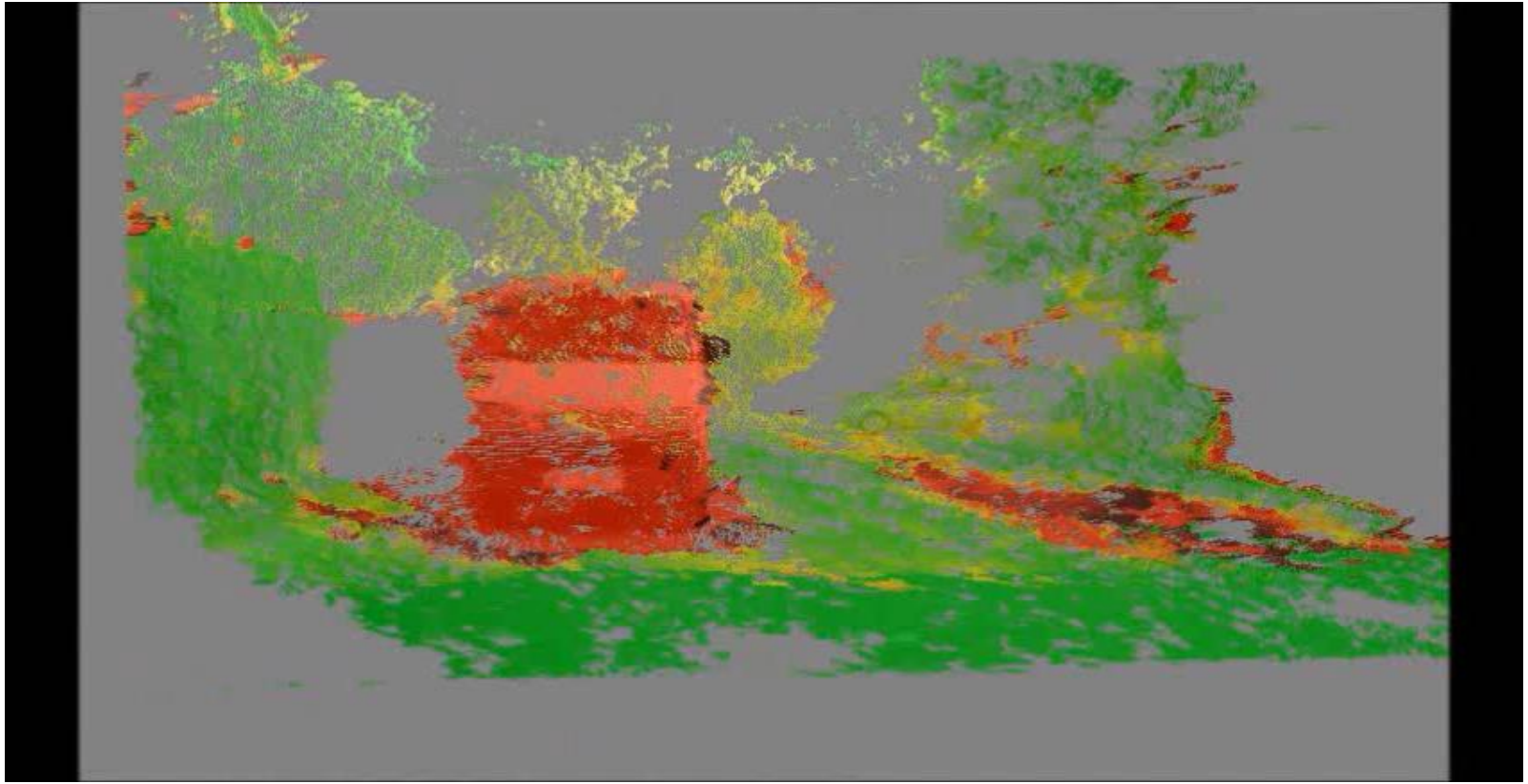
Introduction to Deep Learning

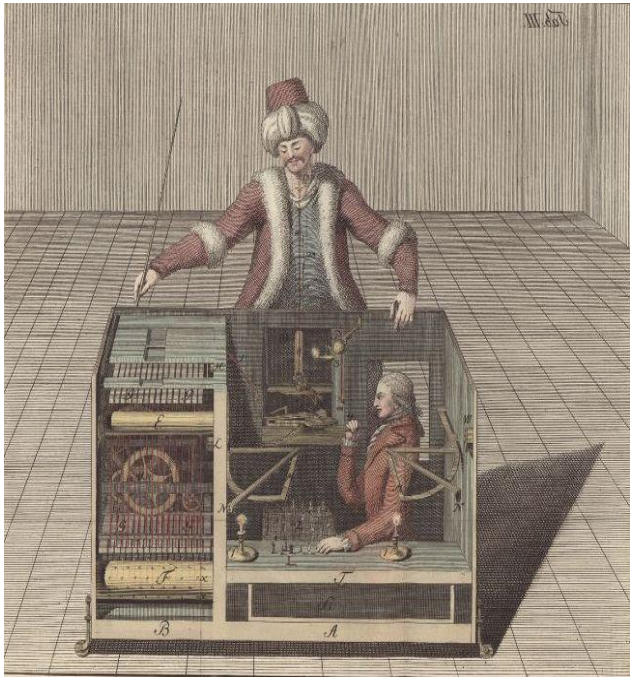
AI for Driver Assistance

AI for Driver Assistance



Wedel et al. ECCV '08, Wedel, Cremers, Springer 2011

Artificial Intelligence: Chess & Go?



“mechanical turk” (1770)
Wolfgang von Kempelen

Deep Blue (1996)

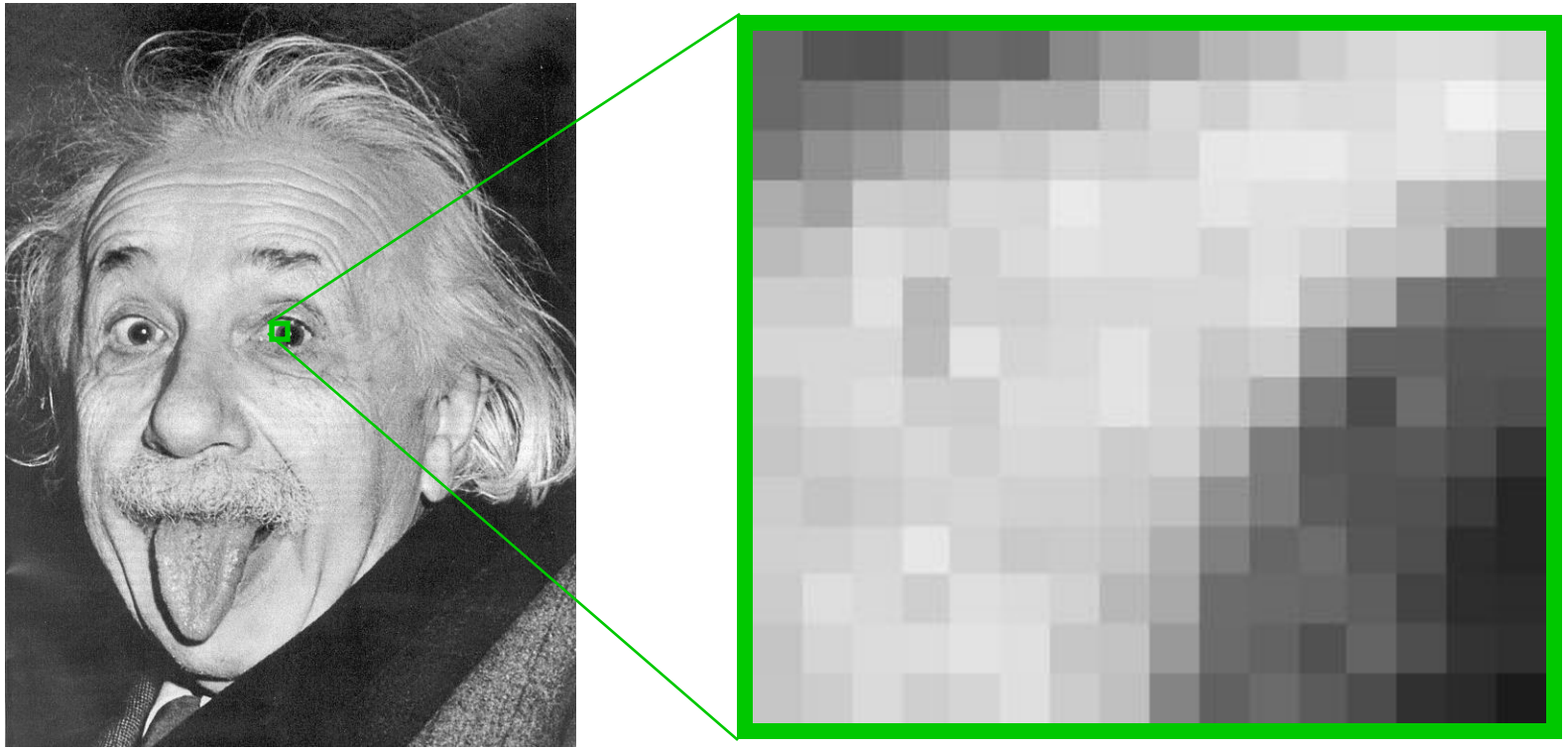
AlphaGo (2016)

126 mio configurations per seconds

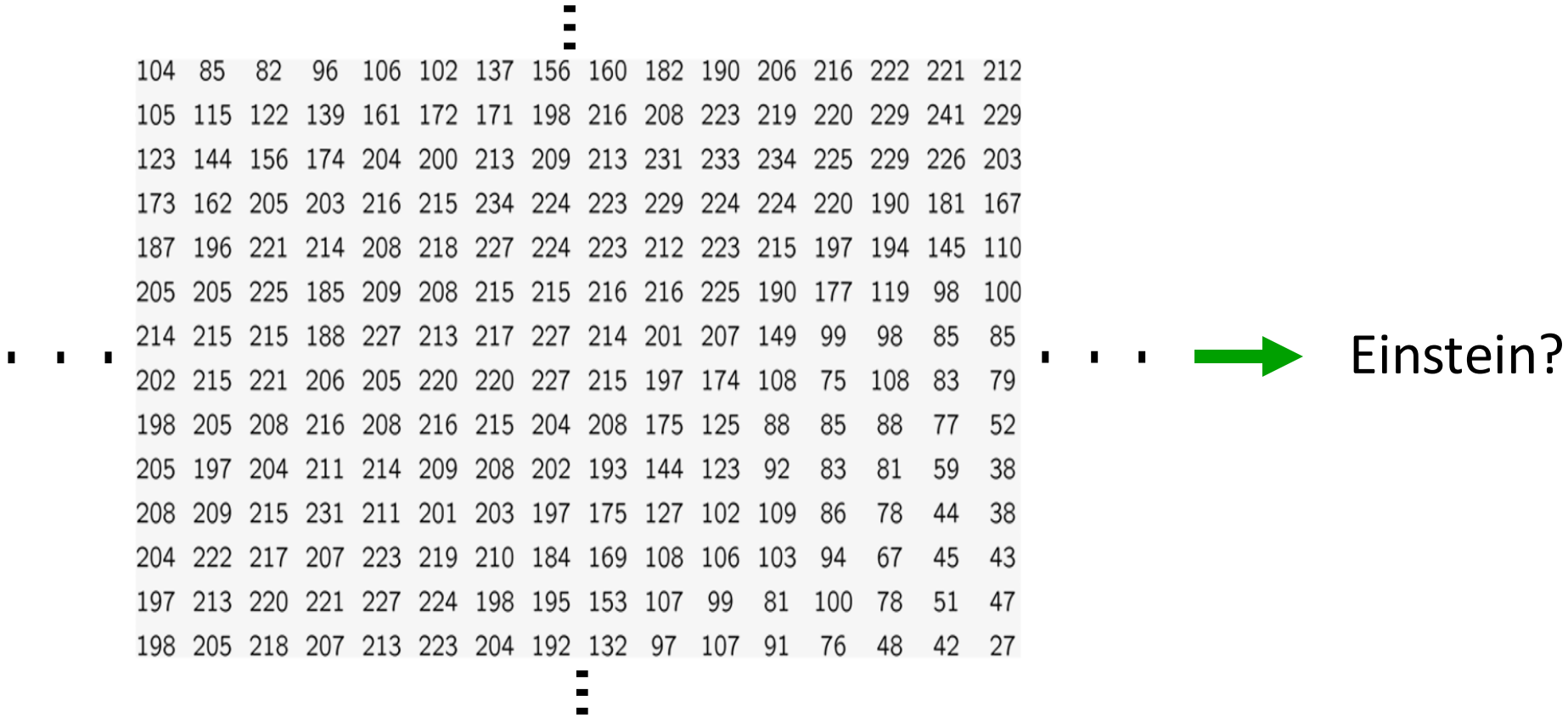
Artificial Intelligence & Computer Vision

