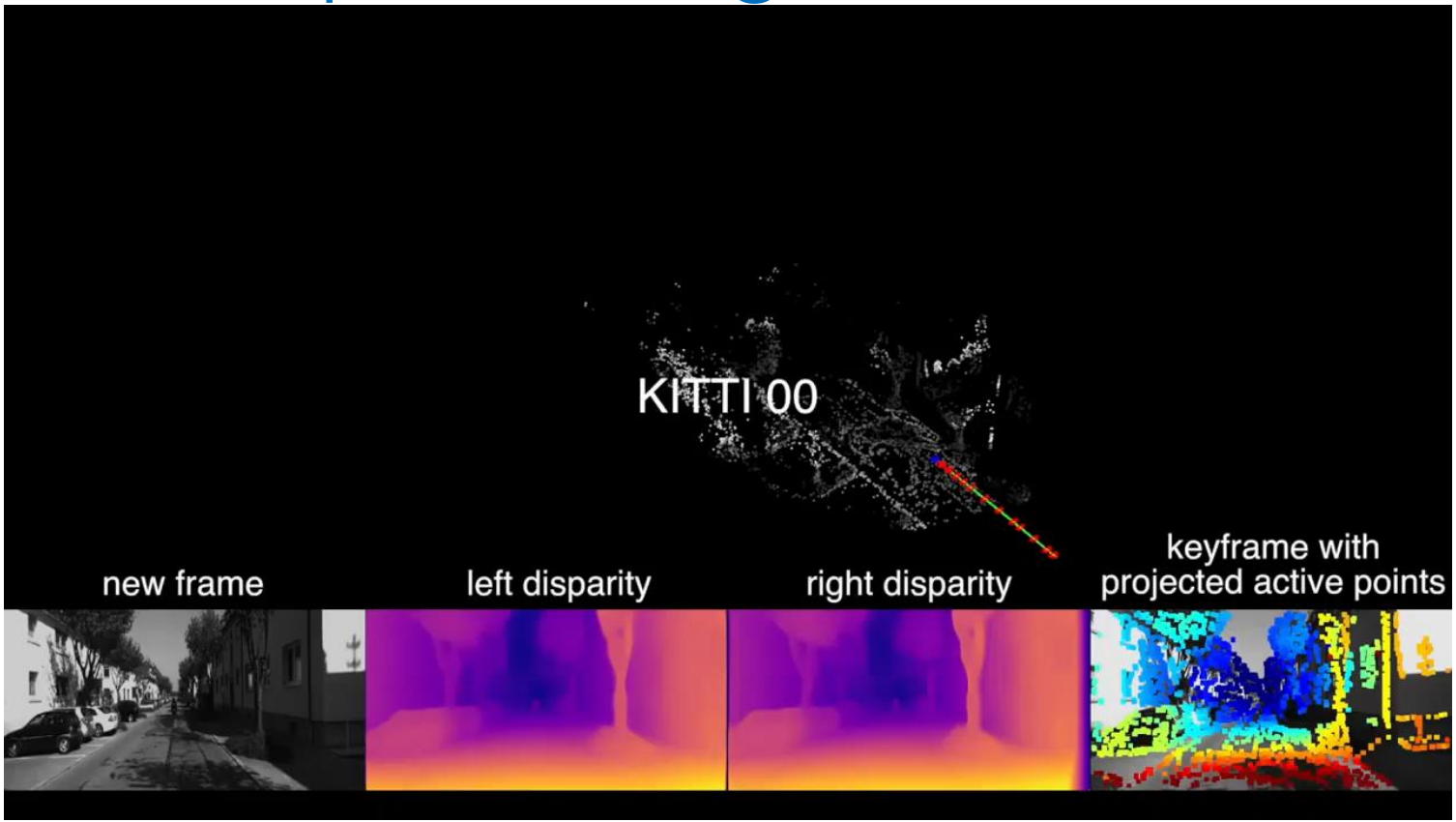
- Multiple object tracking with graph neural networks



(a) Input (b) Graph Construction + Feature Encoding (c) Neural Message Passing (d) Edge Classification (e) Output

