Deep Learning

Deeper, Better, _____ , Stronger than Machine Learning

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CC6204, Primavera 2025

Introducción

Deep Learning

Figure 1: Conversational Agent, Image/Video generation, Protein structure

Outline : Significacion de las termas

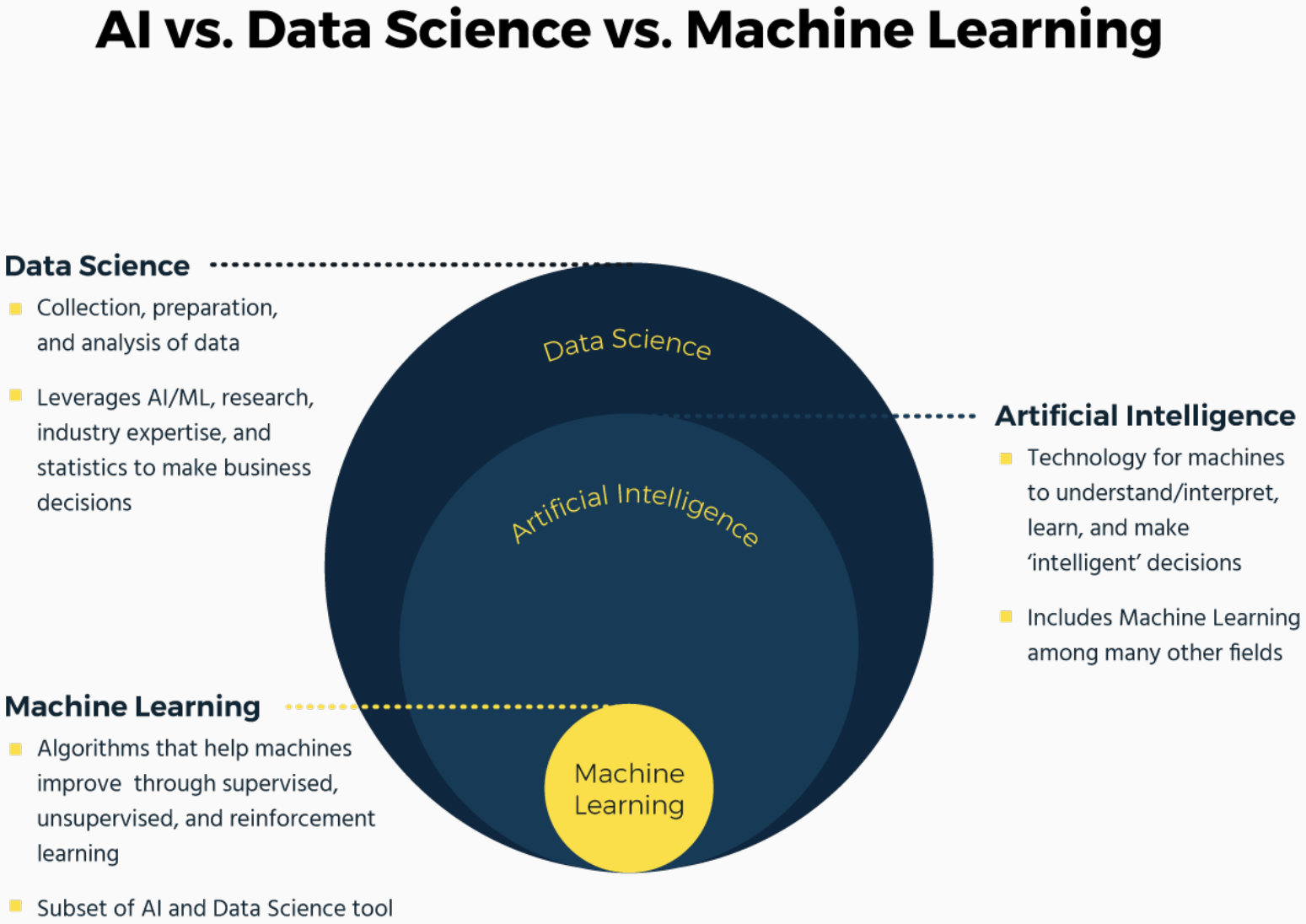

Figure 2: Diferencias entre campos

Data Science

In summary

Data Science focuses on analyzing data to extract knowledge, Machine Learning uses algorithms to make predictions and decisions based on data, and Artificial Intelligence refers to the development of systems that can perform intelligent tasks autonomously.