German Museum, Munich 2024

Artificial Intelligence & Computer Vision

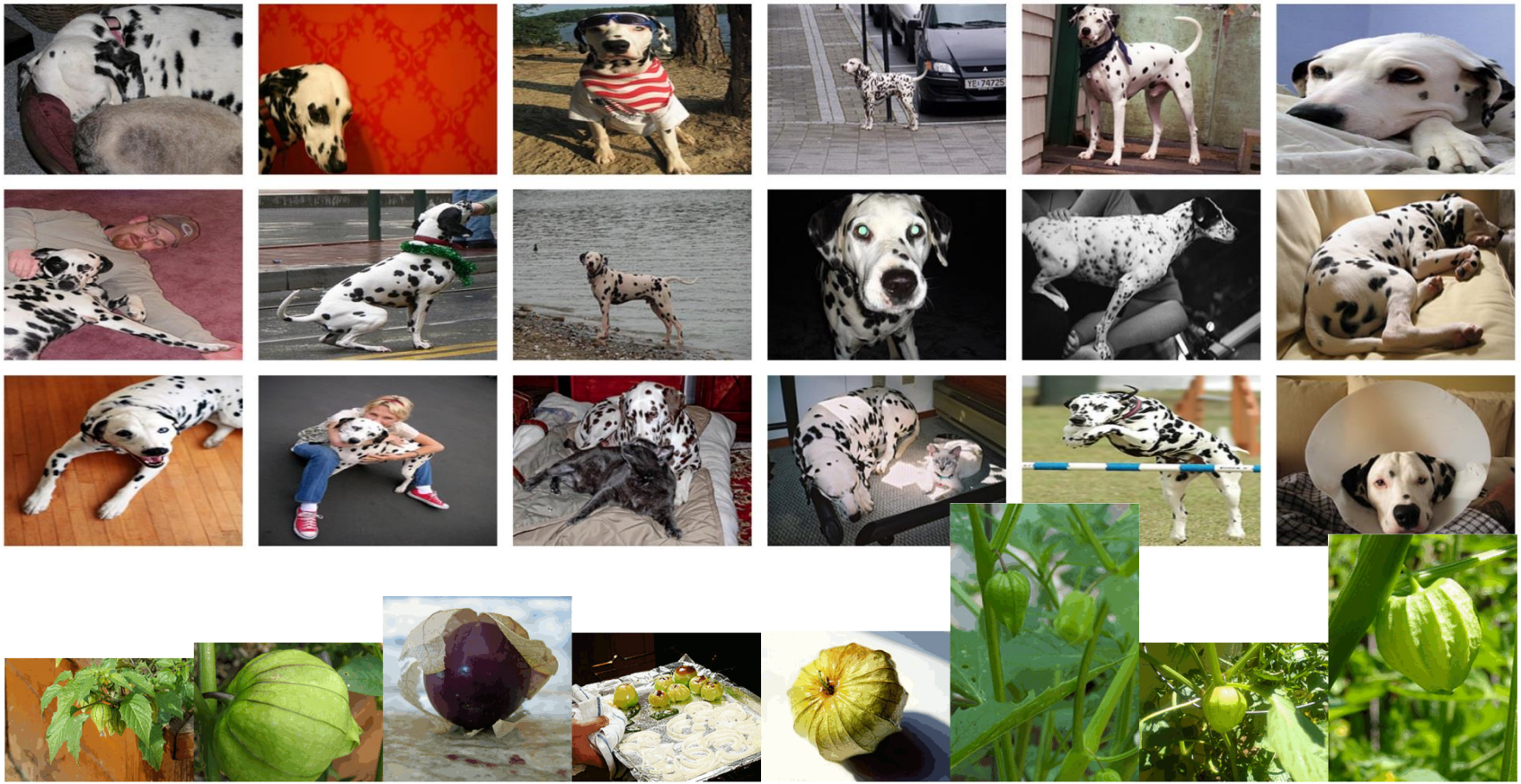


Artificial Intelligence & Computer Vision

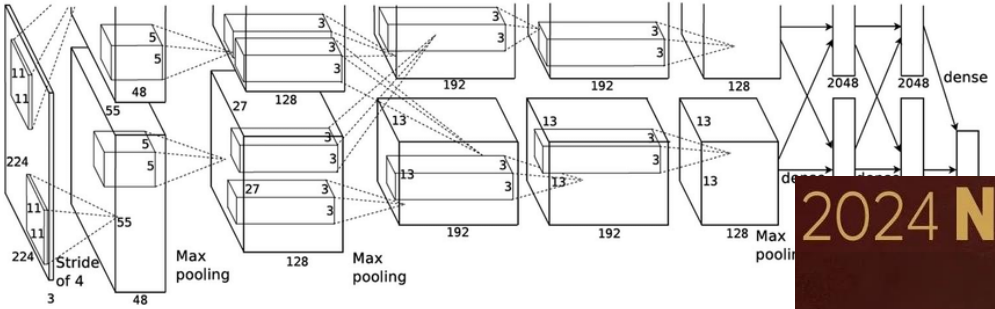


Einstein?

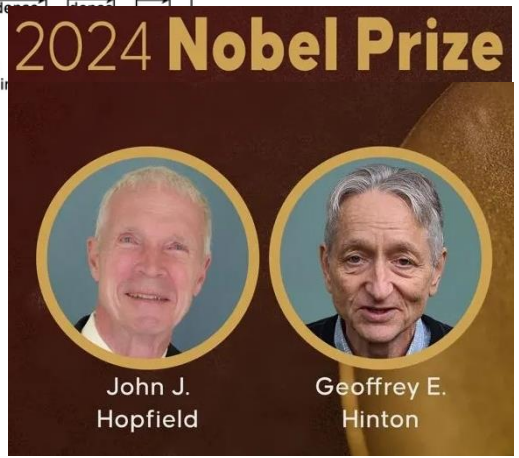
ImageNet: Objects in 14 Mio Images



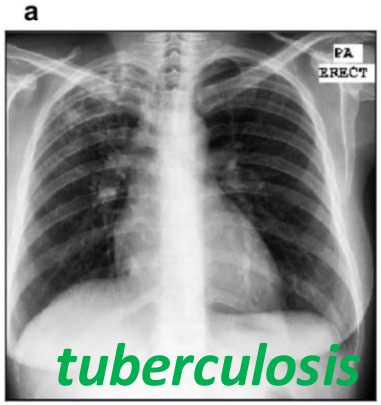
The Breakthrough of Deep Networks

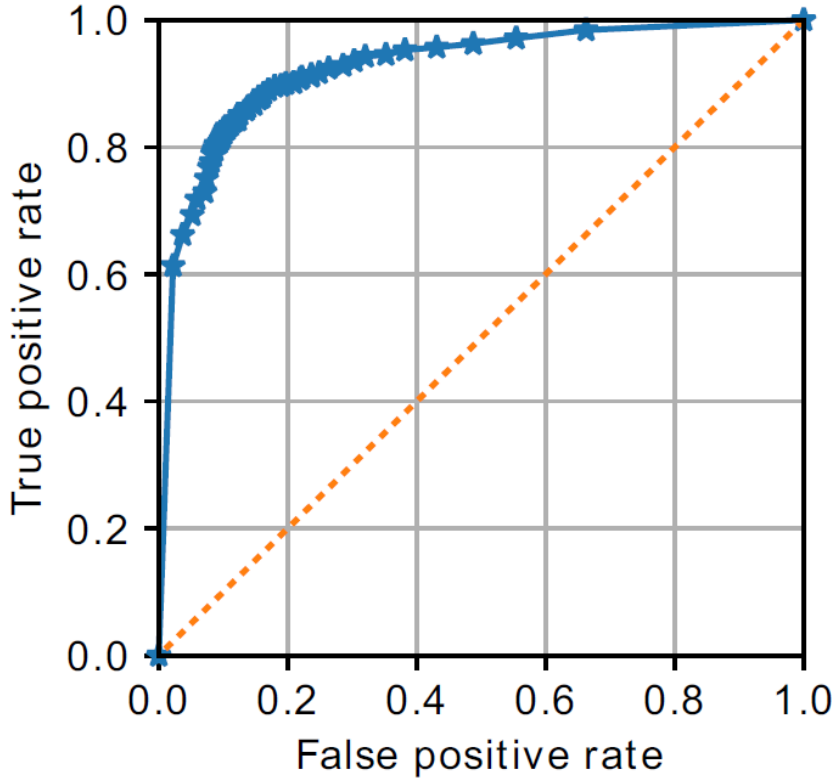


Krizhevsky et al., NIPS 2012



Deep Nets for Tuberculosis Screening





Pasa et al., "Efficient Deep Nets for X-Ray Tuberculosis Screening", Sci. Rep. 2019

Deep Nets for Protein Prediction

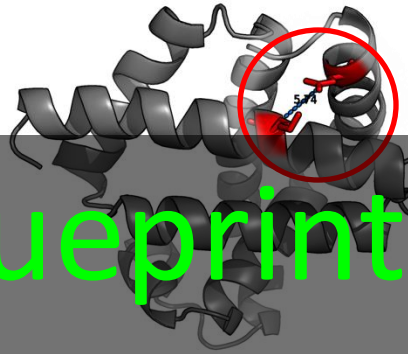
VLSEGEWQLVLHVWAKVEADVAGH
GQDILIRLFKSHPETLEKFDRFKH
LKTEAEMKASEDLKKHGVTVLTAL
GAILKKKGHHEAELKPLAQSHATK
HKIPIKYLEFISEAIIHVLHSRHP
GDFGADAQGAMNKALELFRKDIAA
KYKELGY (Homo sapiens)

HMM

VLSEGEWQLVLHVWAKVEADVAGH
MGLSDGEWQLVLNVWGKVEADIPG
MGLSDGEWQLVLNVWGKVEADLAG
HGQDVLIRLFKGHPETLEKFDKF
HLKTEADMKASEDLKKHGNTVLT
LGAILKKKGHHDAELKPLAQSH
KHKIPIKYLEFISEAIIHVLHSRH
PAEFGADAQGAMNKALELFRKDIA
AKYKEL (Bottlenose dolphin)

Homologous sequences

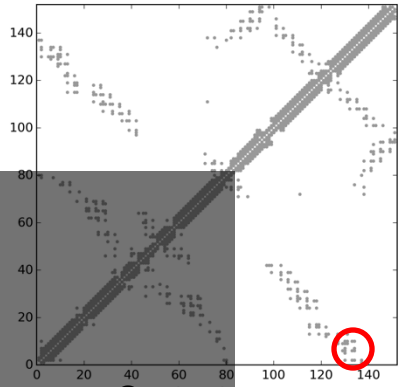
?



3D structure

constraint

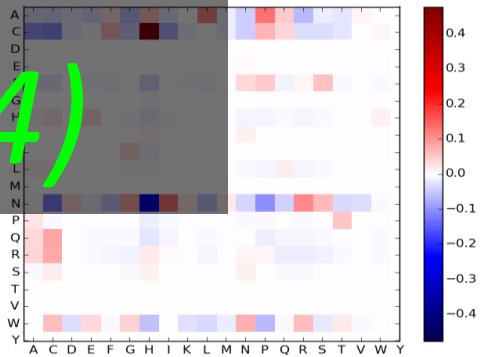
Pairwise variants
of mutations



Contact map

Conv Net

DCA (Potts)

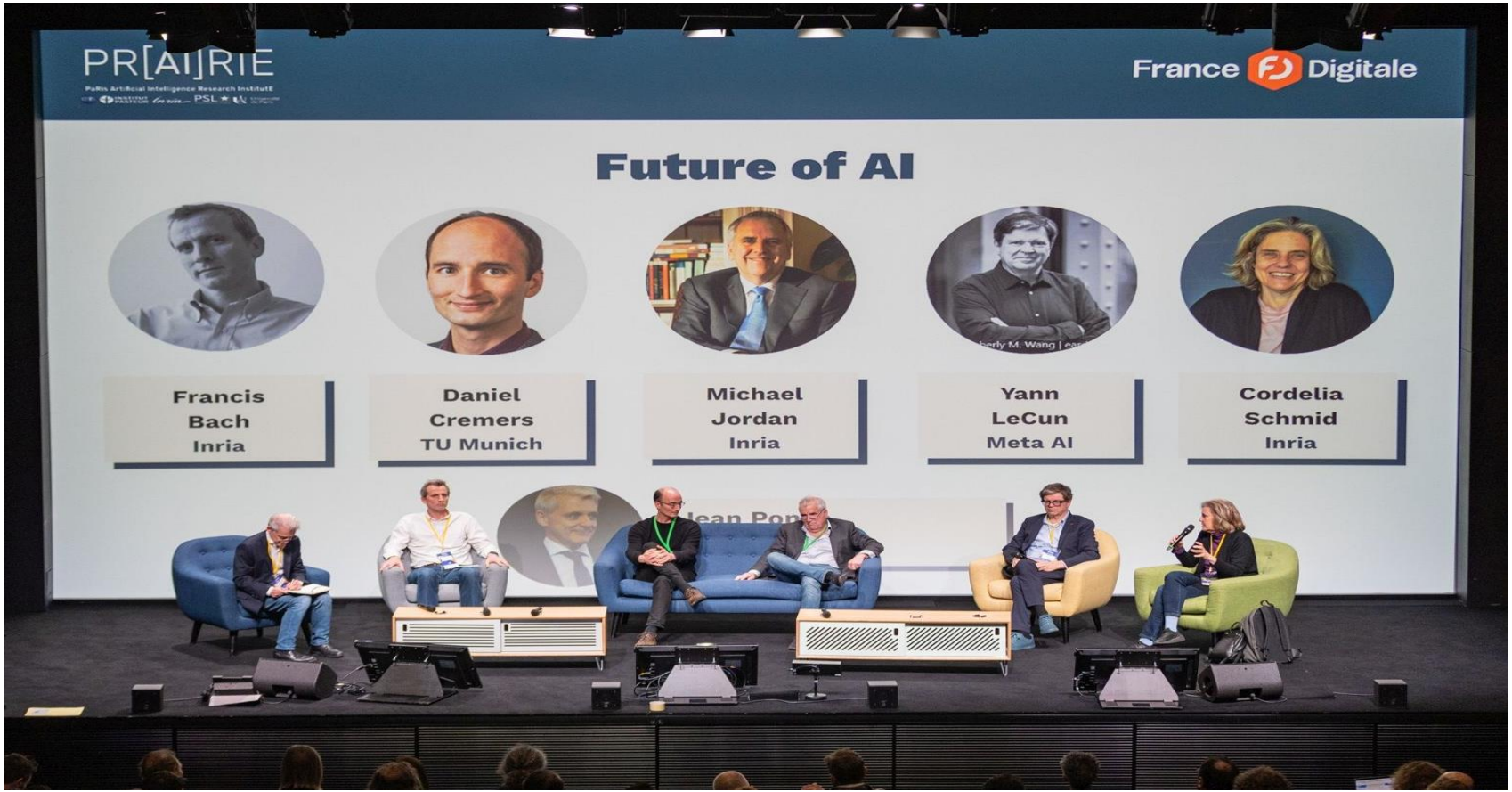


Co-evolution statistics

Blueprint for Google Alphafold (Nobel Prize 2024)

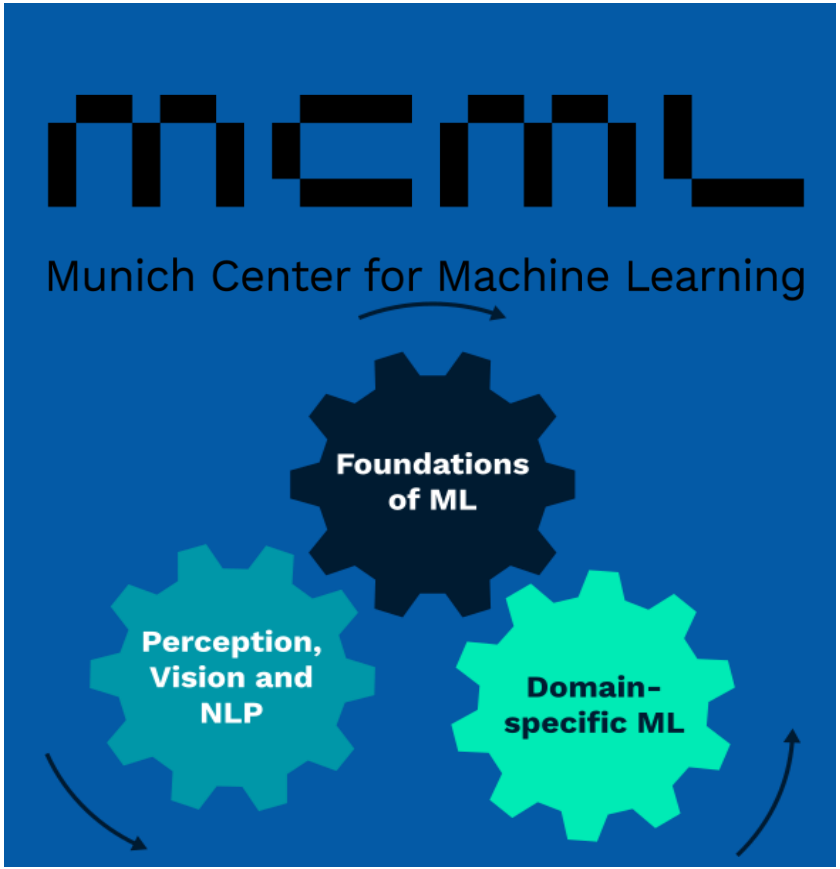
Golkov,…,Cremers, "Protein Contact Map Prediction with Deep Networks", NeurIPS 2016.