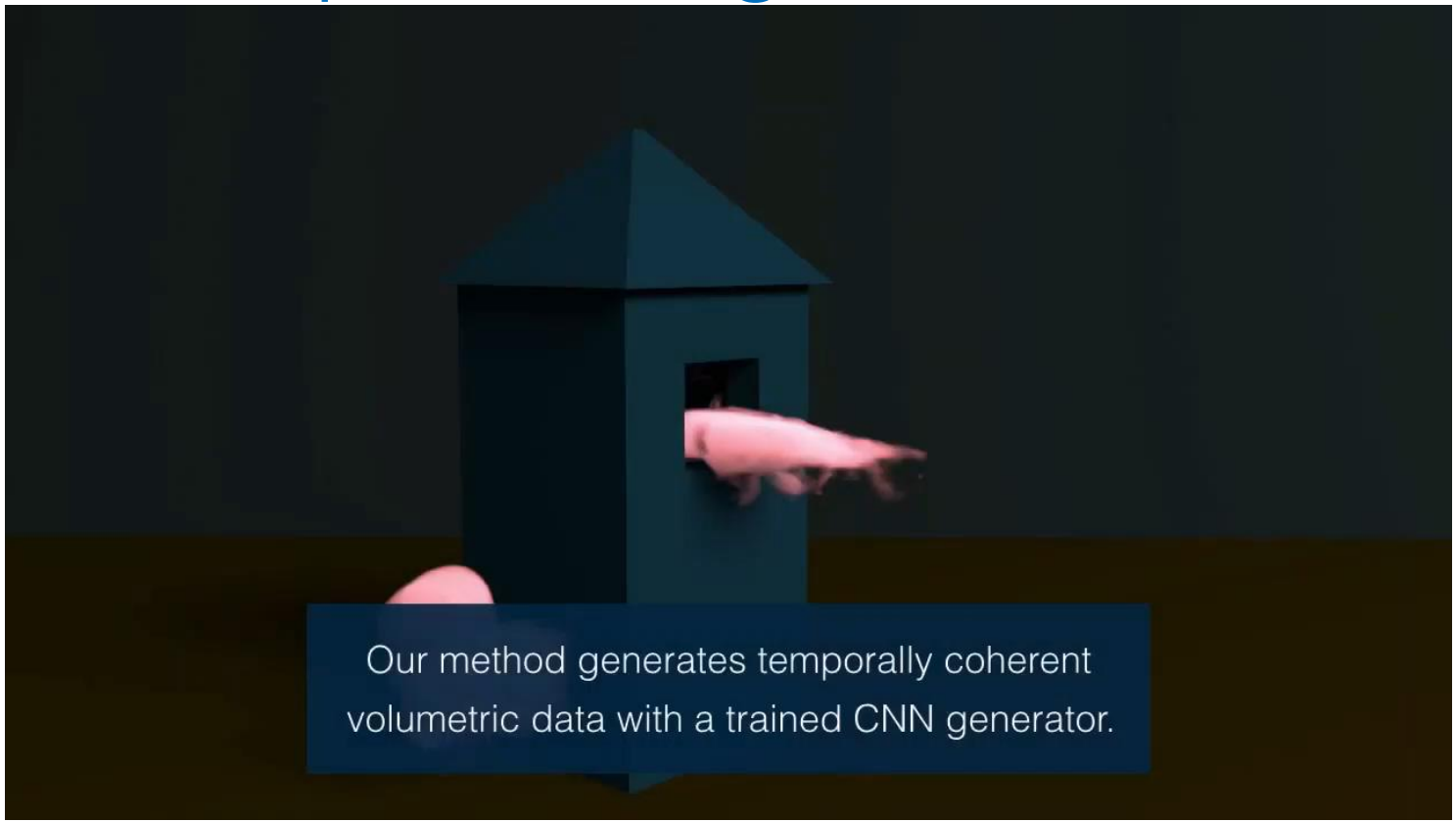
[Brasó and Leal-Taixé, CVPR 2020] Learning a Neural Solver for Multiple Object Tracking.

