

# Deep Learning

Lecture 0: Introduction

Prof. Gilles Louppe  
[g.louppe@uliege.be](mailto:g.louppe@uliege.be)

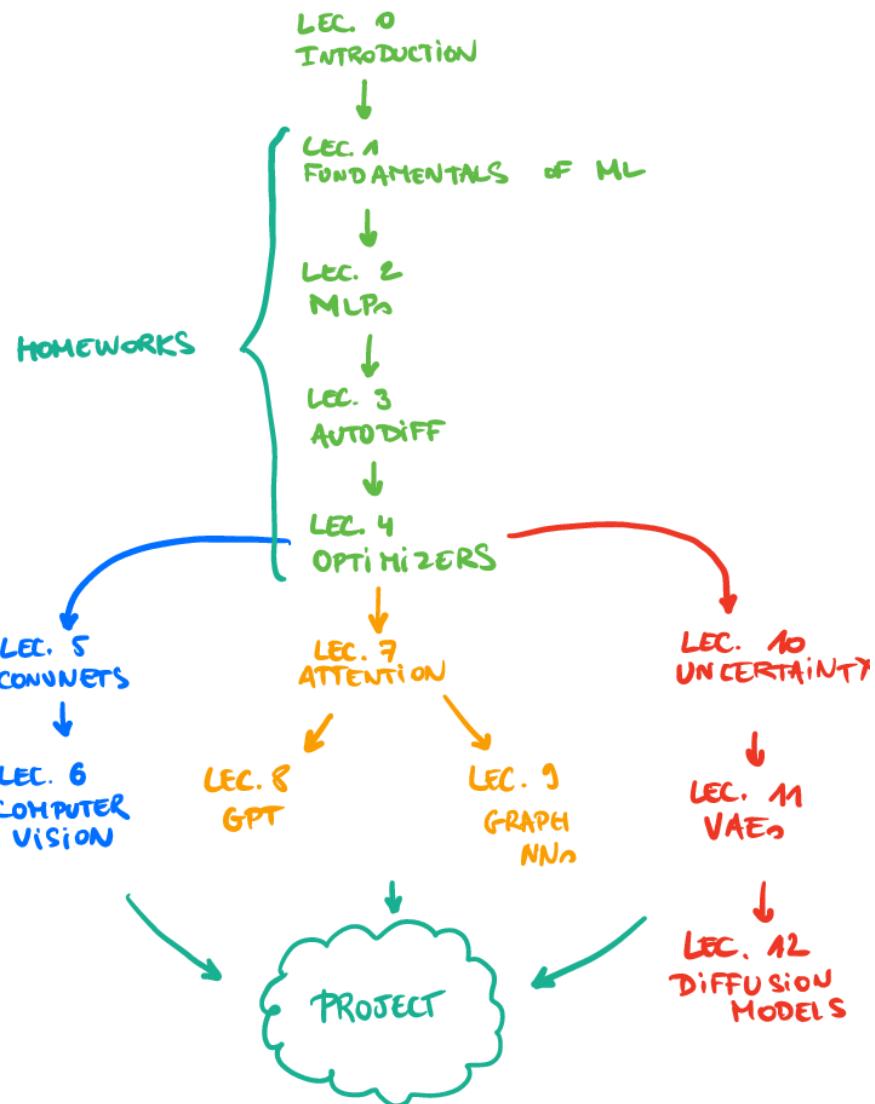


# Today

- Course outline
- Introduction to deep learning
- Fundamentals of machine learning

# Outline

- Lecture 0: Introduction
- Lecture 1: Fundamentals of machine learning
- Lecture 2: Multi-layer perceptron
- Lecture 3: Automatic differentiation
- Lecture 4: Training neural networks
- Lecture 5: Convolutional neural networks
- Lecture 6: Computer vision
- Lecture 7: Attention and transformer networks
- Lecture 8: GPT
- Lecture 9: Graph neural networks
- Lecture 10: Uncertainty
- Lecture 11: Auto-encoders and variational auto-encoders
- Lecture 12: Score-based diffusion models



## **My mission**

By the end of this course, you will have acquired a solid and detailed understanding of the field of deep learning.

You will have learned how to design deep neural networks for a wide range of advanced probabilistic inference tasks and how to train them.

These models seen in the course apply to a wide variety of artificial intelligence problems, with plenty of applications in engineering and science.

# Why learning?



What do you see?



Sheepdog or mop?



Chihuahua or muffin?