AI Panel, Paris, April 5, 2024

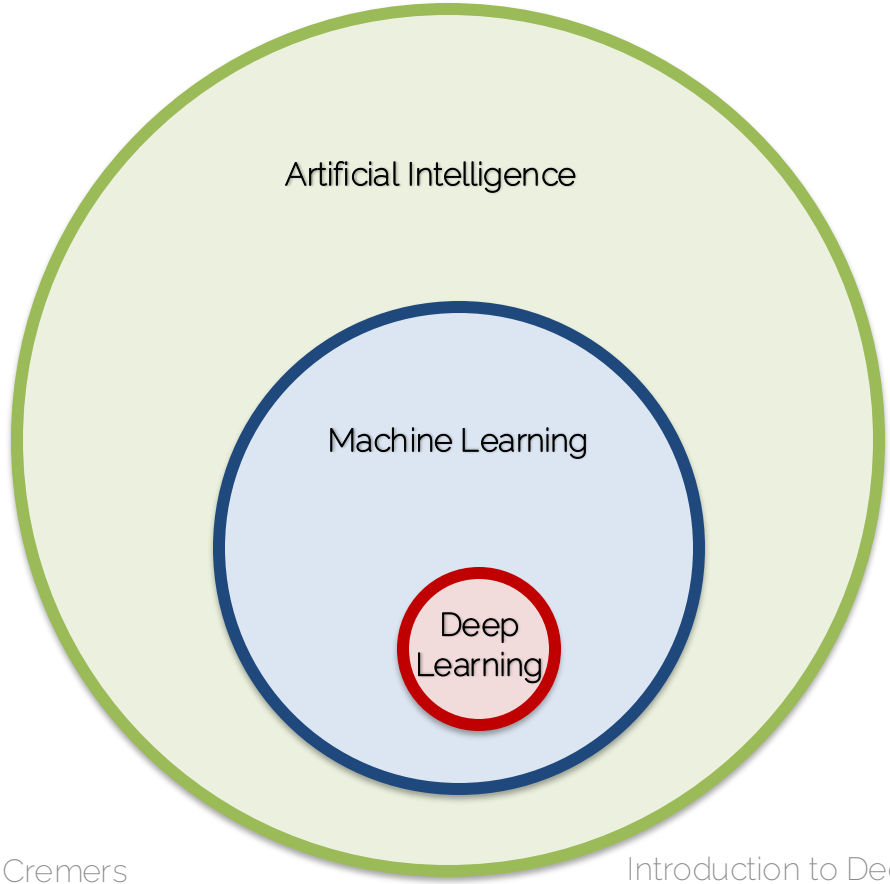


European & National Engagements

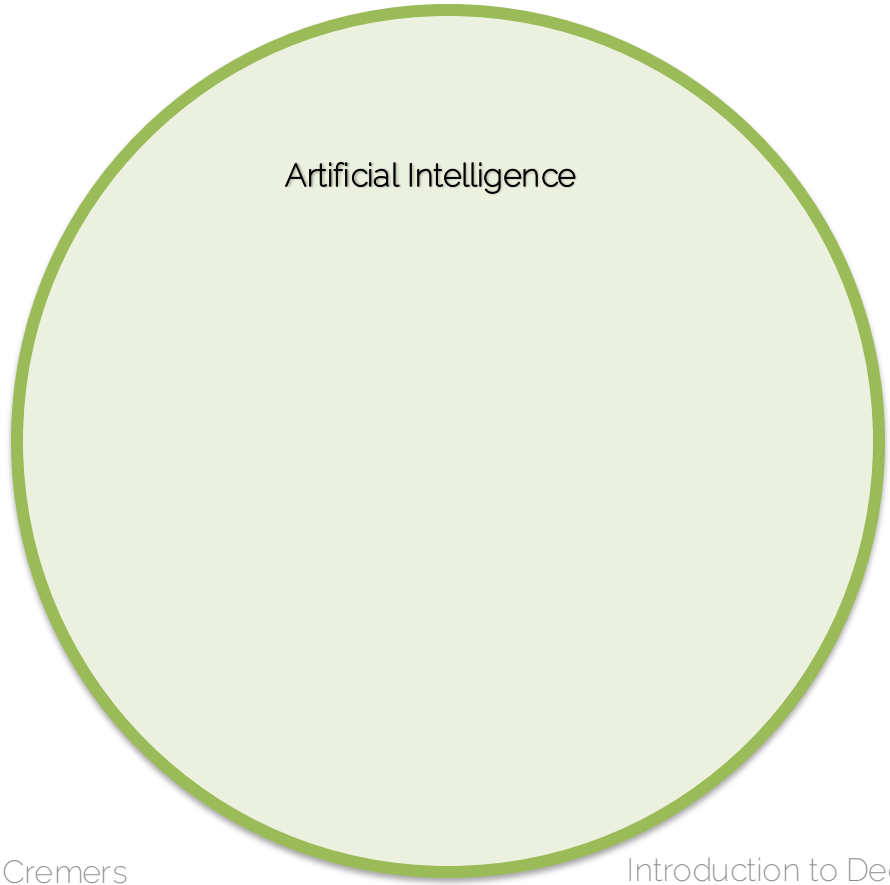
Munich Unit of the
European Lab for Learning
and Intelligent Systems (ELLIS)



What is this Lecture about?



What is this Lecture about?

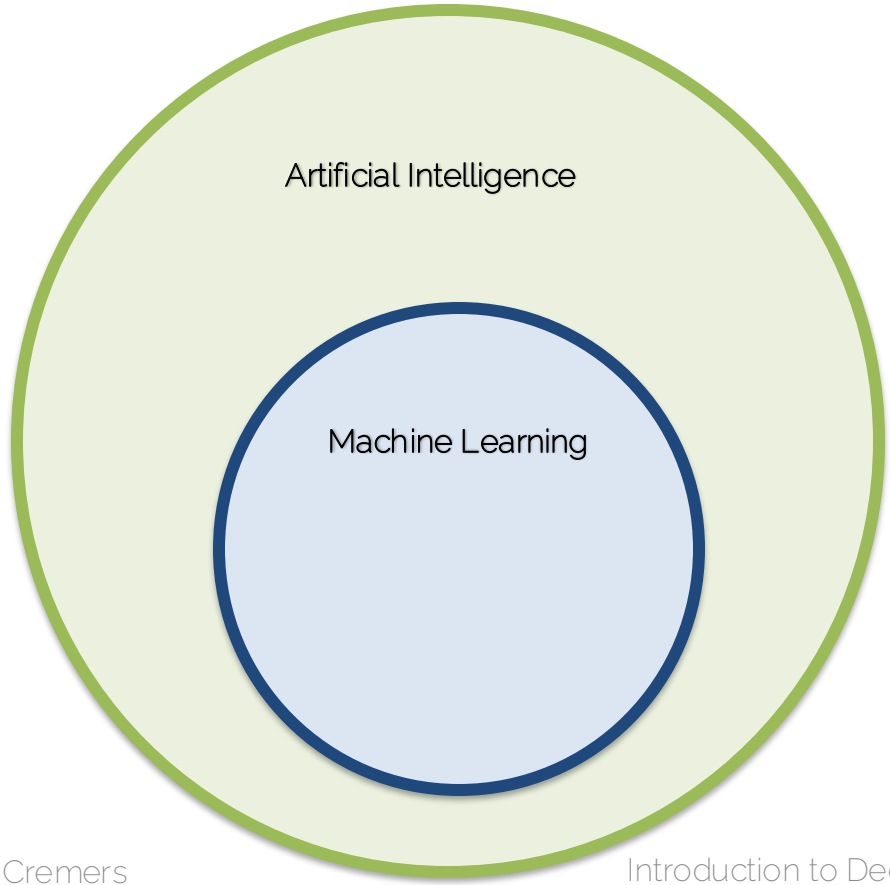


- AI Methods
  - Broad definition!
    - "if" statements"

      if (cold)

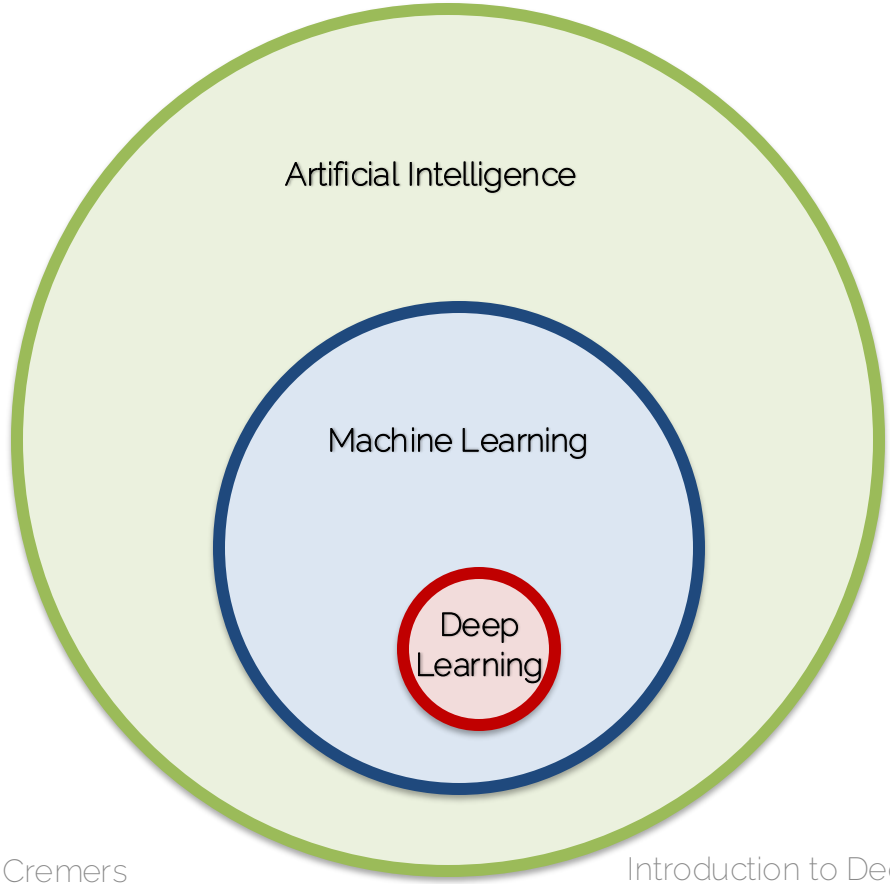
      turn_up_heat();
    - Binary Search
    - Dijkstra, A*, …
    - Prime, Kurskal, …
    - Logic algorithms, etc.
  - ….

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…

Application Areas

- Computer Vision
- Medical Imaging
- Robotics
- Natural Language Processing (NLP)
- Computer Graphics

+ many more ☺

What is Computer Vision?

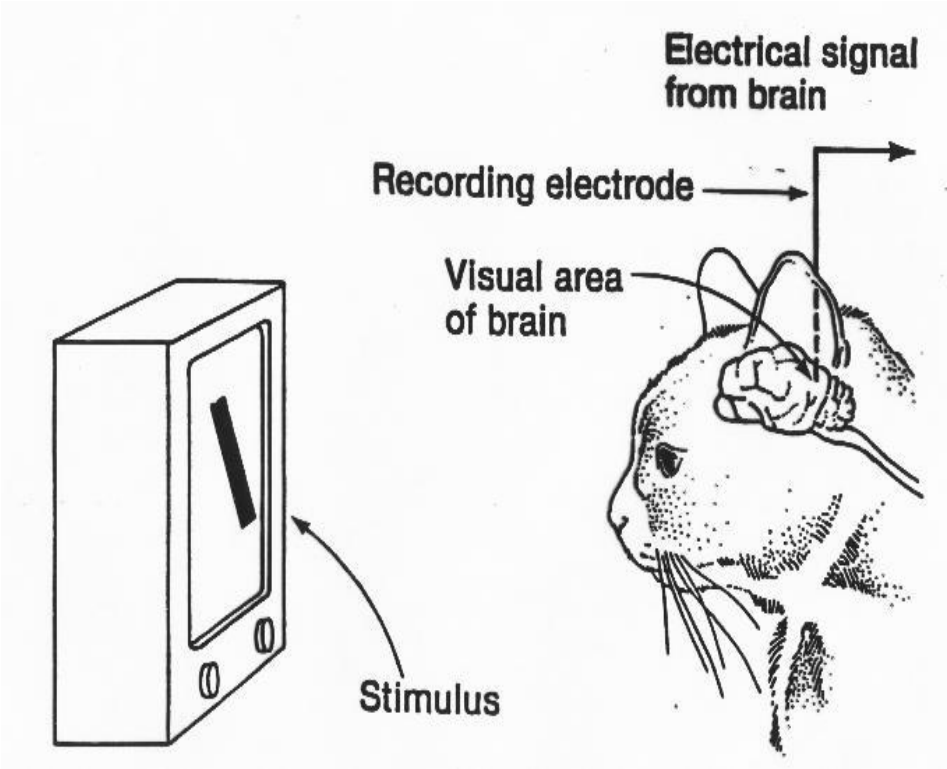
- First defined in the 60s in artificial intelligence groups
- “Mimic the human visual system”
- Center block of robotic intelligence

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.