Deep Learning at TUM



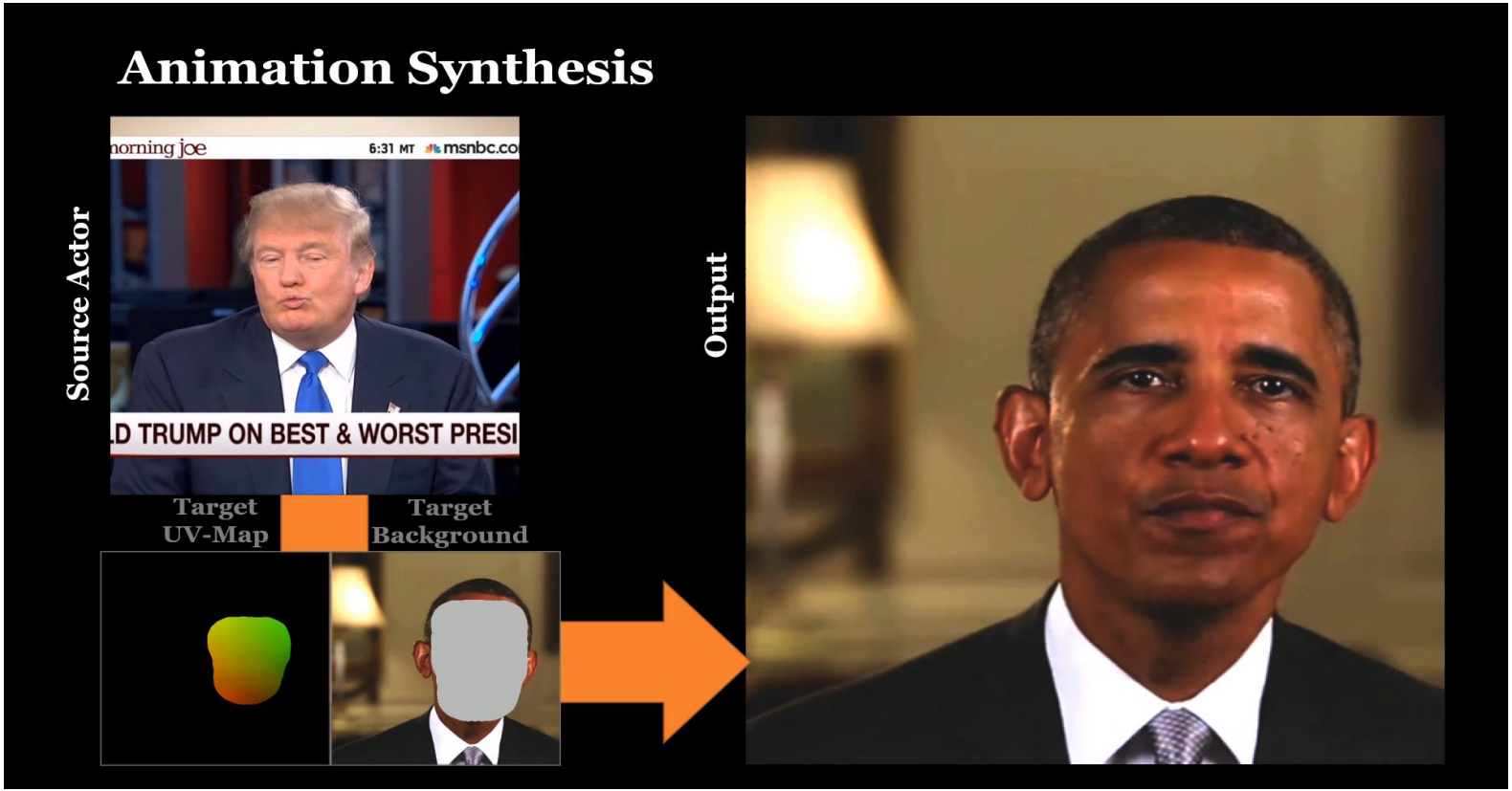
[Yang et al., ECCV' 18] Deep Virtual Stereo Odometry