Overly simplistic definition:

- Data mining generates understanding.
- Machine learning generates predictions.
- Artificial intelligence generates actions.

Example on a Music Platform

Data Scientist

Collects and analyzes user data from music platforms to identify patterns and musical preferences.

Machine Learner

Develops and optimizes a music recommendation model using machine learning algorithms to predict user preferences.

Artificial Intelligence

Implements a social agent that can interact with the user, to enhance the personalization of music recommendations and provide a more accurate and contextualized experience.

Data

Different types of data:

- Structured data:
  - Social data: Age, Salary, Skin color, Place of residence
  - Metric data: *Likes* on a post, Time spent on a page, Number of mutual friends
- Unstructured data:
  - Text: Sentence, Paragraph, Document
  - Sound: Song, Speech
  - Image: Photo, Video

Mining

Different types of Mining:

- Data exploration: Detect simple values, biases
- Classification/Regression task: Use data to characterize new data by class or with a value in a supervised manner
- Clustering task: Group data into classes in an unsupervised manner
- Dimensionality reduction: Develop common structures for compressed data representations

Mining

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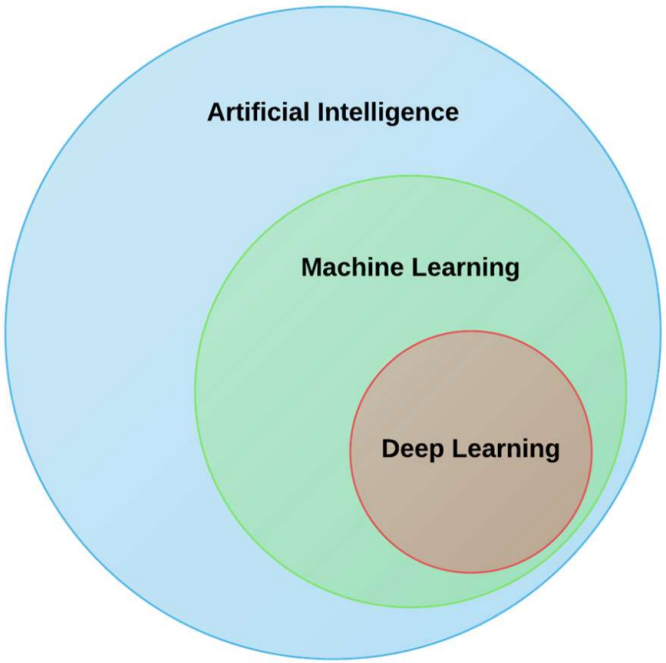
- Dimensionality reduction: Develop common structures for compressed data representations
- **Generation: generate data wrt a specific distribution particular** (more complex)

Outline : History

Qué es Deep learning?

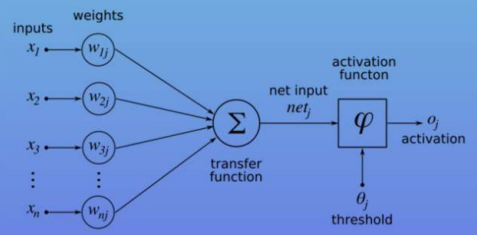


Historia

Redes neuronales no siempre fueron profundas

1943 El primer modelo matemático de una neurona (McCulloch-Pitts)

1957 El perceptrón



1959 Hubel y Wiesel descubrieron las células simplex y complex en sistemas de visión biológica.

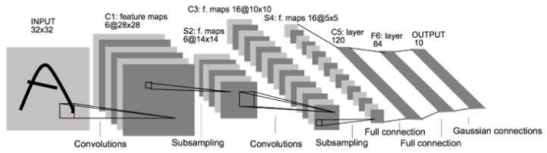
1965 Primera red profunda (8 capas) – Ivakhnenko and Lapa

1979 Red neuronal para reconocer patrones visuales (Neocognitron) – Fukushima

1982 Primera red recurrente – Hopfield

1986 Algoritmo Backpropagation

1989 Redes neuronales convolucionales – Handwritten recognition



1989 Reinforcement learning – Q-learning

Historia

Redes neuronales no siempre fueron profundas (no tanto)