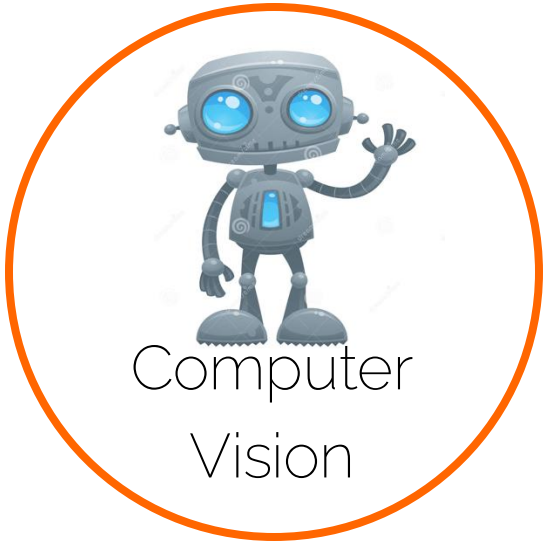
July 7, 1966

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

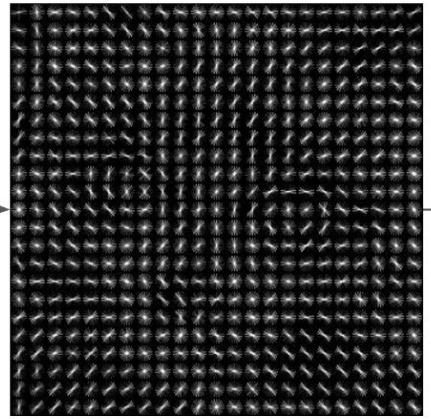
Biology

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

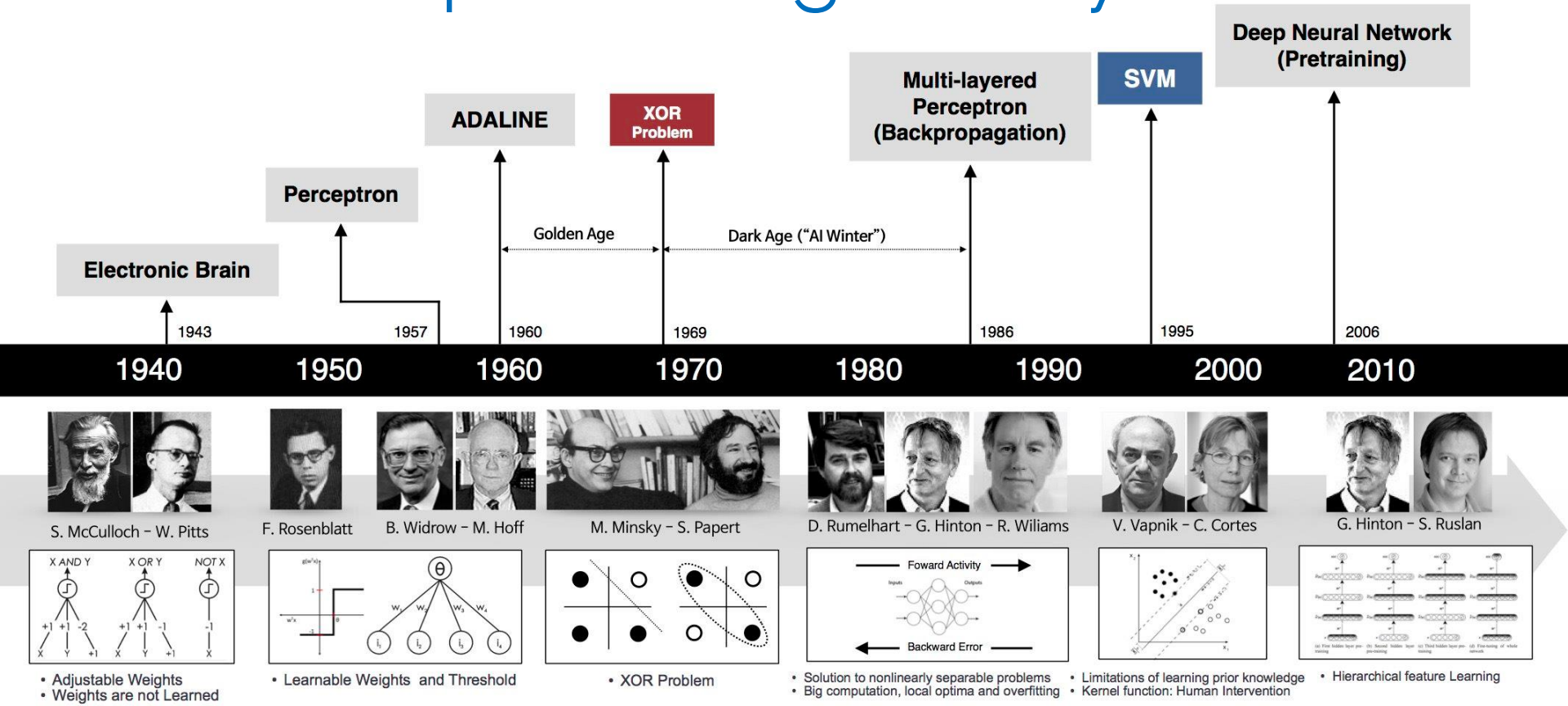
Cat or Background

Open the box

Become magicians

Post 2012

Deep Learning History



- Adjustable Weights
- Weights are not Learned

- Learnable Weights and Threshold

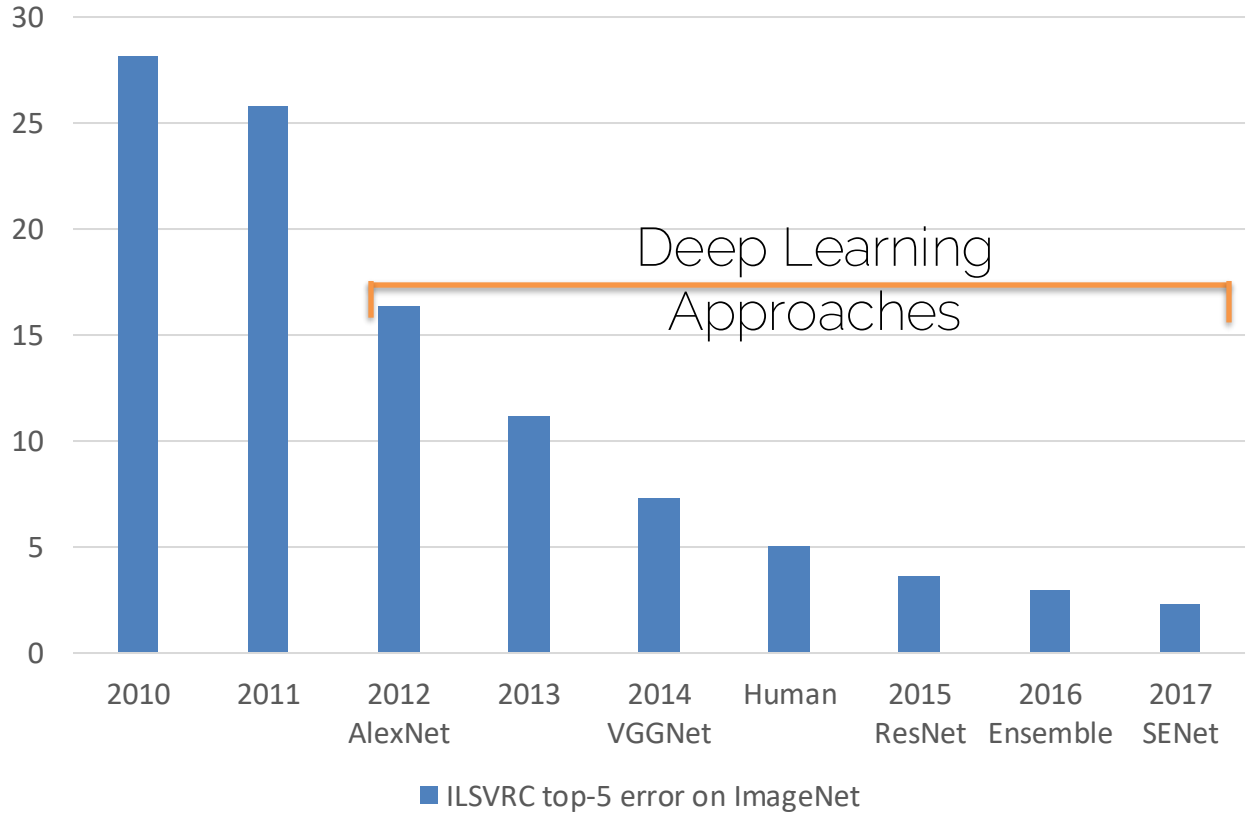
- XOR Problem

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

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

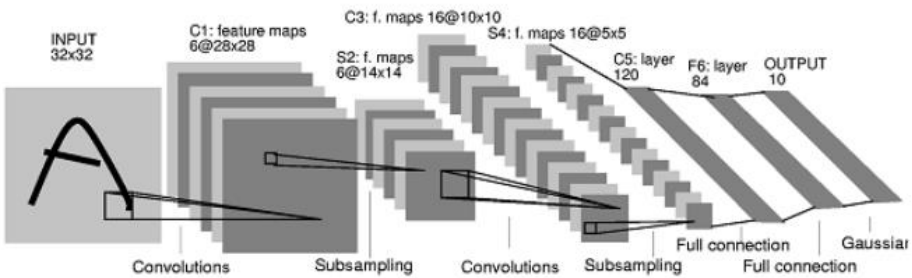
- Hierarchical feature Learning

The Empire strikes Back



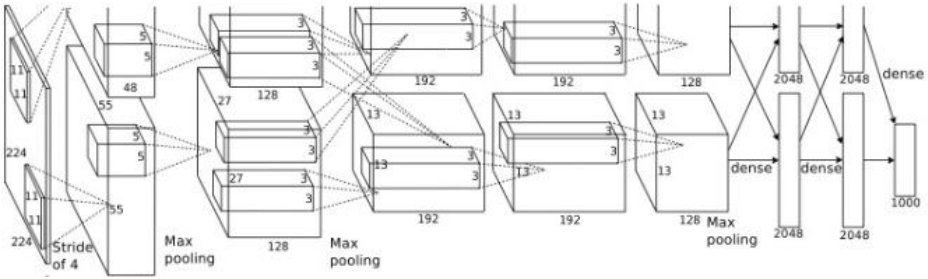
What has Changed?

1998
LeCun
et al.



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

2012
Krizhevsky
et al.

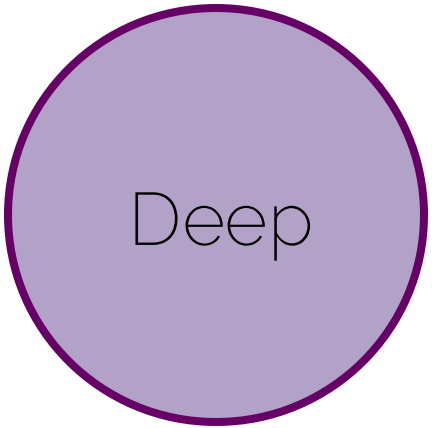


- ImageNet image recognition dataset
- 10^{14} pixels used in training

What Made this Possible?

Models know where to learn from

Models are trainable

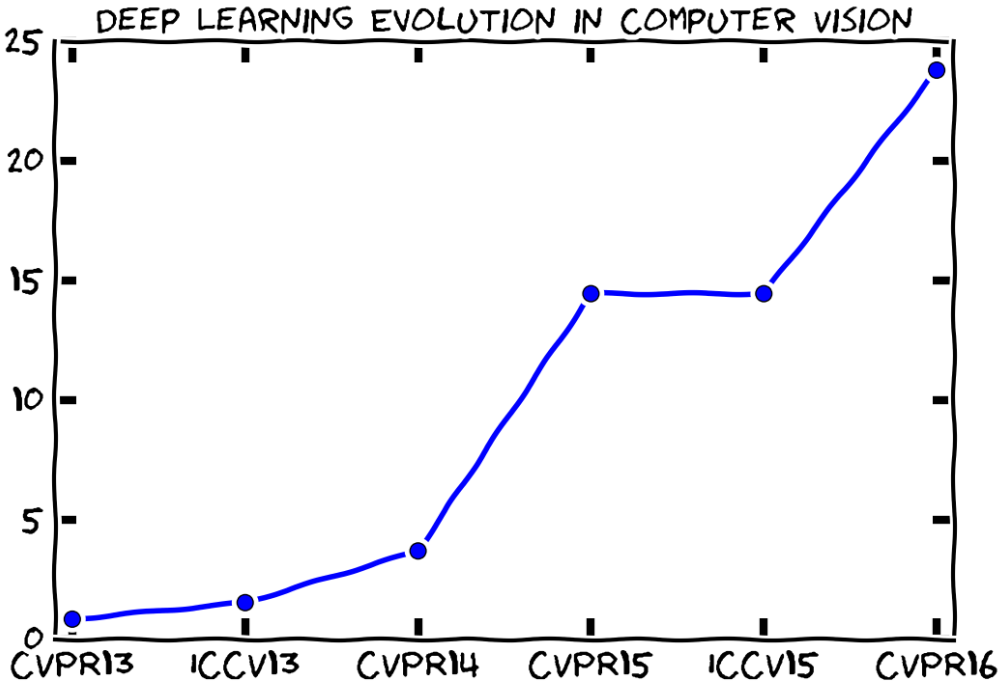


Models are complex

Deep Learning Recognition

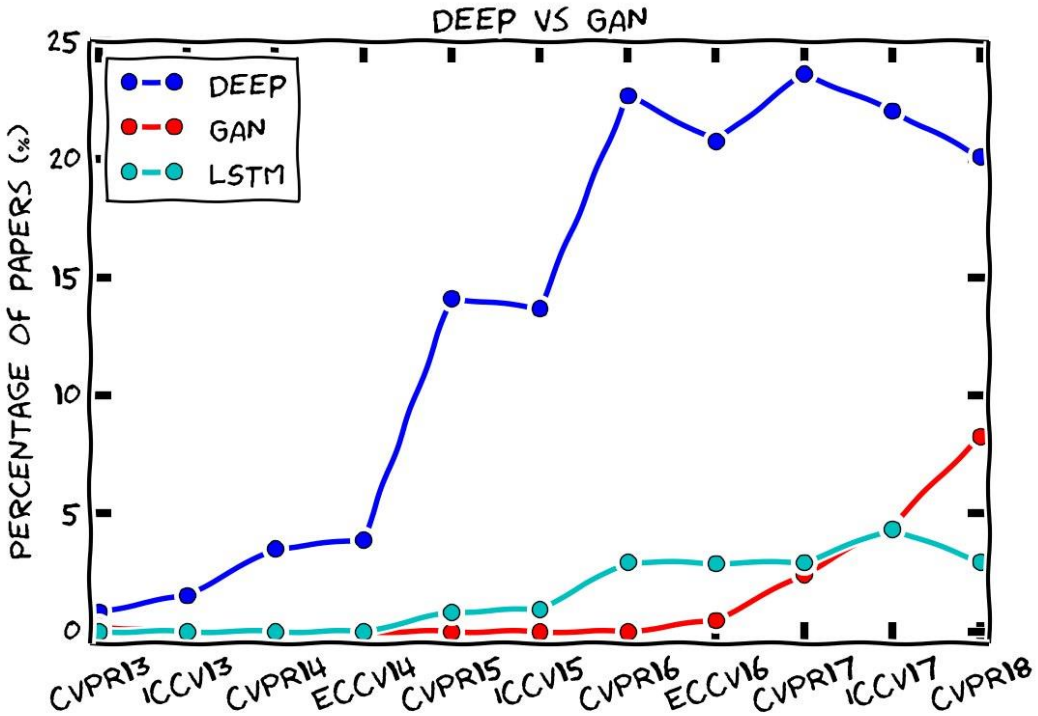
ACM Turing Award 2019 (Nobel Prize of Computing)
Yann LeCun, Geoffrey Hinton, and Yoshua Bengio