Deep Learning at TUM



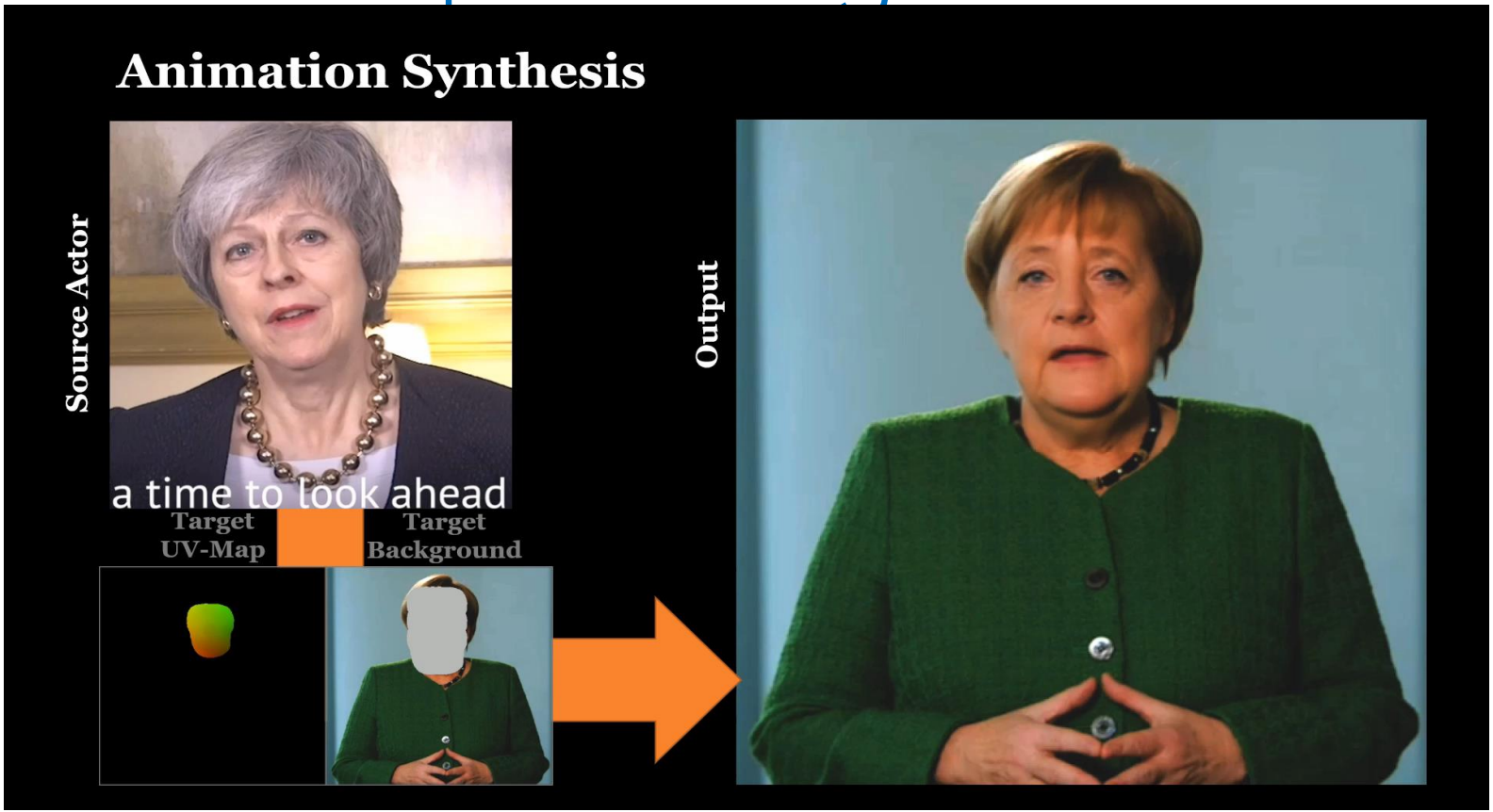
[Xie et al. Siggraph' 18] tempoGAN

Deep Learning at TUM



[Thies et al., Siggraph'19]: Neural Textures

Deep Learning at TUM



[Thies et al., Siggraph'19]: Neural Textures

Deep Learning at TUM

[Kirchstein et al., ToG'23] Nersemble

Deep Learning at TUM

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

[Dai et al., CVPR'17] ScanNet

Deep Learning at TUM

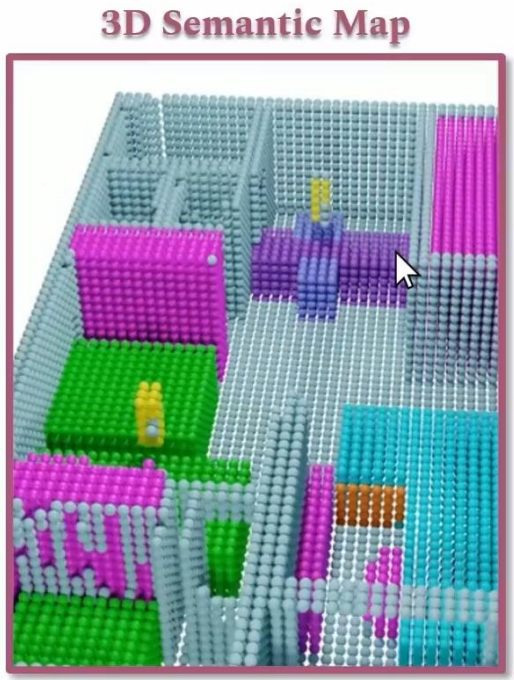
ScanNet++:
-1006 high-fidelity Scenes
- 1mm laser scans
-DSLR images
-iPhone RGB-D
-semantics