1997 Long short-term memory. Redes recurrentes que recuerdan información.

1998 Stochastic gradient descent + backpropagation.

Deep learning winter

2009 Competición Imagenet para clasificación de imágenes a gran escala.

2011 Alexnet

2012-2015 Arquitecturas mejoradas para reconocimiento visual –

2014 Redes generativas adversarias (GAN)

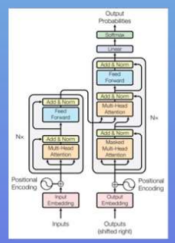
2015 ~ Explosión de la industria DL

Historia

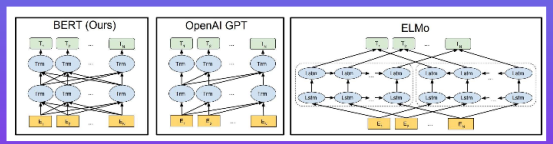
Redes neuronales profundas

2014 Mecanismo de atención – Bahdanau et al.

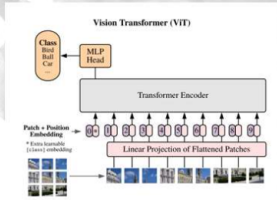
2017 Arquitectura Transformer – Machine translation.



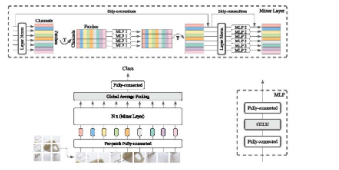
2018-2020 Modelos de NLP: BERT, GPTs, XLM