Deep Learning and Computer Vision



Credits: Dr. Pont-Tuset, ETH Zurich

Deep Learning and Computer Vision

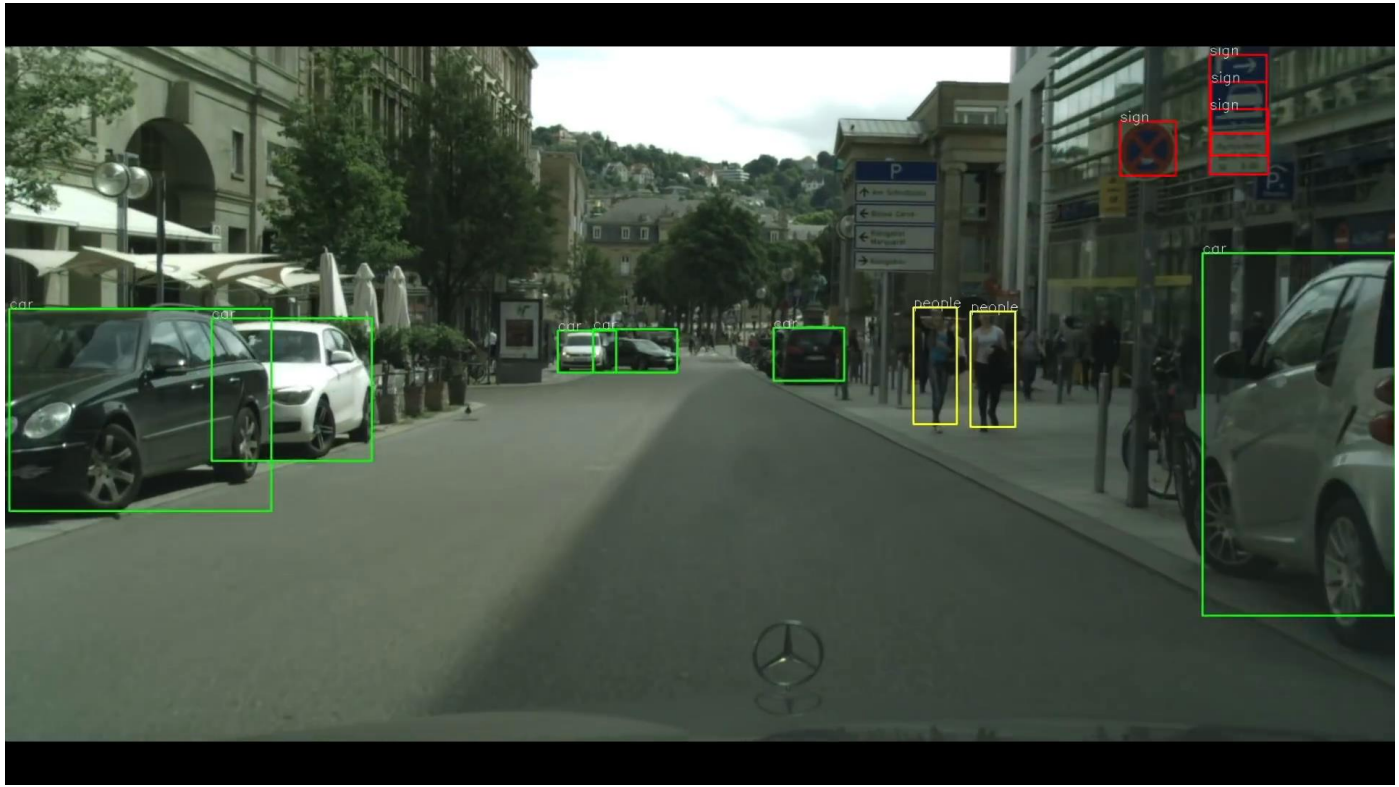


Credits: Dr. Pont-Tuset, ETH Zurich

Deep Learning Today

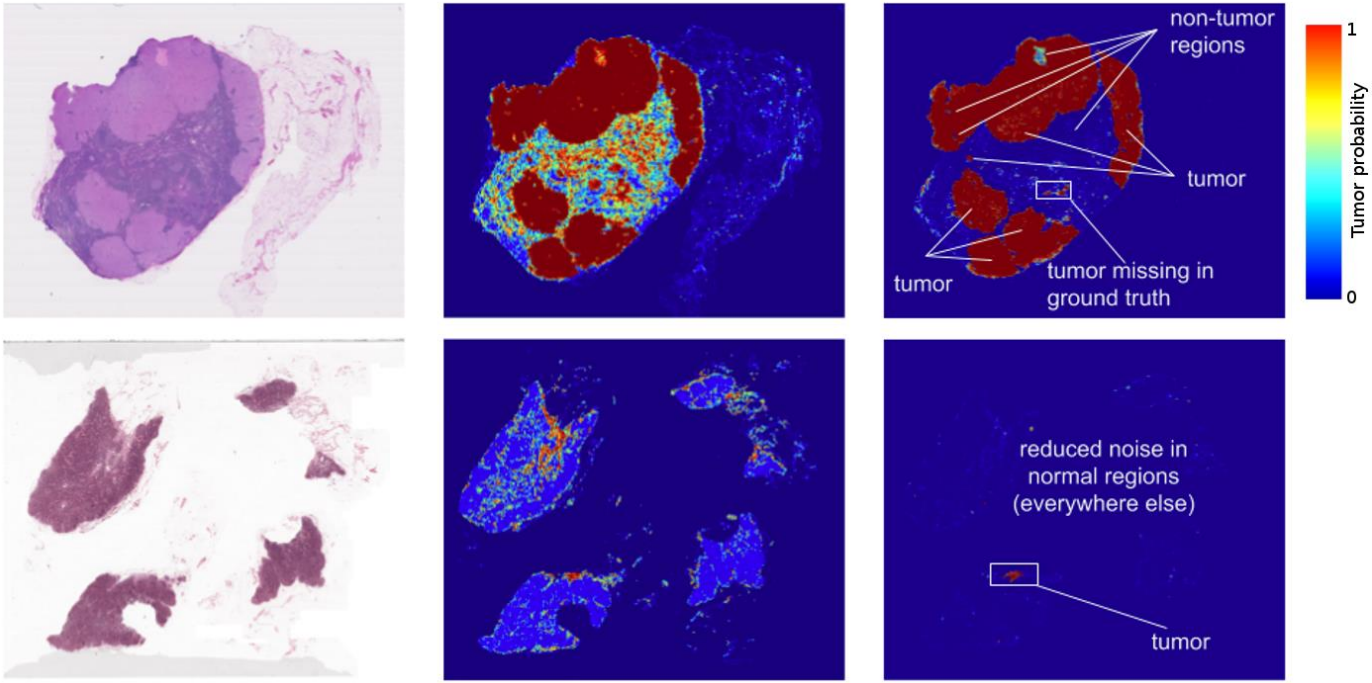
Object Detection

Deep Learning Today



Self-driving cars

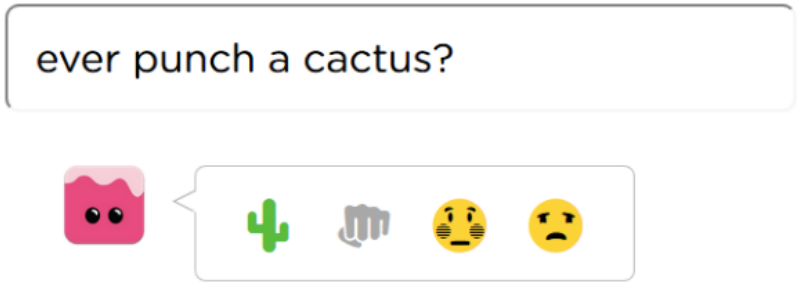
Deep Learning Today



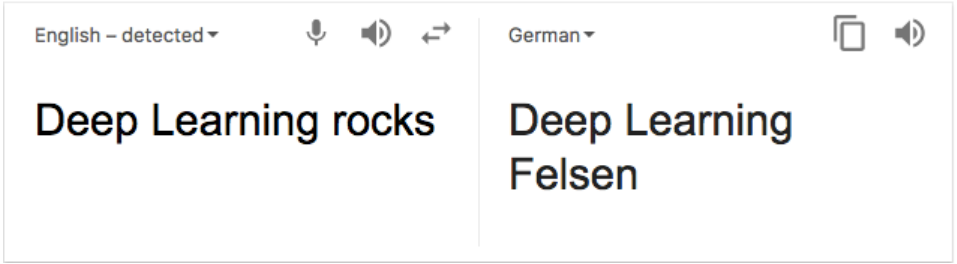
Healthcare, cancer detection

Deep Learning Today

AlphaGo

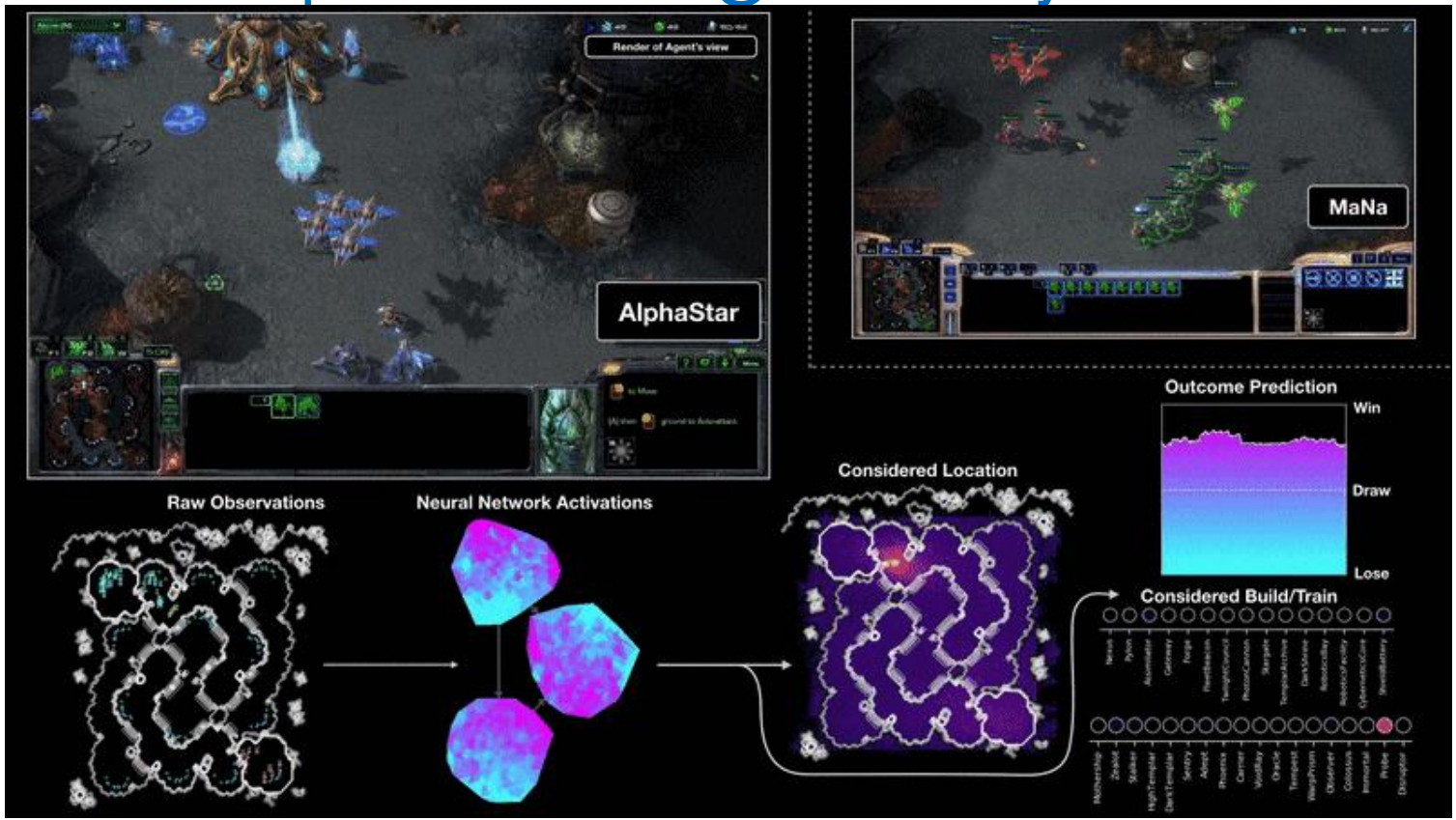


Emoticon suggestion



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

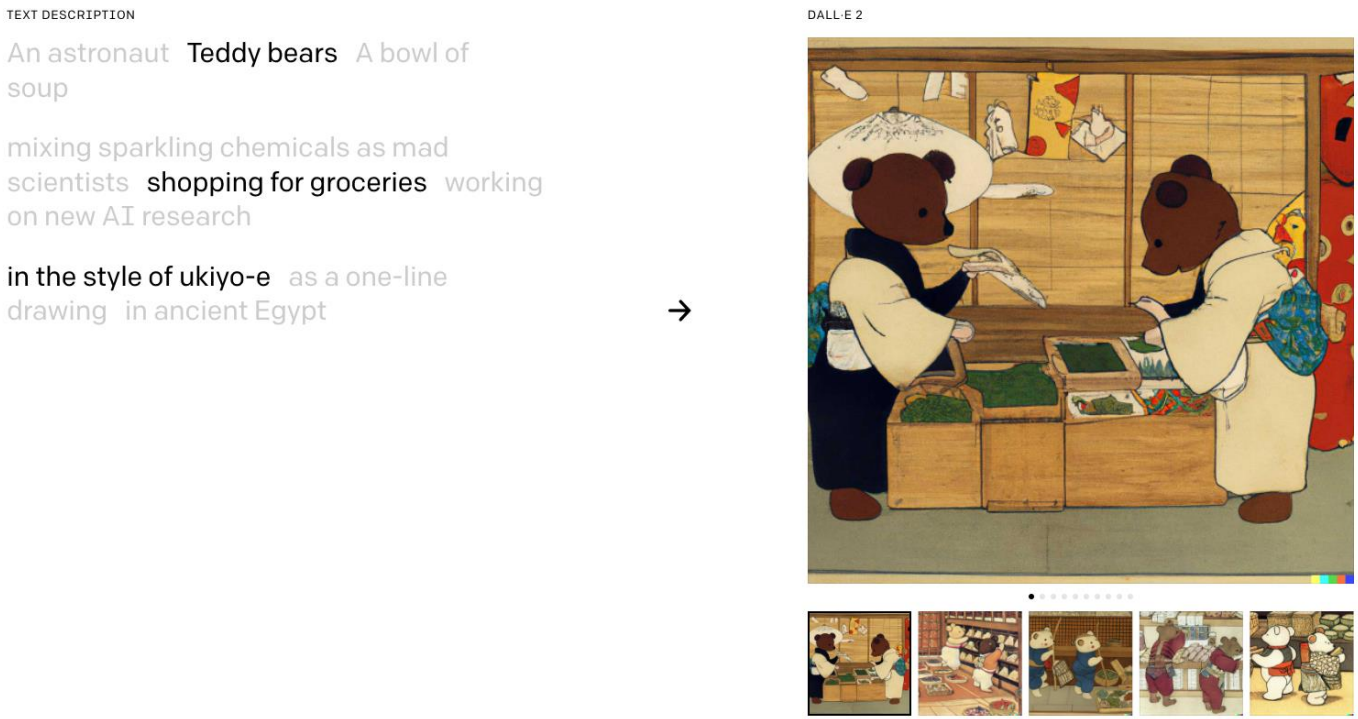
Tell me about deep learning and how I can teach it at TUM.

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.
2. Unsupervised learning: This involves training a model to identify patterns in data without explicit labels.