[Yeshwanth & Liu et al., ICCV'23] ScanNet++

Deep Learning at TUM

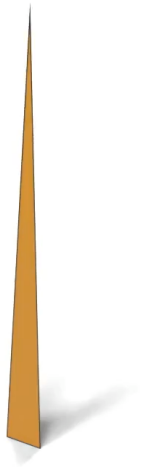
[Bokhovkin et al., CVPR'25] SceneFactor

Deep Learning at TUM



[Bokhovkin et al., CVPR'25] SceneFactor

Deep Learning at TUM

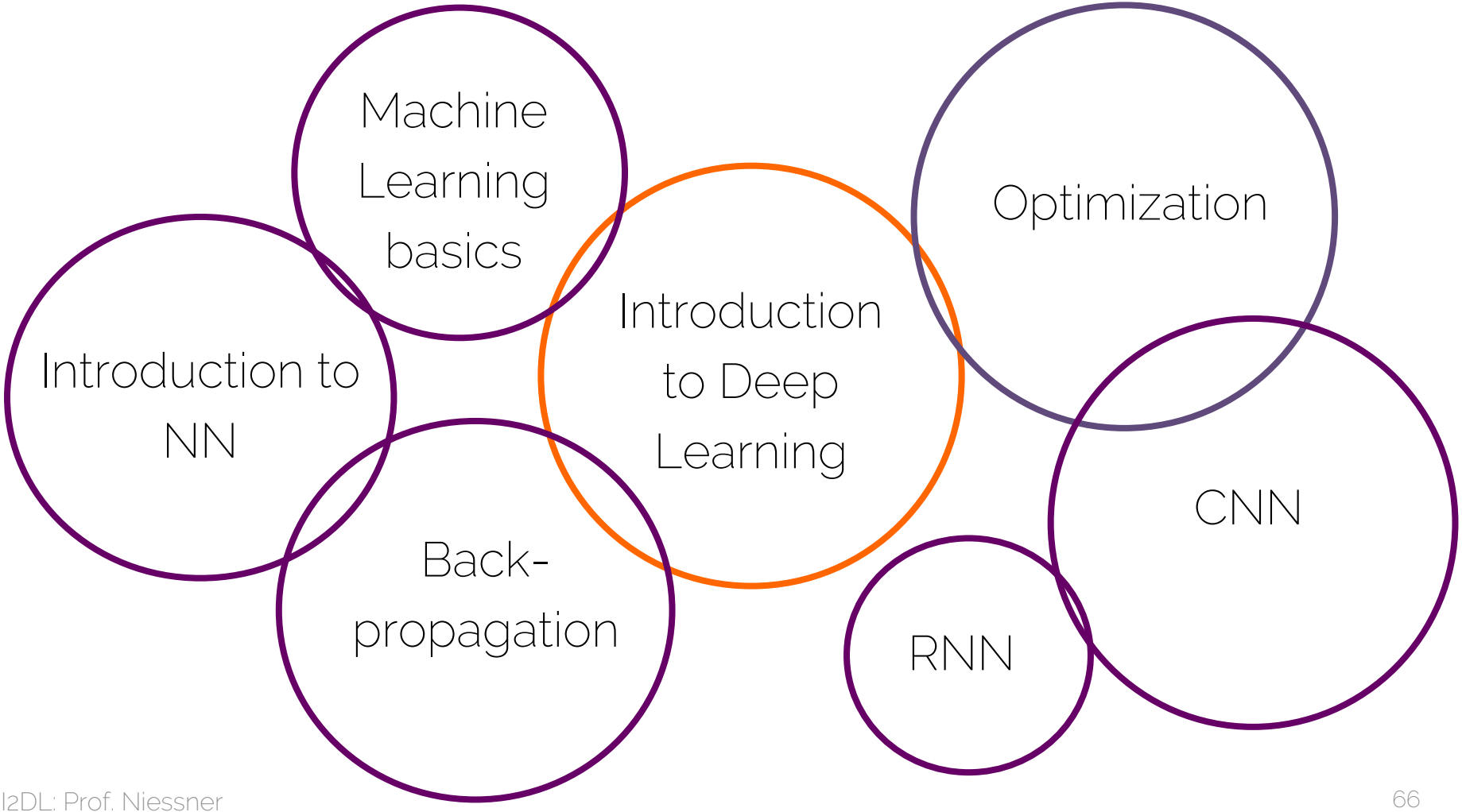


[Siddiqui et al., CVPR'24] MeshGPT

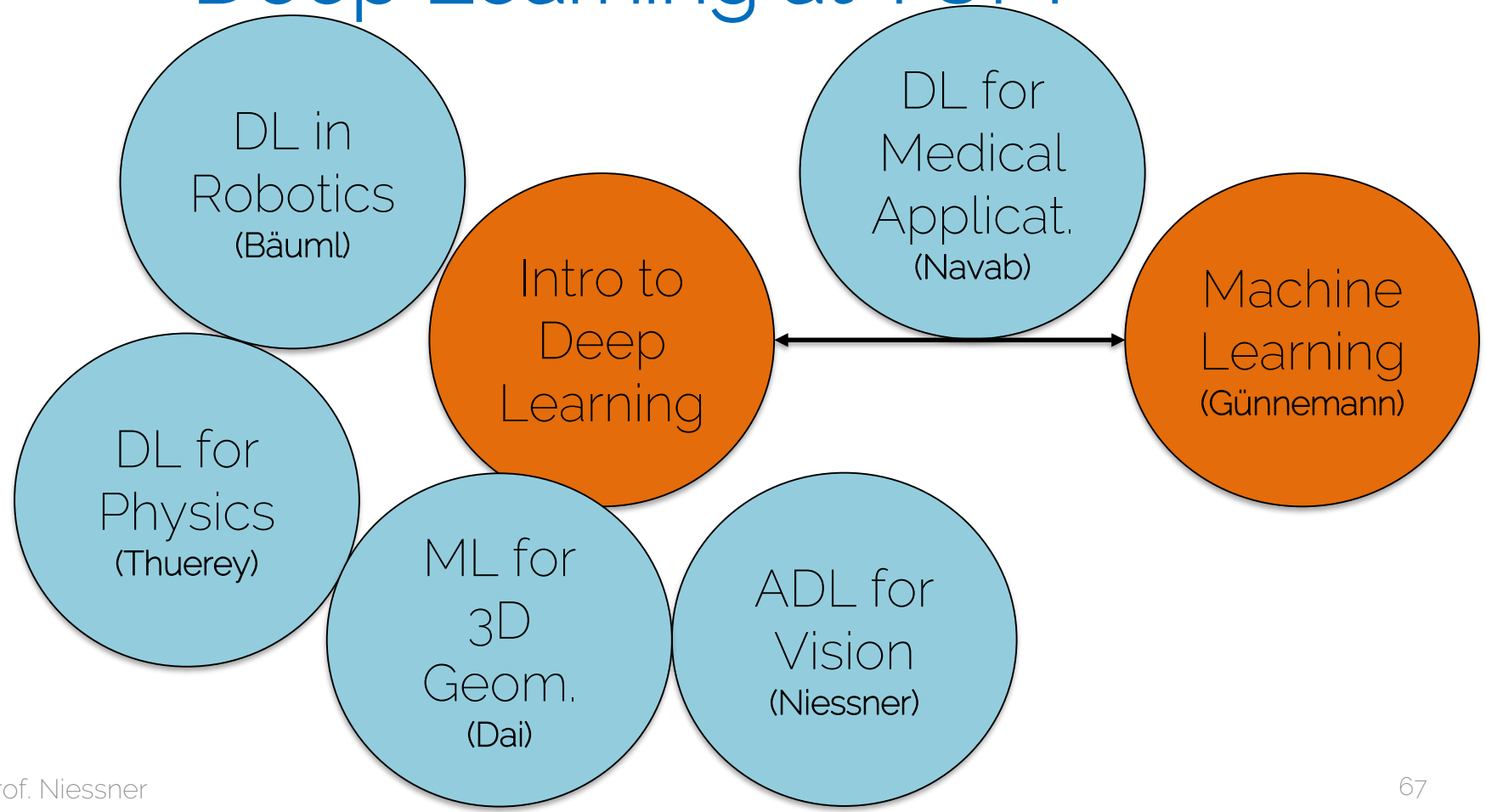
Deep Learning at TUM

[Schneider et al., SIGGRAPH Asia'25] WorldExplorer

Relation to other lectures at TUM


Machine Learning basics
Optimization
Introduction to NN
Introduction to Deep Learning
CNN
Back-propagation
RNN

Deep Learning at TUM



Deep Learning at TUM

- I2DL is critical for the curriculum:
  - often a pre-requisite for many other lectures
  - many lectures build on top of it

- Follow up lectures such as Advanced Deep Learning for Visual Computing (generative models etc.)

- Take I2DL first -> AdvancedDL -> practical/GR/IDP

Introduction to Deep Learning