2020 Vision Transformer



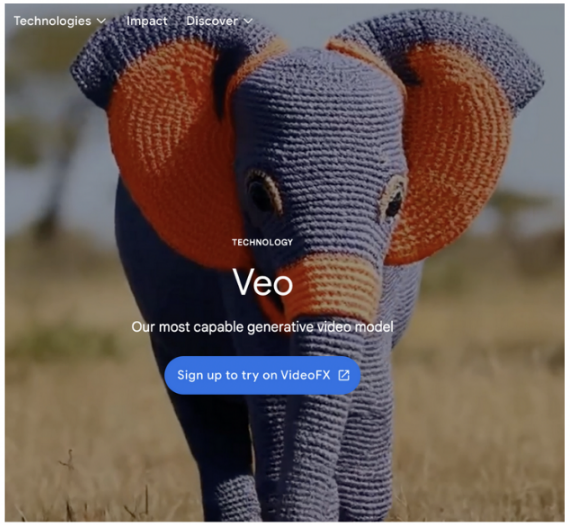
2021 MLP Mixer

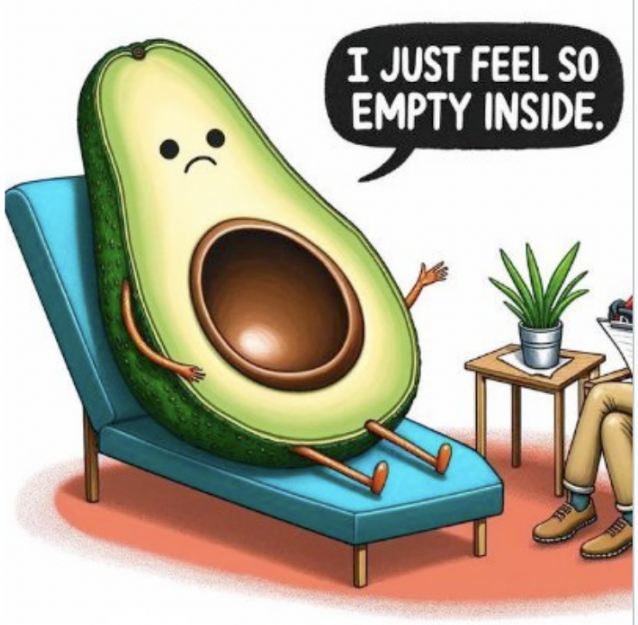


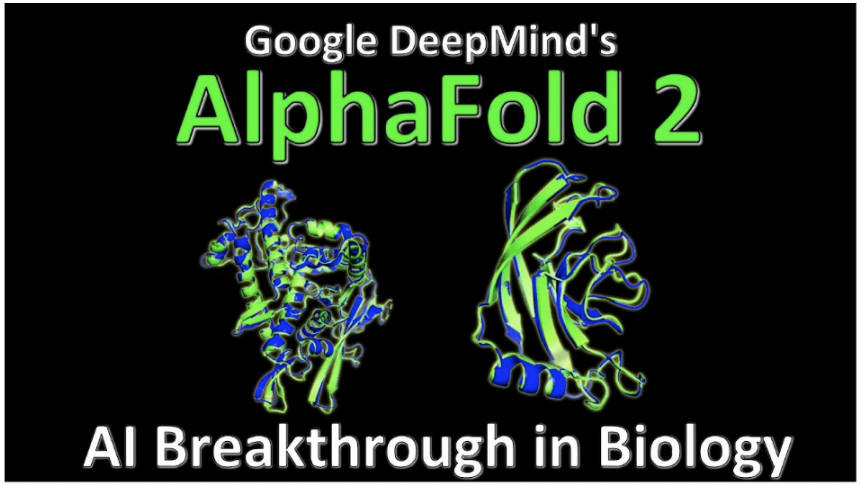
2022 Dall-e, Imagen, LaMDA

And now this


ChatGPT


Technologies
Impact
Discover
TECHNOLOGY
Veo
Our most capable generative video model
Sign up to try on VideoFX


I JUST FEEL SO EMPTY INSIDE.