Deep Learning Today



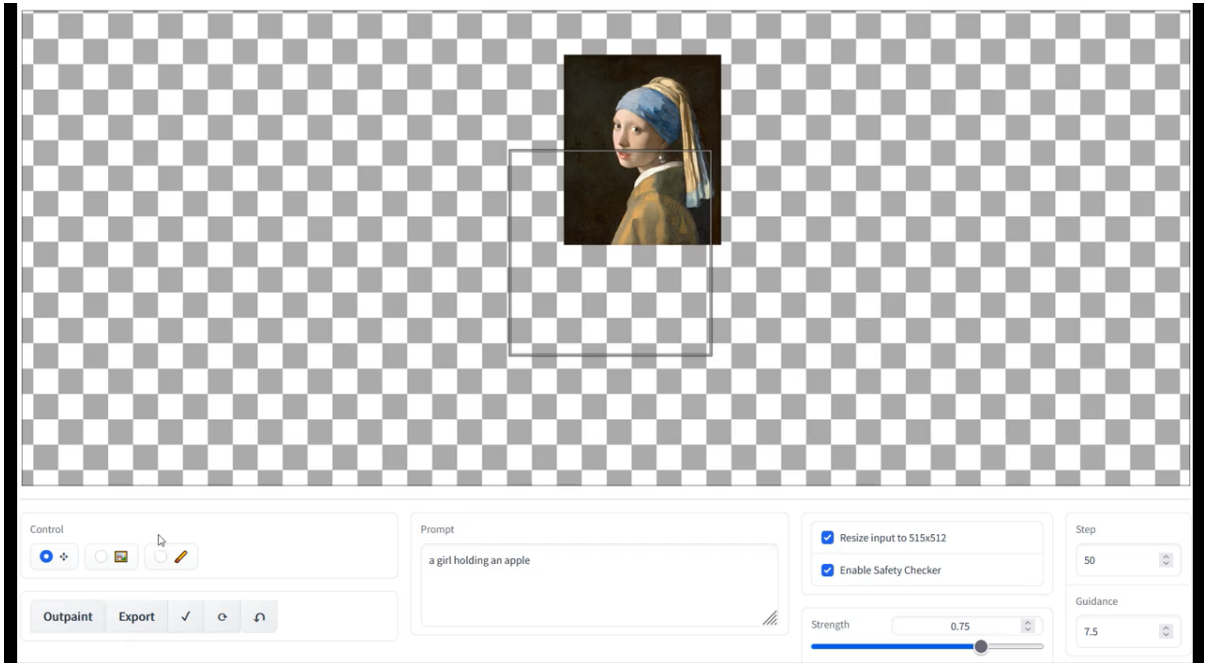
Dall-E 2 Image generation from text

Deep Learning Today

Darth Vader
on a unicorn
in Oxford

Esser, Rombach, Ommer CVPR 2021 *Rombach et al, CVPR 2022*

Deep Learning Today

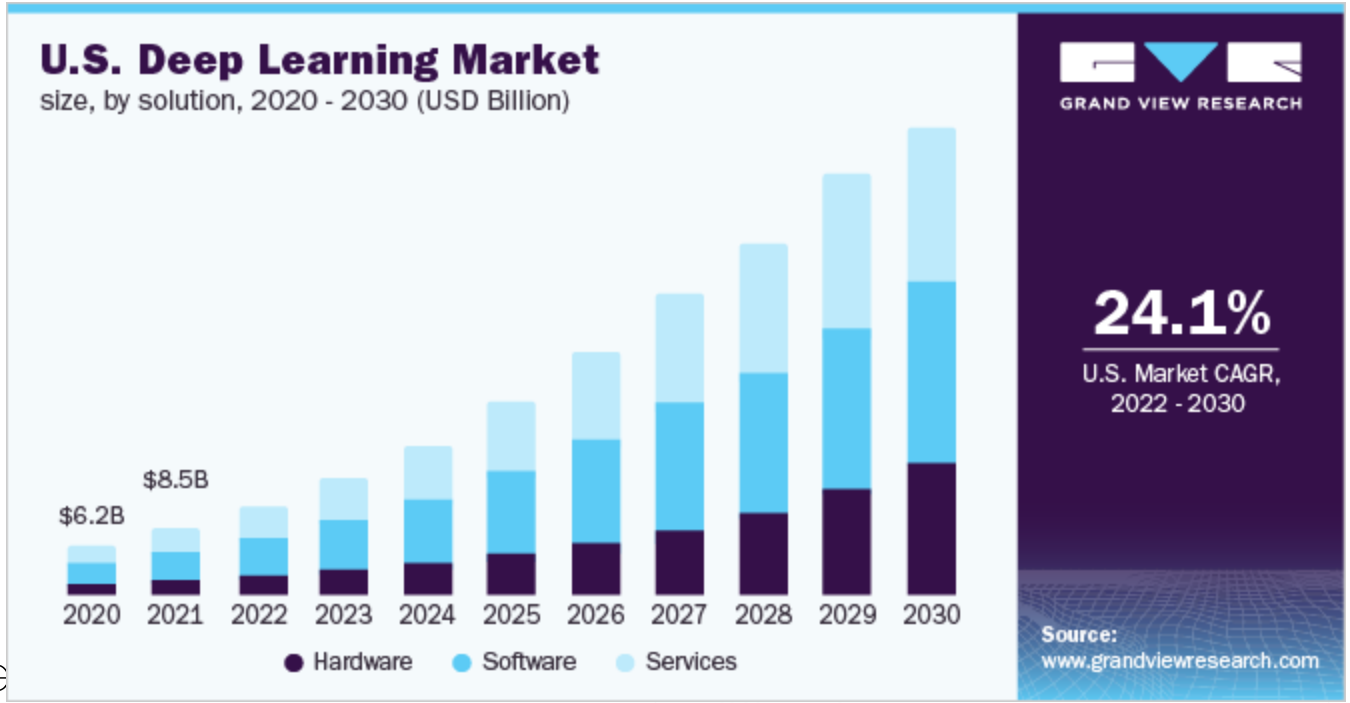


StableDiffusion Image Outpainting

Deep Learning Today

Deep Learning Today

Deep Learning Market



[…] market re
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…

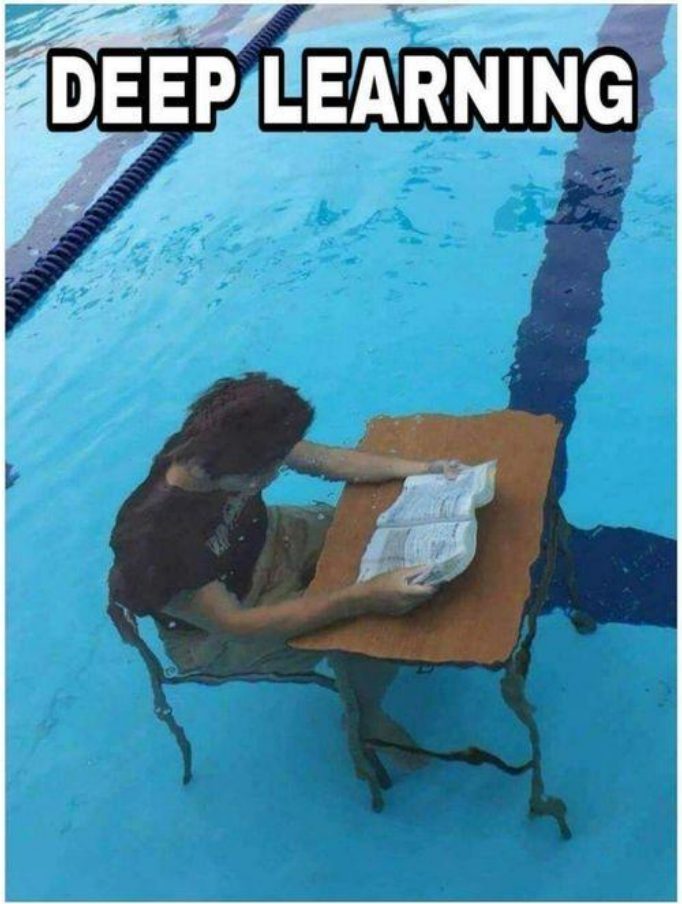
But: Also Challenging!

- 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

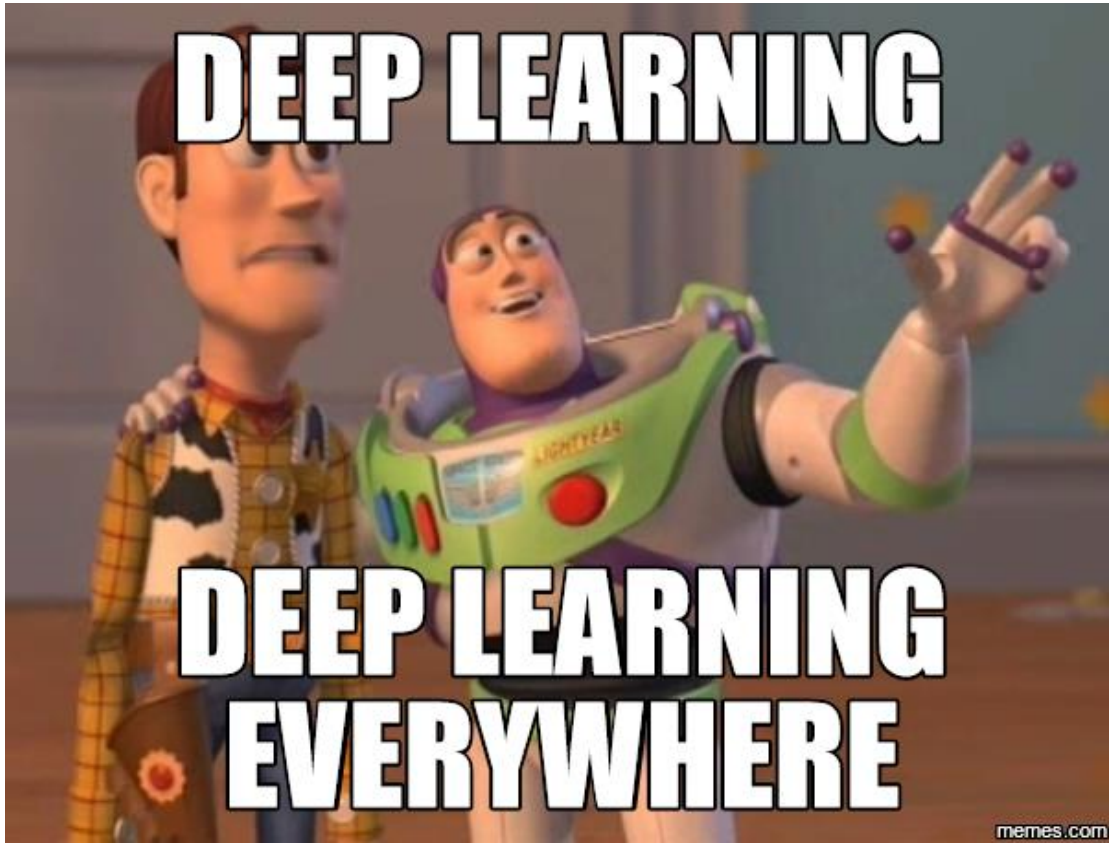
Deep Learning on the Internet

Deep Learning Memes

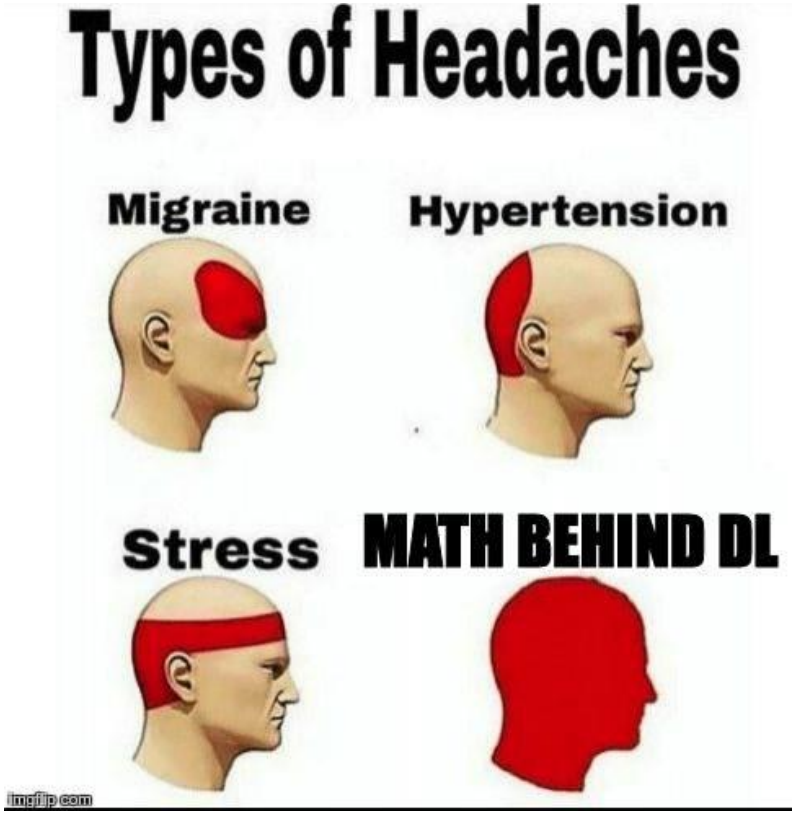


Deep Learning Memes

Deep Learning Memes



Deep Learning Memes



Deep Learning at TUM

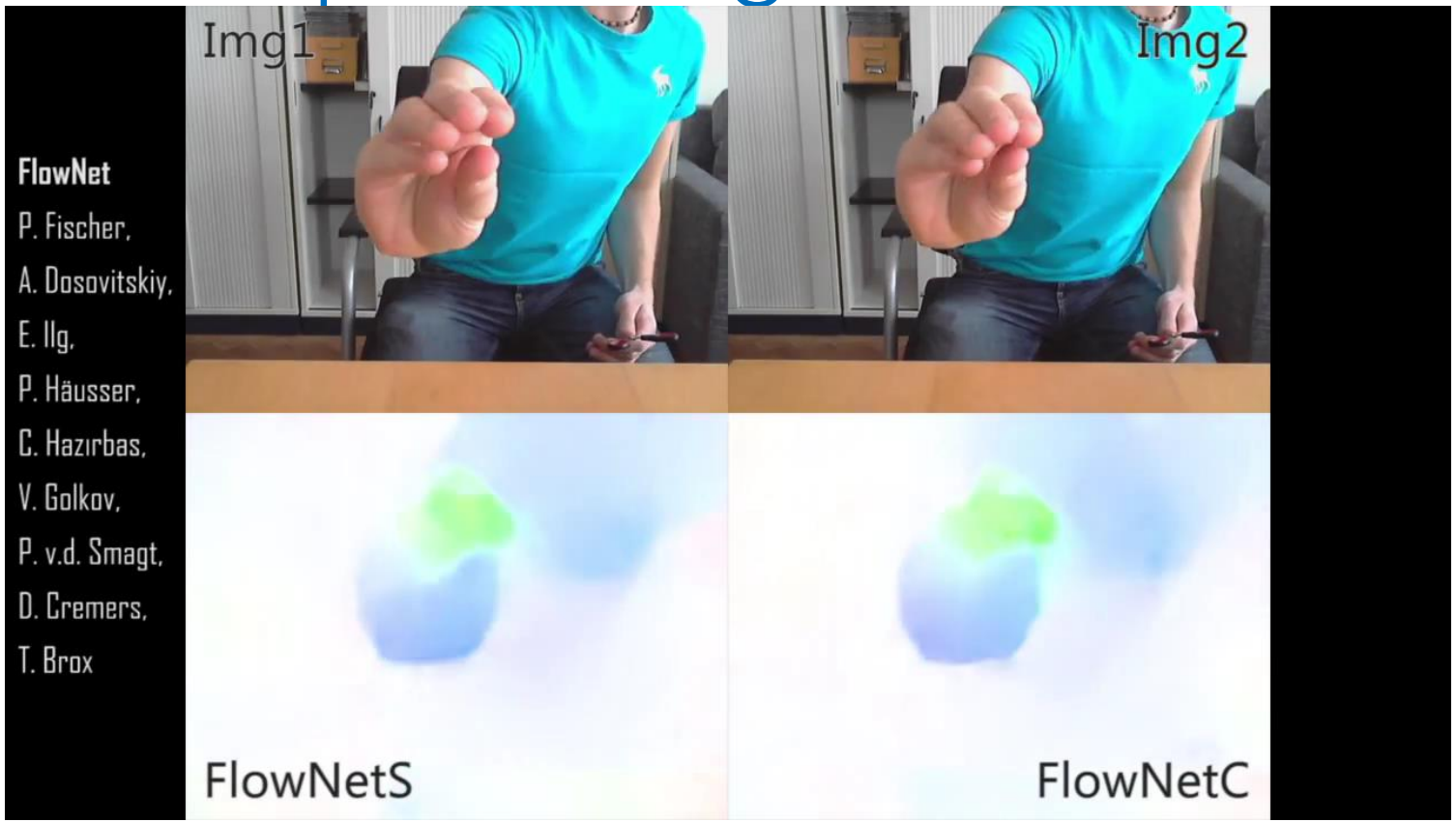
Many TUM Research Labs use DL

- Computer Vision Group (Prof. Cremers)
  - Research in computer vision, machine learning and robotics
- 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
- 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