Logistics

About the Lecture

- Course webpage: https://niessner.github.io/I2DL/
- Theory lectures (every Tuesday at 14:15)
  - In-person, live-streamed

- Tutorials and exercises (every Thursday at 10:00)
  - Tutorial: Online videos posted to Piazza and the webpage
  - Practical exercises

- Guest Lecture ☺

Preliminary Syllabus

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

~~Moodle~~ → Piazza

- Announcements via Piazza - IMPORTANT!
  - Sign up online for access: http://piazza.com/tum.de
    - Select "Winter 2026" 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 questions 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

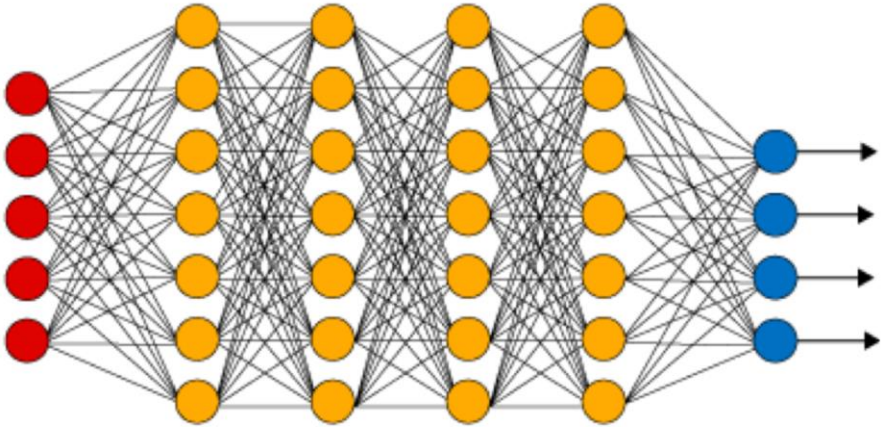
- Email list for organizational questions only!
  - Content questions -> Piazza or Office Hours
  - Or post the question/issue in a private thread on Piazza

Website

Visual Computing Group
Prof. Matthias Nießner

Home Publications Teaching Openings Team

Introduction to Deep Learning (I2DL) (IN2346)



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

(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

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" programming 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)
- Reimplement 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 Piazza and course website
  - Video length
    Ex02: Full lecture with written exercise
    Ex03-12: Short (~30min) video and coding exercises
- Programming:
  - Interactive coding notebooks (~4h each)
- Start time: Thursdays 10:00
- Working Time: 1-2 weeks
- Deadline: Wednesdays, 23:59

Upcoming Lecture

- Important:
  - **No lecture next week, Oct 21st** (I'll be at ICCV – Hawaii)
  - Next lecture is on Oct 28th

- Next Lecture: Lecture 2: Machine Learning basics

- Thursday: Tutorial 1 and Exercise 1

See you next time ☺