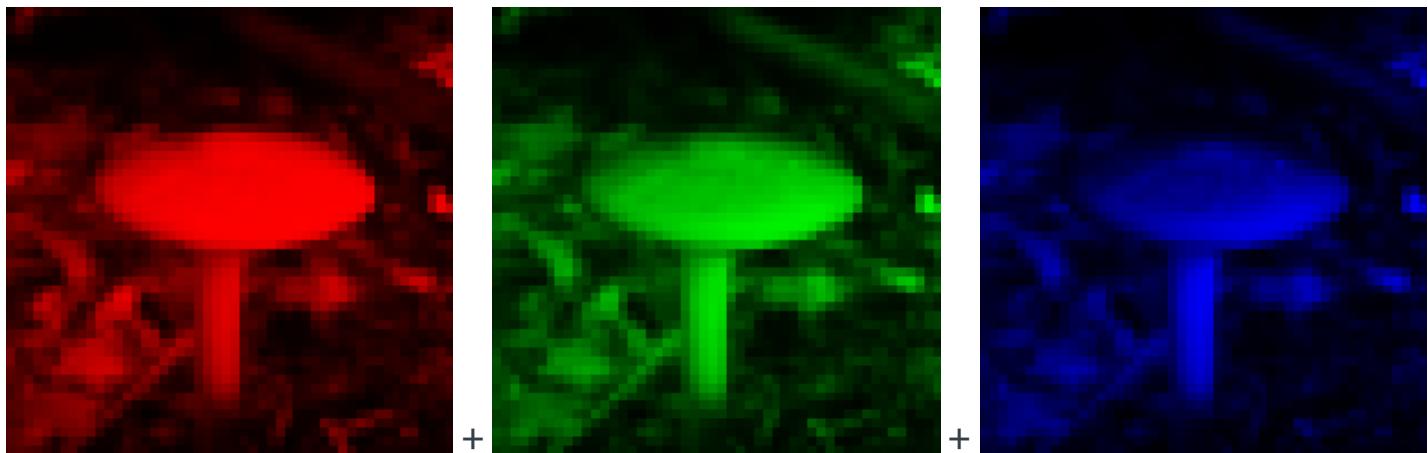
The (human) brain is so good at interpreting visual information that the **gap** between raw data and its semantic interpretation is difficult to assess intuitively:



This is a mushroom.



This is a mushroom.