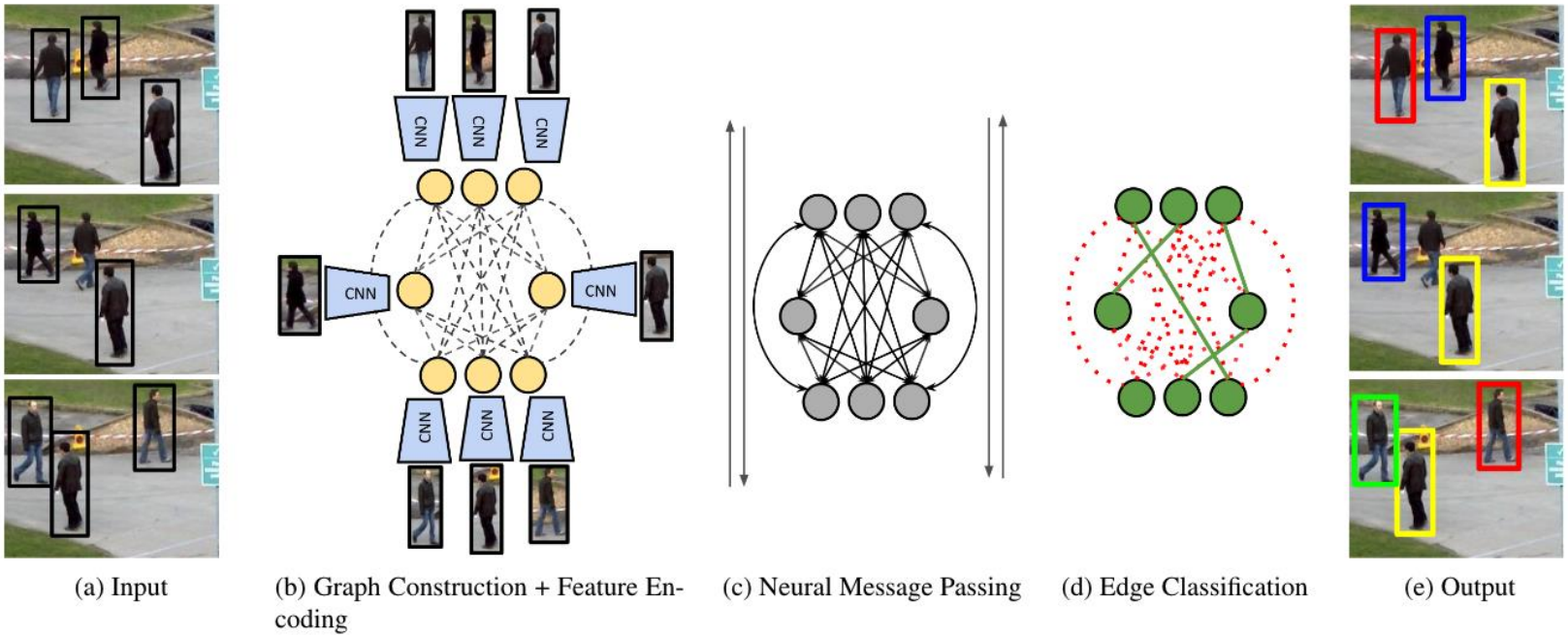
Deep Learning at TUM



[Dosovitskiy et al., ICCV' 15] FlowNet

Deep Learning at TUM

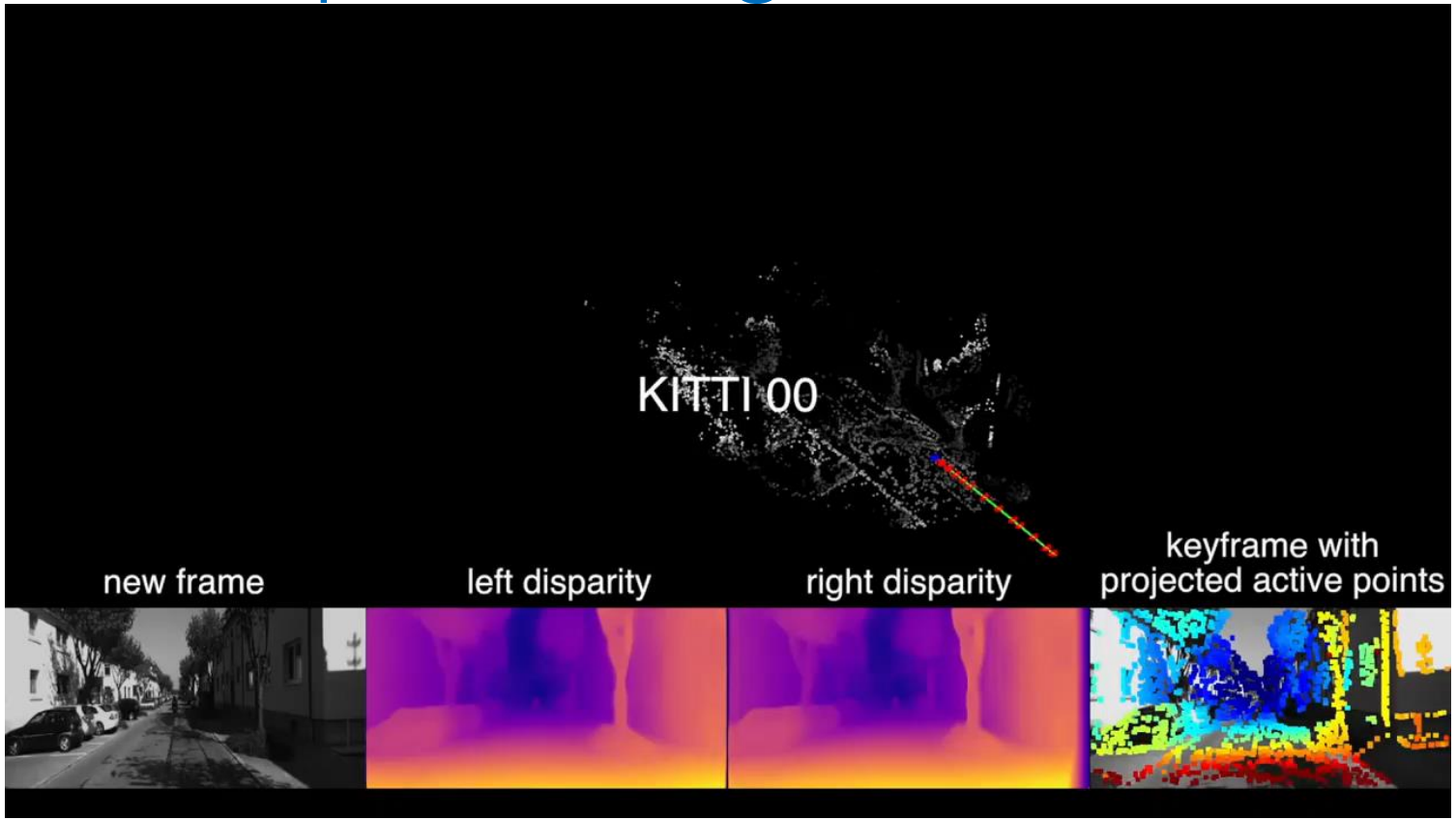
- Multiple object tracking with graph neural networks



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

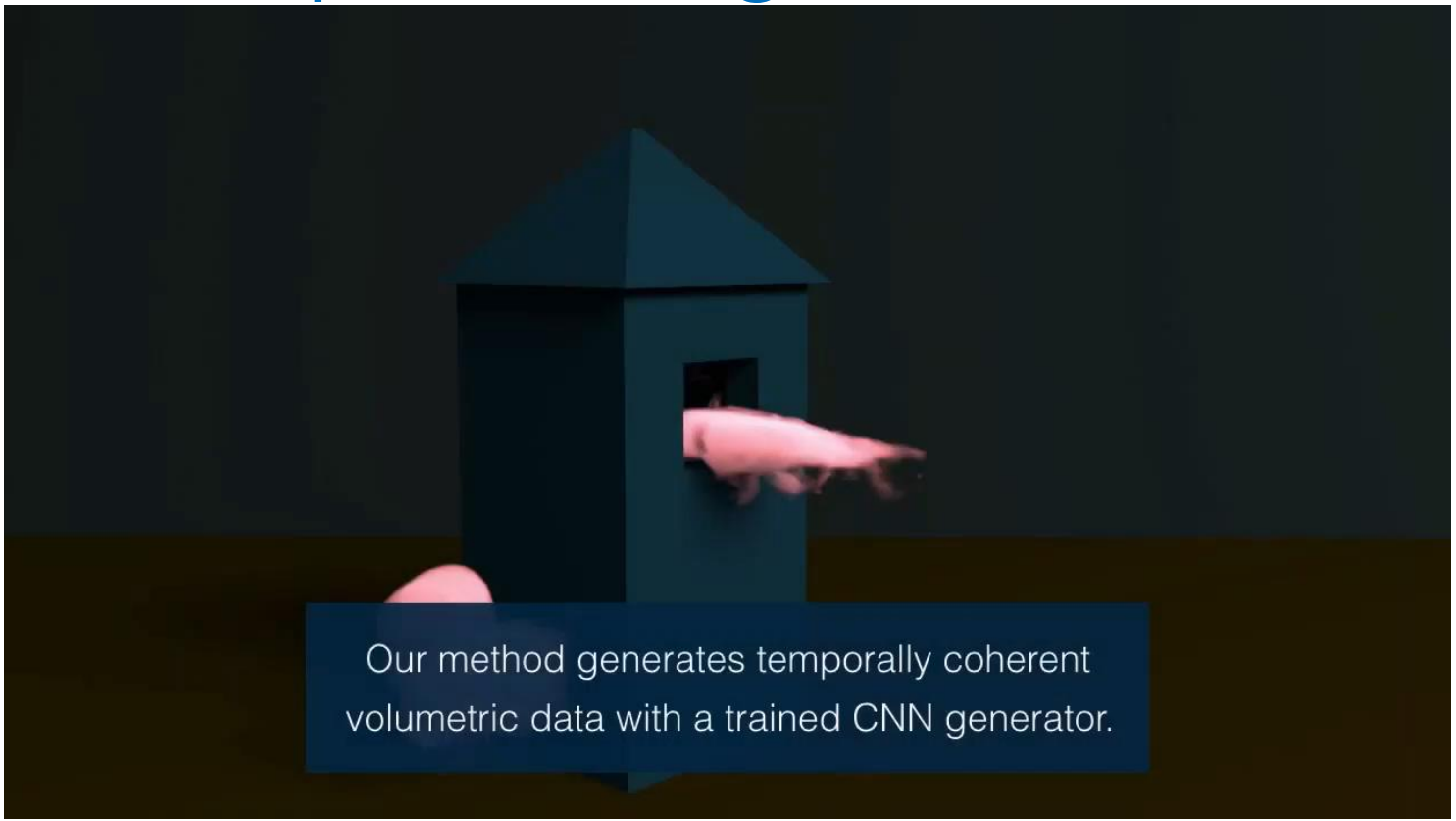
[Brasó and Leal-Taixé, CVPR 2020] Learning a Neural Solver for Multiple Object Tracking.

Deep Learning at TUM



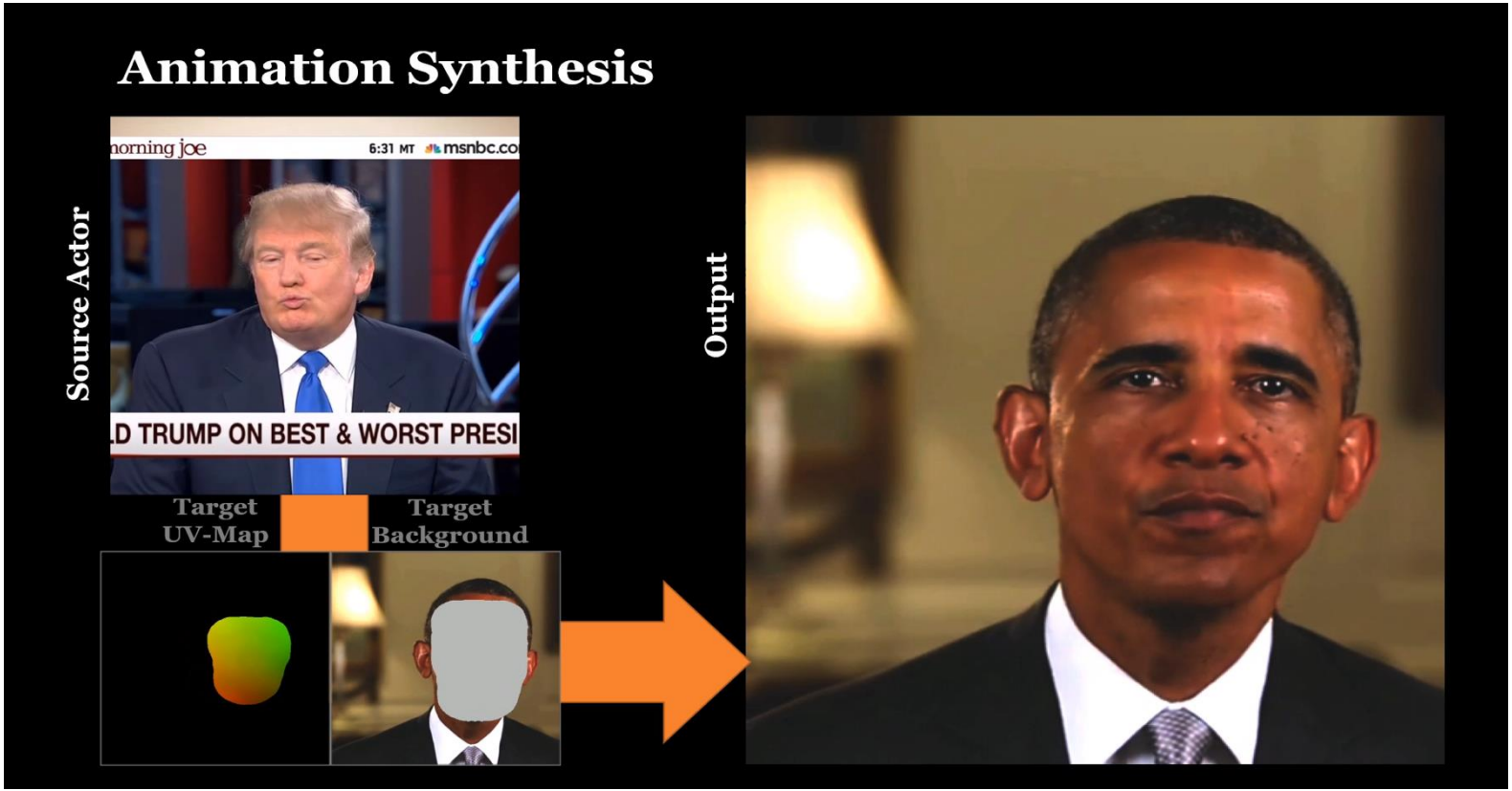
[Yang et al., ECCV' 18] Deep Virtual Stereo Odometry