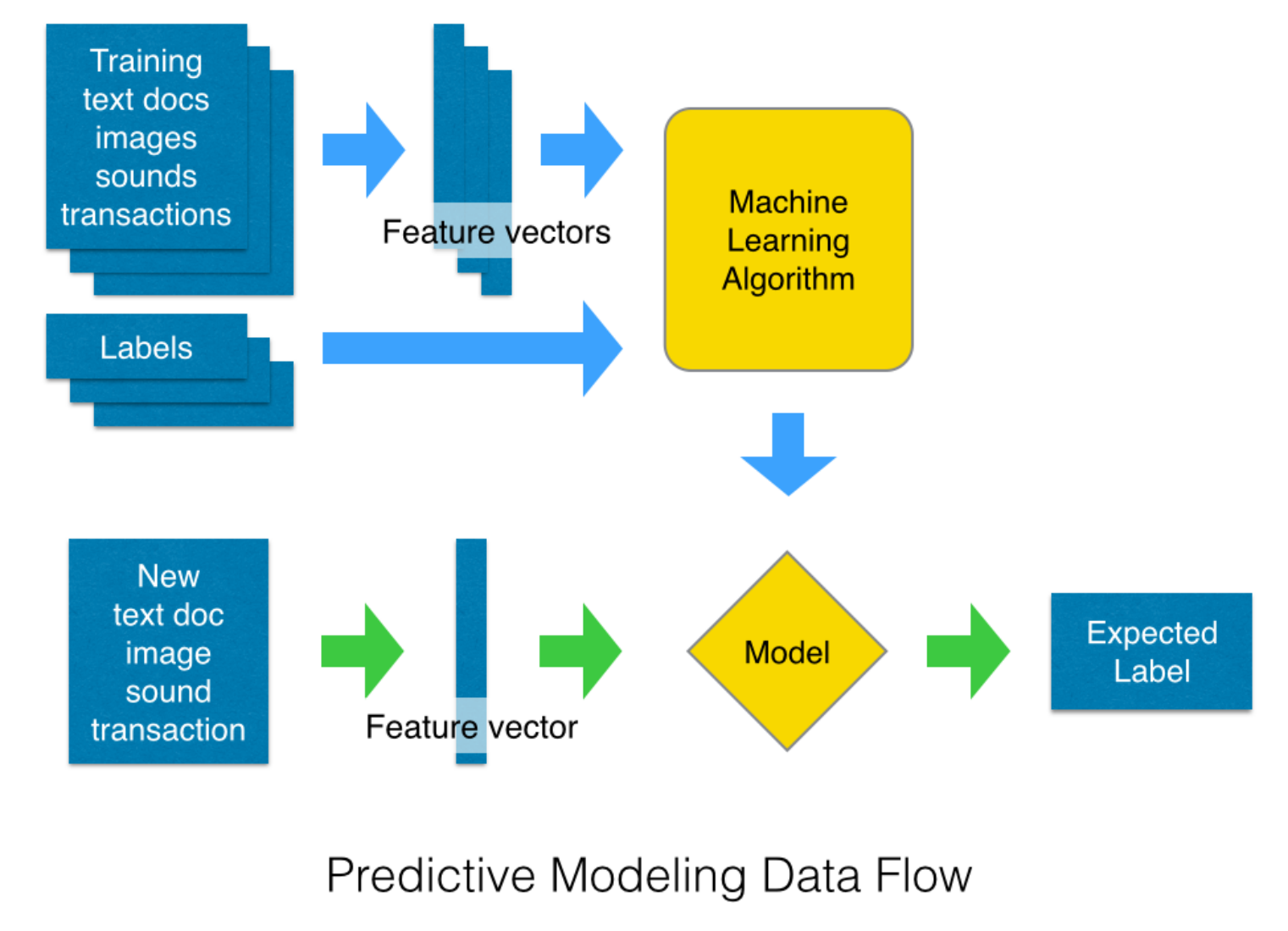

Google DeepMind's
AlphaFold 2
AI Breakthrough in Biology


Gemma 2
9B & 27B


LLAMA 3.1
OPEN SOURCE AI

Outline : Principle

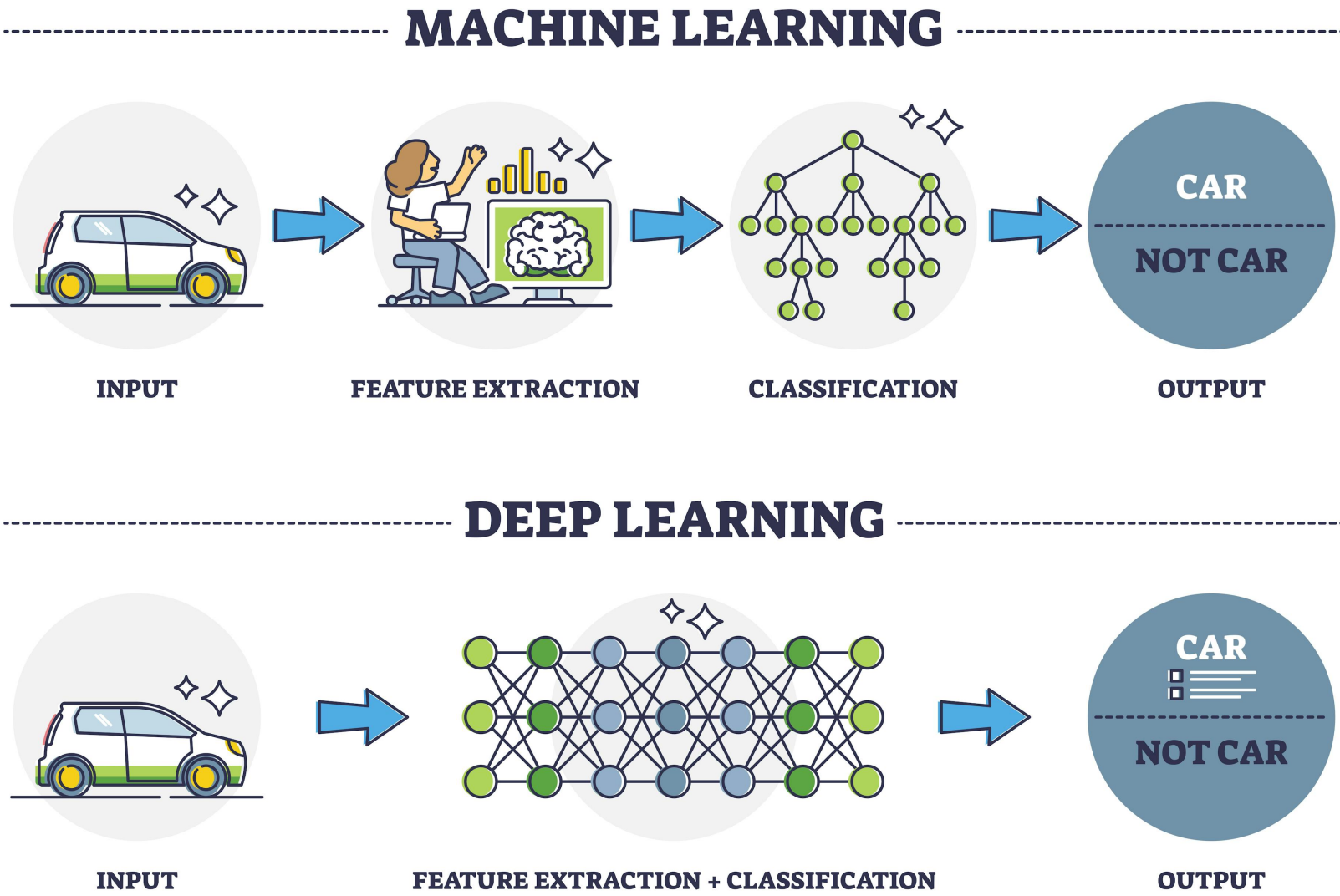