This is a mushroom.

```
array([[[0.03921569, 0.03529412, 0.02352941, 1.          ],
       [0.2509804 , 0.1882353 , 0.20392157, 1.          ],
       [0.4117647 , 0.34117648, 0.37254903, 1.          ],
       ...,
       [0.20392157, 0.23529412, 0.17254902, 1.          ],
       [0.16470589, 0.18039216, 0.12156863, 1.          ],
       [0.18039216, 0.18039216, 0.14117648, 1.          ]],

      [[0.1254902 , 0.11372549, 0.09411765, 1.          ],
       [0.2901961 , 0.2509804 , 0.24705882, 1.          ],
       [0.21176471, 0.2        , 0.20392157, 1.          ],
       ...,
       [0.1764706 , 0.24705882, 0.12156863, 1.          ],
       [0.10980392, 0.15686275, 0.07843138, 1.          ],
       [0.16470589, 0.20784314, 0.11764706, 1.          ]],

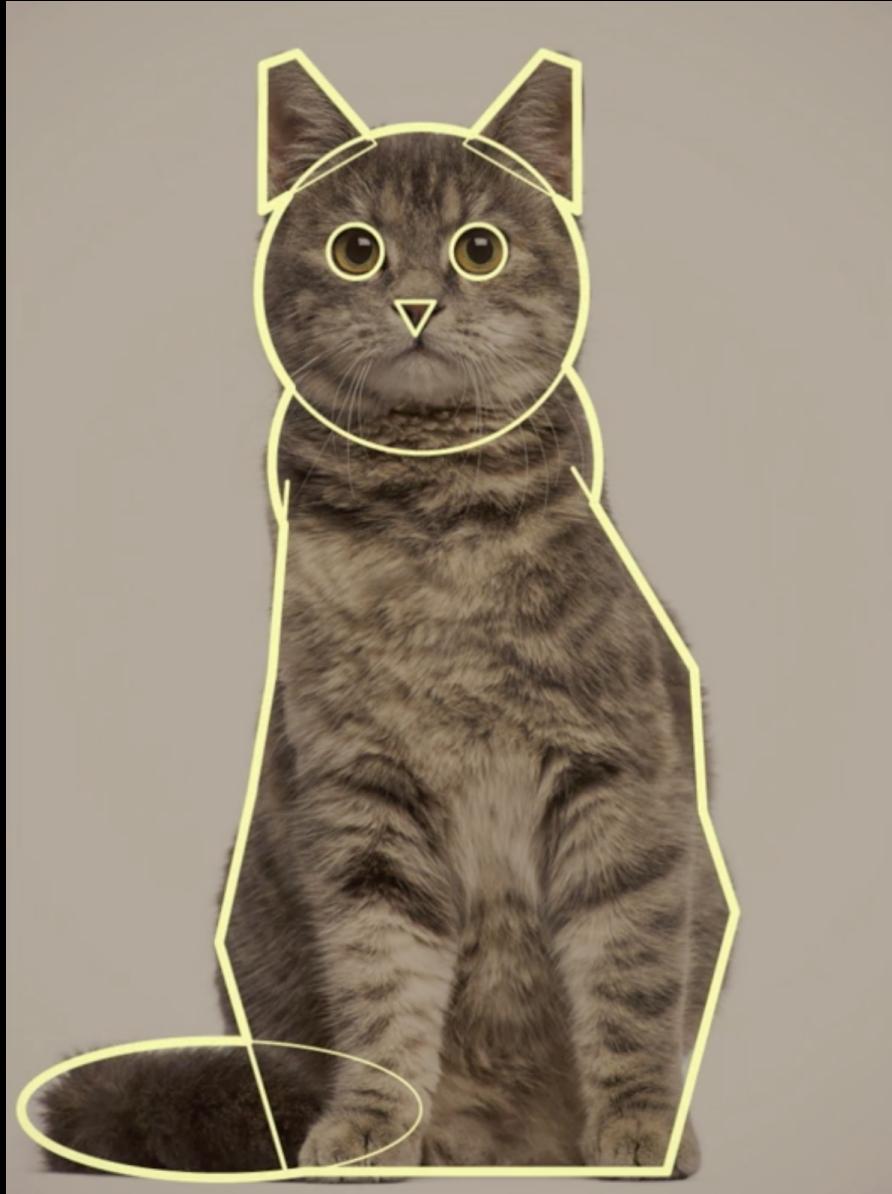
      [[0.14117648, 0.12941177, 0.10980392, 1.          ],
       [0.21176471, 0.1882353 , 0.16862746, 1.          ],
       [0.14117648, 0.13725491, 0.12941177, 1.          ],
       ...,
       [0.10980392, 0.15686275, 0.08627451, 1.          ],
       [0.0627451 , 0.08235294, 0.05098039, 1.          ],
       [0.14117648, 0.2        , 0.09803922, 1.          ]],

      ...,
```

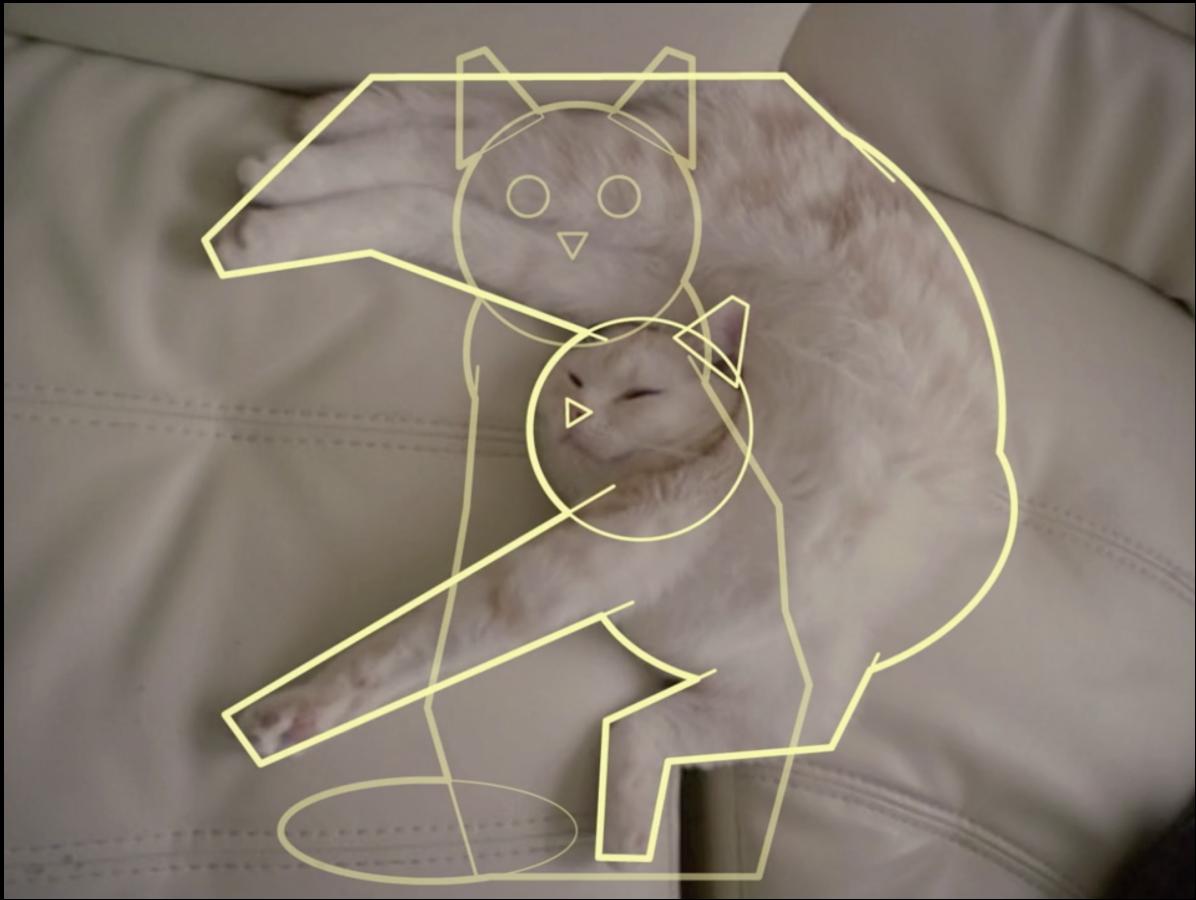
This is a mushroom.