Deep Learning at TUM



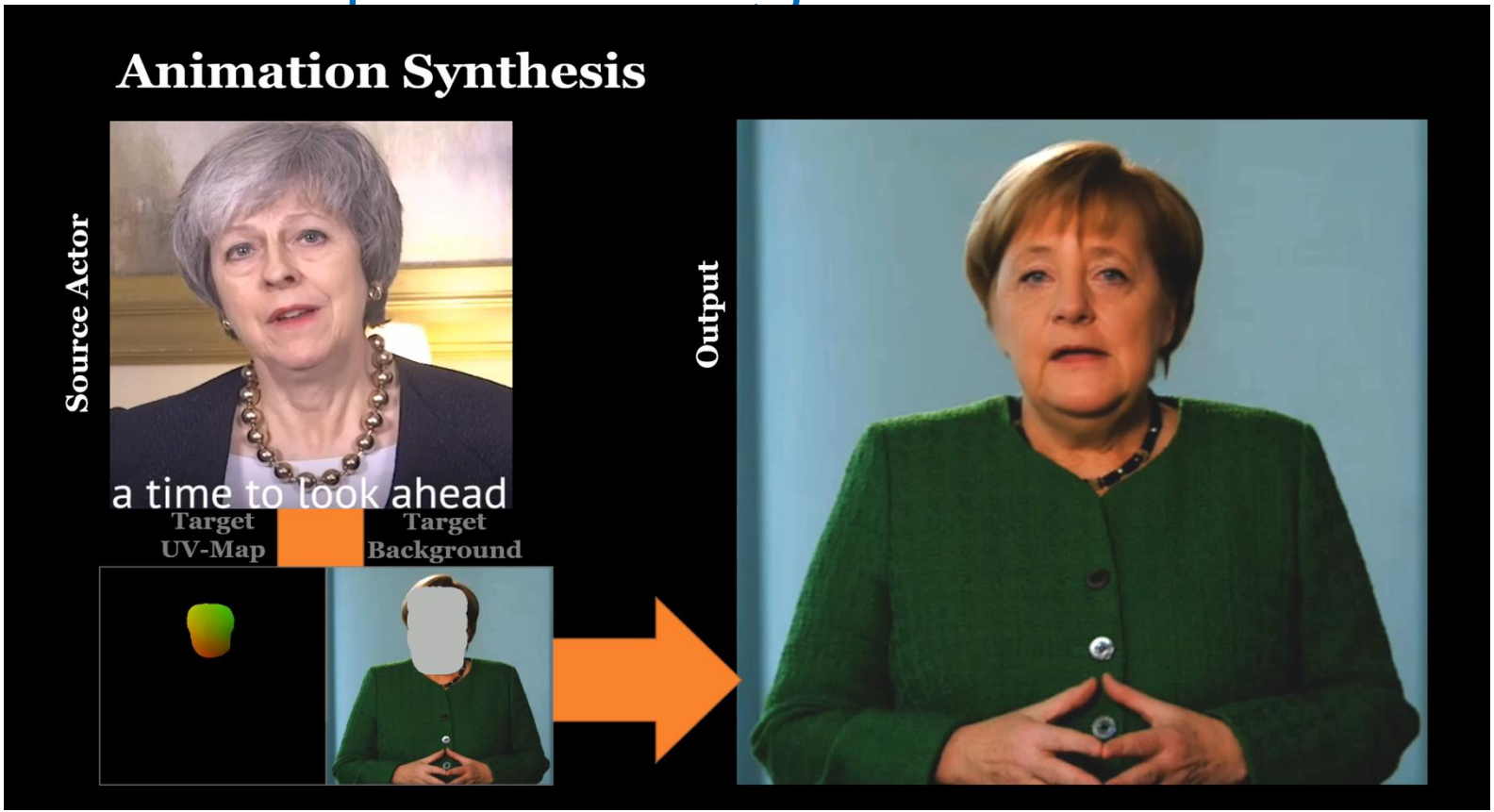
[Xie et al. Siggraph' 18] tempoGAN

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

Wimbauer et al., "MonoRec: Monocular Dense Reconstruction", CVPR '21

Deep Learning at TUM

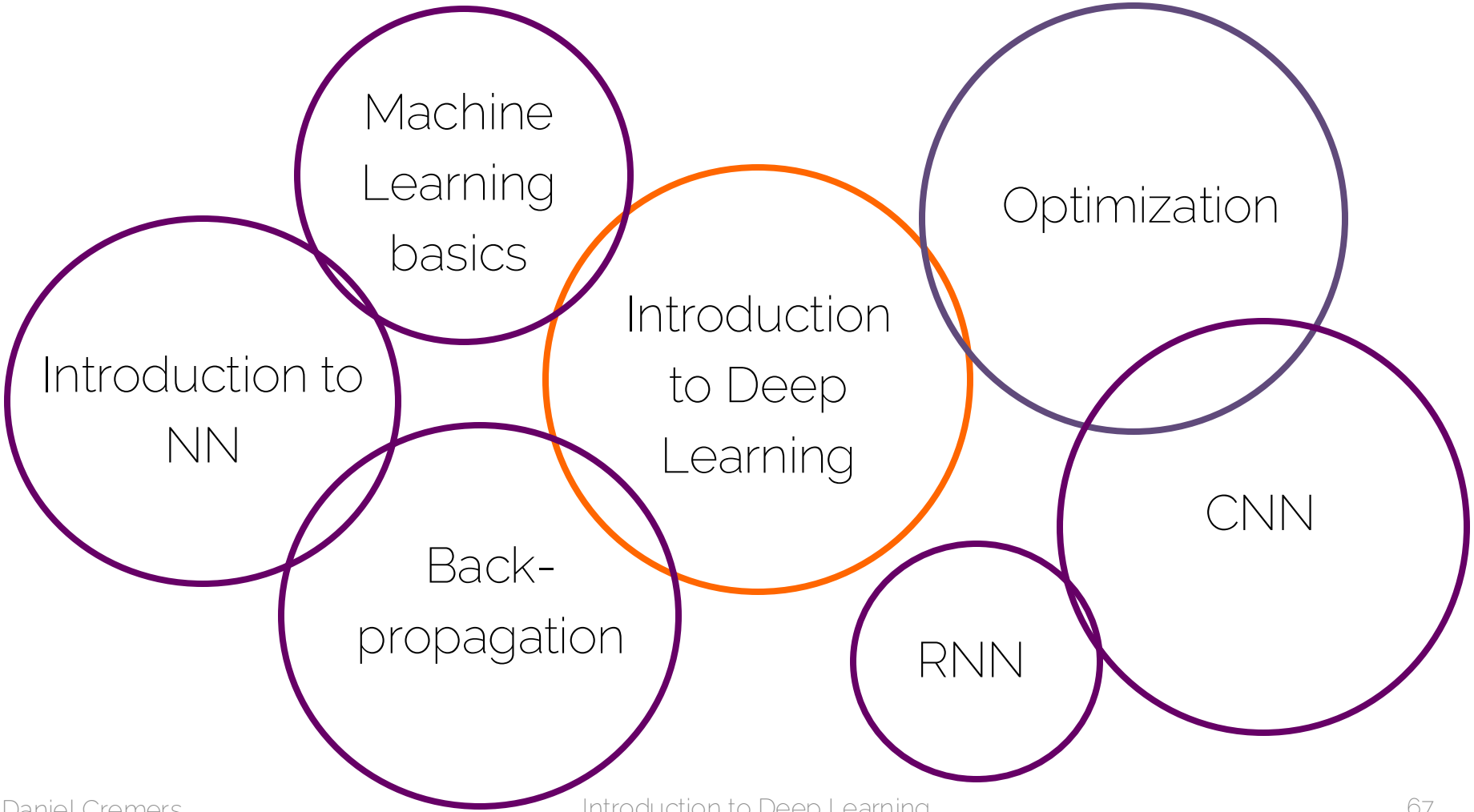
Köstler et al., "TANDEM: Tracking and Dense Mapping", CoRL '21

Deep Learning at TUM

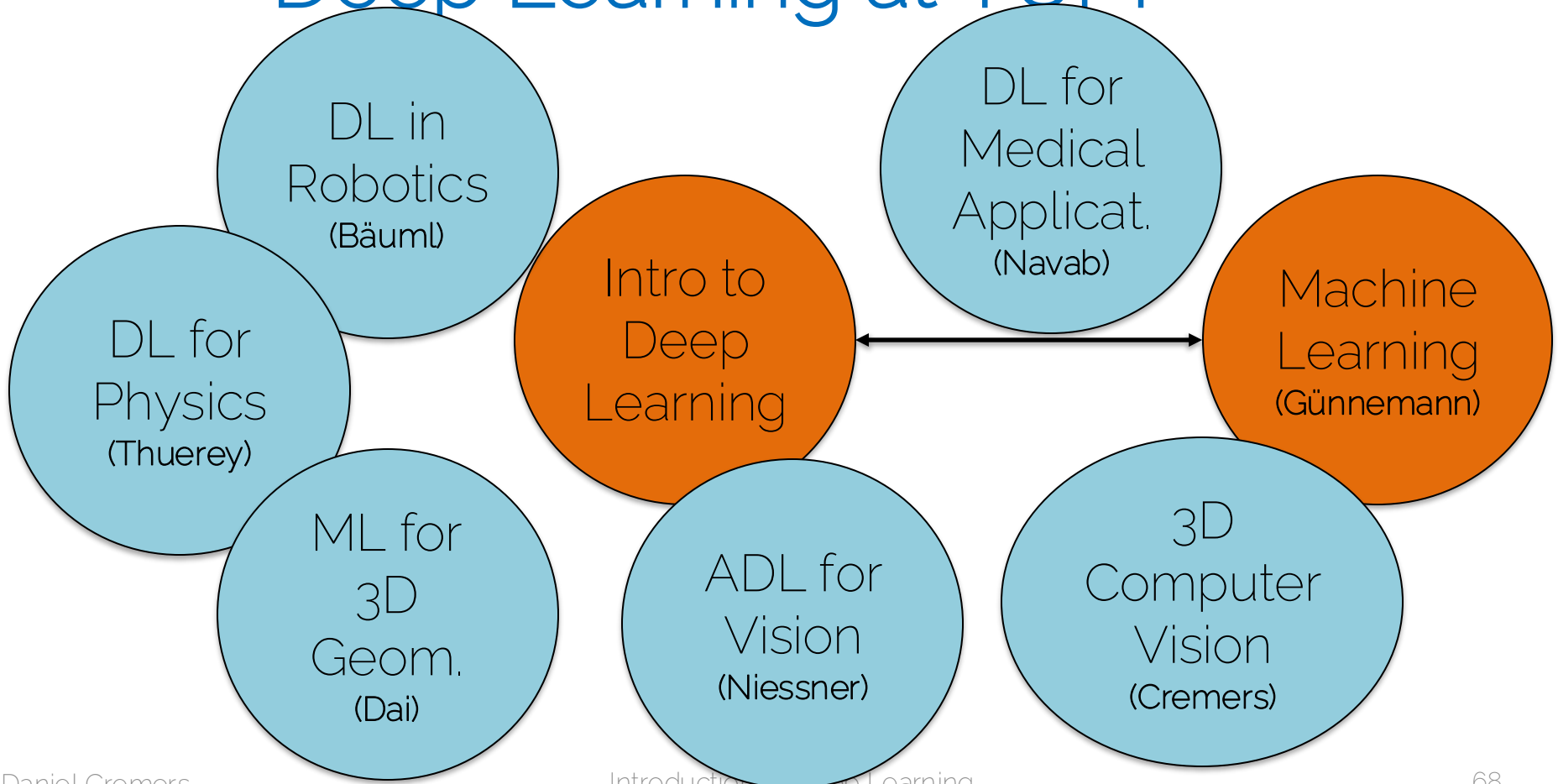
ScanNet Stats:
-Kinect-style RGB-D sensors
-1513 scans of 3D environments
-2.5 Mio RGB-D frames
-Dense 3D, crowd-source MTurk labels
-Annotations projected to 2D frames

[Dai et al., CVPR'17] ScanNet

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



Introduction to Deep Learning

Logistics

The Team

Lecturer

Prof. Dr. Daniel Cremers

TAs

Shenhan Qian

Jason Chui

Yan Xia

Student Tutors

Julius Horsch

Oleg Magnes

Luca Fehling-Schuh

Subhan Kamilov

Benjamin Heltzel

Alexandra Samoylova

Yunxiang Lu

About the Lecture

- Theory lectures (every Tuesday at 14:00)
  - 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

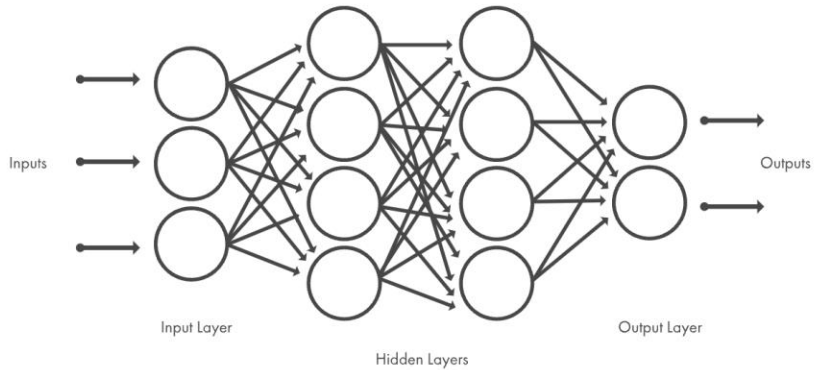
- Announcements via Piazza - IMPORTANT!
  - Sign up online for access: http://piazza.com/tum.de
    - Select "**Fall 2024**" term, search for IN2346
    - Use your @mytum.de email address
  - We will share common information (e.g., regarding exam)
- Forum
  - Ask and discuss questions
    - Tutors will 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

Website

Computer Vision Group
TUM School of Computation, Information and Technology
Technical University of Munich

- Home
- Application Form
- TUM AI Lecture Series
- Members +
- Research Areas +
- Publications
- **Teaching** –
- **Winter Semester 2024/25** –
  - Computer Vision III: Detection, Segmentation and Tracking (IN2375)
  - **Introduction to Deep Learning (IN2346)**
  - Master Seminar - Beyond Deep Learning (5 ECTS)
  - Master Seminar - Recent Advances in 4D

Introduction to Deep Learning (IN2346)



Informatik IX
Computer Vision Group

Boltzmannstrasse 3
85748 Garching
info@vision.in.tum.de

Follow us on:

YouTube
X / Twitter
Facebook

News

03.07.2024
We have **seven papers** accepted to **ECCV 2024**. Check our publication page for more details.

09.06.2024
GCPR / VMV 2024

We are organizing GCPR / VMV 2024 this fall.

https://cvg.cit.tum.de/teaching/ws2024/i2dl

Email

- Email list:

  i2dl@vision.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

Exam FAQ

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

- Grade Bonus:
  - Solve 9 out of 10 "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://cvg.cit.tum.de/teaching/ws2024/i2dl

See you next time ☺

Upcoming Lecture

- Next Lecture: Lecture 2: Machine Learning basics
- Thursday: Tutorial 1 and Exercise 1