Supervised Machine Learning



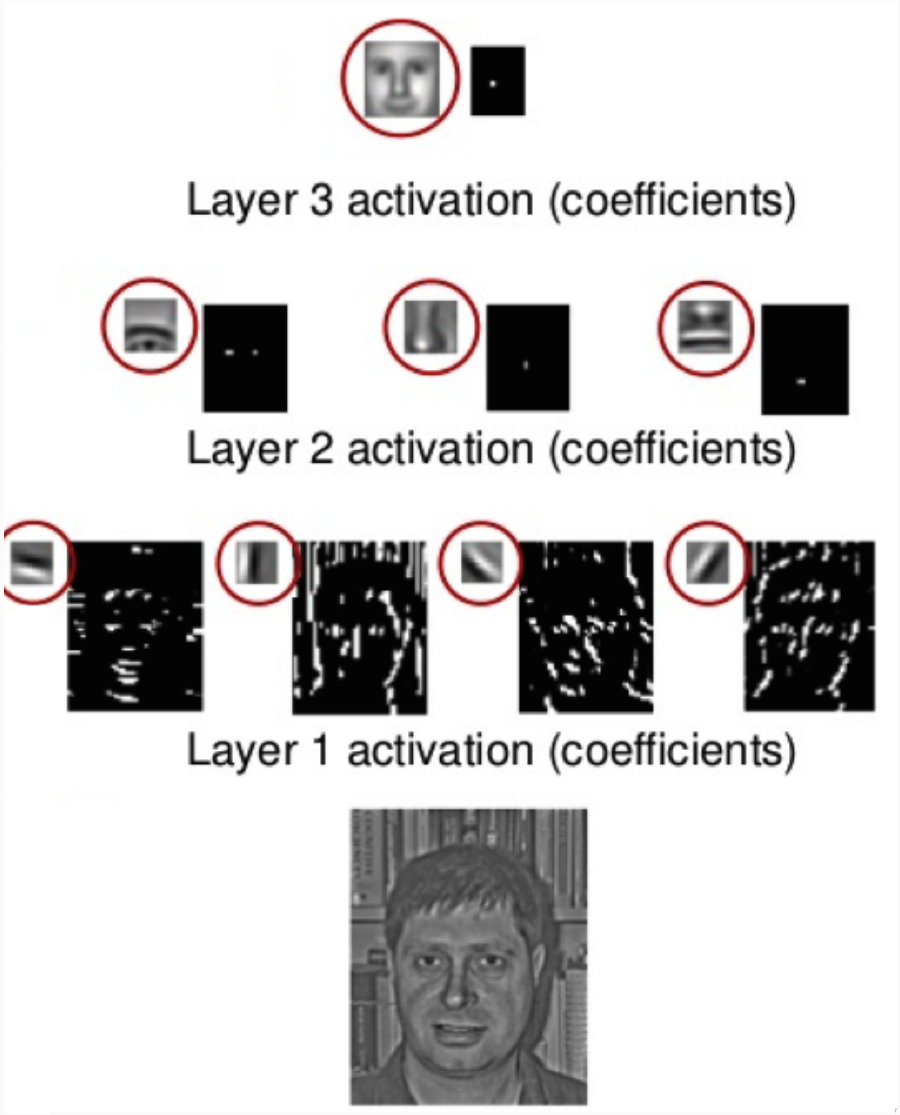
Predictive Modeling Data Flow

ML: Need to **create the feature vectors** to use them as input.