Writing a computer program that sees?









Extracting semantic information requires models of **high complexity**, which cannot be designed by hand.

However, one can write a program that **learns** the task of extracting semantic information.



The common approach used in practice consists of:

- defining a parametric model with high capacity,
- optimizing its parameters, by "making it work" on the training data.



# **Applications and successes**



Detectron2: A PyTorch-based modular obje...



Later bekij...



Delen



Object detection, pose estimation, segmentation (2019)



Google DeepMind's Deep Q-learning playing...



Later bekij...  
Later bekijken



Delen



Reinforcement learning (Mnih et al, 2014)



NVIDIA Autonomous Car



Later bekij...  
Later bekijken



Delen



Autonomous cars (NVIDIA, 2016)



Sense, Solve, and Go: The Magic of the Wa...



Later bekij...



Delen



Autonomous cars (Waymo, 2022)



AlphaFold: The making of a scientific breakt...



Later bekij...



Delen



AI for Science (Deepmind, AlphaFold, 2020)



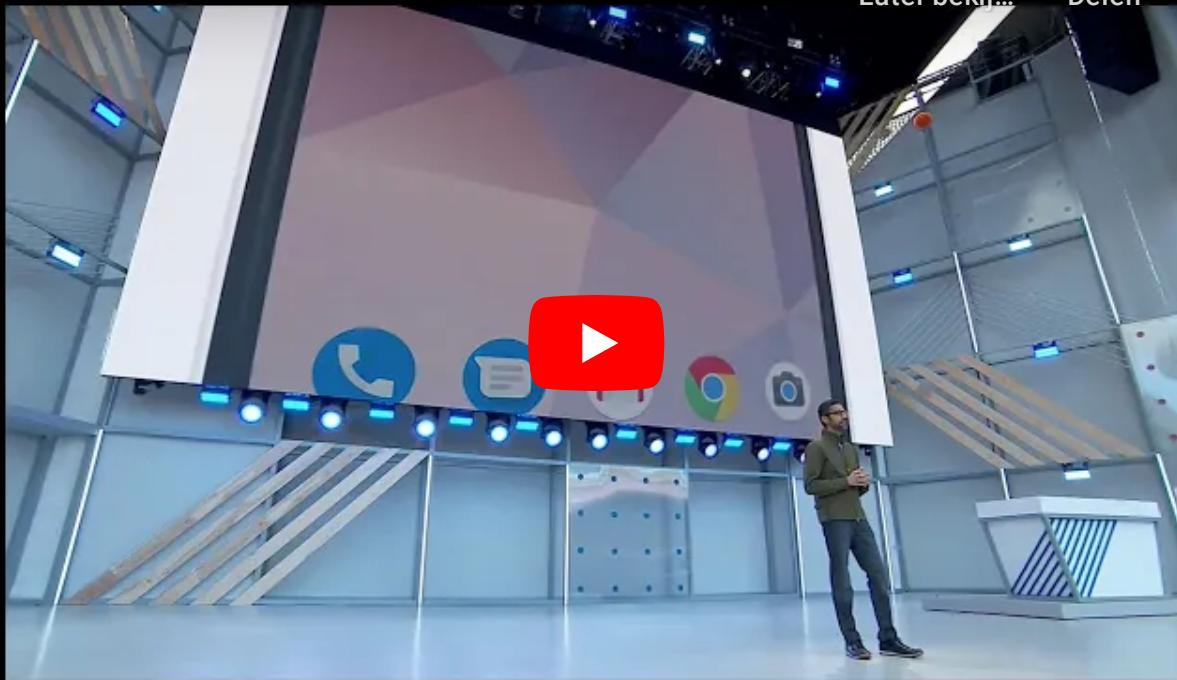
Google Assistant will soon be able to call re...



Later bekij...



Delen



Speech synthesis and question answering (Google, 2018)



DALL·E 2 Explained



Later bekij...  
...



Delen



Image generation and AI art (OpenAI, 2022)



## Creating a Space Game with OpenAI Codex

The screenshot shows a browser window with a video player at the top displaying a space scene with a rocketship and an asteroid. Below the video is a text input field containing the instruction: "Make it be the size of the rocketship times 0.75". To the right of the input field is a green arrow button. On the far right of the screen is a block of computer code.

```
text.style.left = rocketship.offsetLeft + 'px';
text.style.top = rocketship.offsetTop + 'px';

document.body.appendChild(text);
xSpeed = 20;
setTimeout(function() {
  xSpeed = 5;

  document.body.removeChild(text);
}, 250);
};

/* Now add an image of an
asteroid:
https://d.newsweek.com/en/full
/1721338/asteroid.jpg?
w=1600&h=1600&q=88&f=9d82d35c9
de96a82b3fcdf7705eb325b */
var asteroid =
document.createElement('img');
asteroid.src =
'https://d.newsweek.com/en/full
/1721338/asteroid.jpg?
w=1600&h=1600&q=88&f=9d82d35c9
de96a82b3fcdf7705eb325b';
document.body.appendChild(asteroid);
```

Write computer code (OpenAI, 2021)

+ New Thread

# ChatGPT

Examples	Capabilities	Limitations
"Explain quantum computing in simple terms" →	Remembers what user said earlier in the conversation	May occasionally generate incorrect information
"Got any creative ideas for a 10 year old's birthday?" →	Allows user to provide follow-up corrections	May occasionally produce harmful instructions or biased content
"How do I make an HTTP request in Javascript?" →	Trained to decline inappropriate requests	Limited knowledge of world and events after 2021

Light Mode

OpenAI Discord

Updates & FAQ

Log out

Free Research Preview: ChatGPT is optimized for dialogue. Our goal is to make AI systems more natural to interact with, and your feedback will help us improve our systems and make them safer. ➤

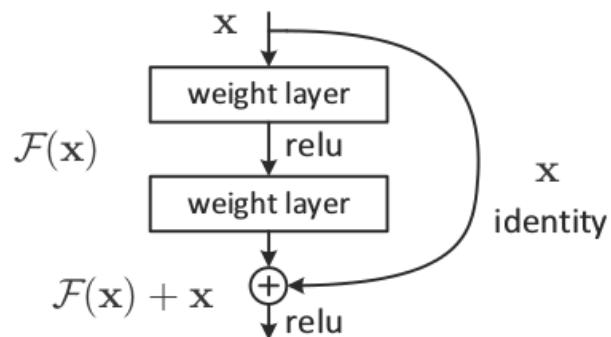
Answer all your questions (OpenAI, 2022)



*"ACM named **Yoshua Bengio, Geoffrey Hinton, and Yann LeCun** recipients of the **2018 ACM A.M. Turing Award** for conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing."*

# Why does it work now?

Algorithms (old and new)



More data



Software



Faster compute engines



## **Building on the shoulders of giants**

Five decades of research in machine learning provided

- a taxonomy of ML concepts (classification, generative models, clustering, kernels, linear embeddings, etc.),
- a sound statistical formalization (Bayesian estimation, PAC),
- a clear picture of fundamental issues (bias/variance dilemma, VC dimension, generalization bounds, etc.),
- a good understanding of optimization issues,
- efficient large-scale algorithms.

## Deep learning

From a practical perspective, deep learning

- lessens the need for a deep mathematical grasp,
- makes the design of large learning architectures a system/software development task,
- allows to leverage modern hardware (clusters of GPUs),
- does not plateau when using more data,
- makes large trained networks a commodity.



*For the last forty years we have programmed computers; for the next forty years we will train them.*

Chris Bishop, 2020.

The end.