Differences between ML y DL: Feature Extraction

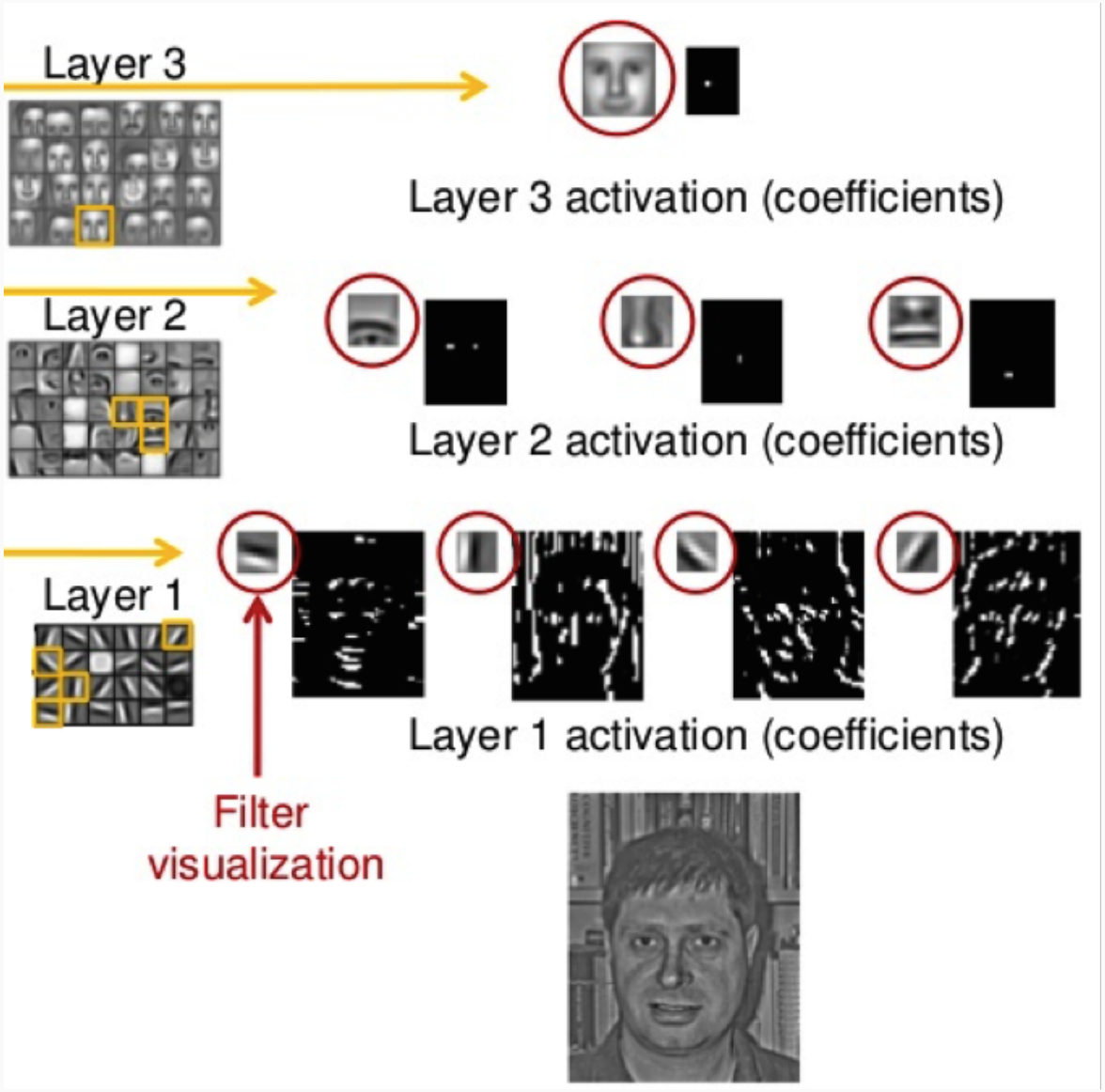


Representation Complexity: Example



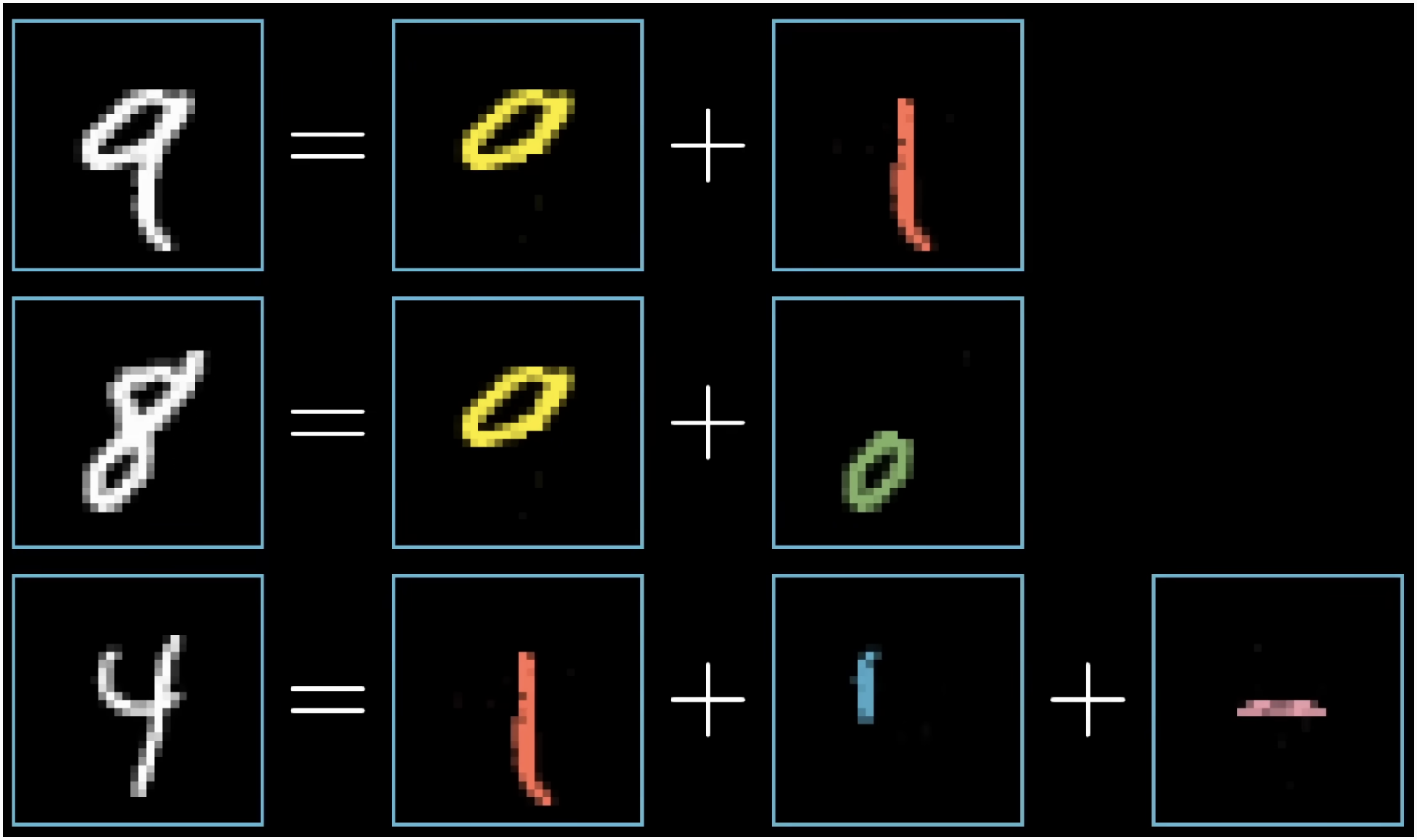
DL **extract feature vectors from raw data**

Representation Complexity: Compositionality



DL extract feature vectors from raw data and **combine them**

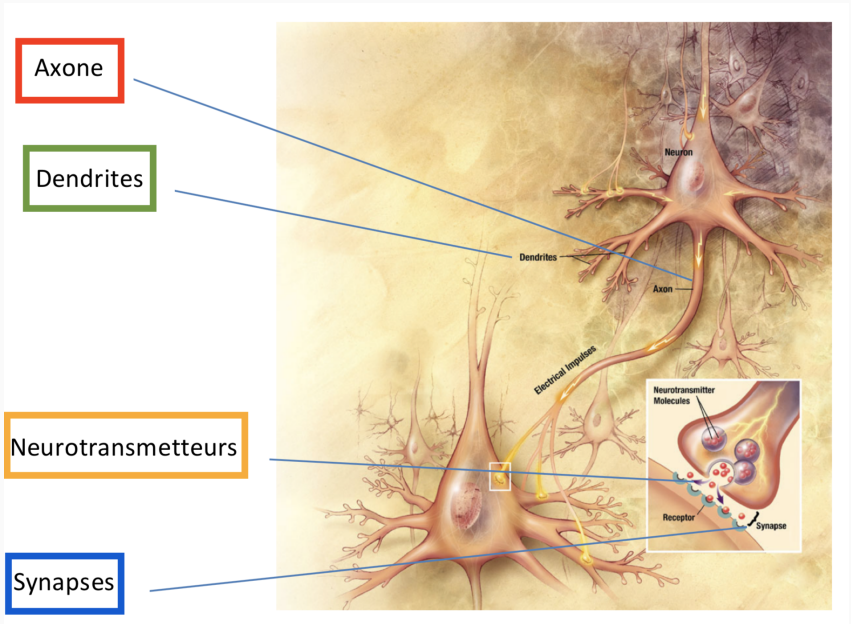
Representation Complexity: Compositionality



More information in this video.

First, why this name?

A neuron receives multiple signals from other neurons at its **dendrites**. These signals are **neurotransmitters**, which are released at the other neurons' **synapses**. When the total input exceeds a certain **threshold**, the neuron "fires," sending an electrical impulse along its **axon**, which in turn allows it to release neurotransmitters through its own **synapses**.



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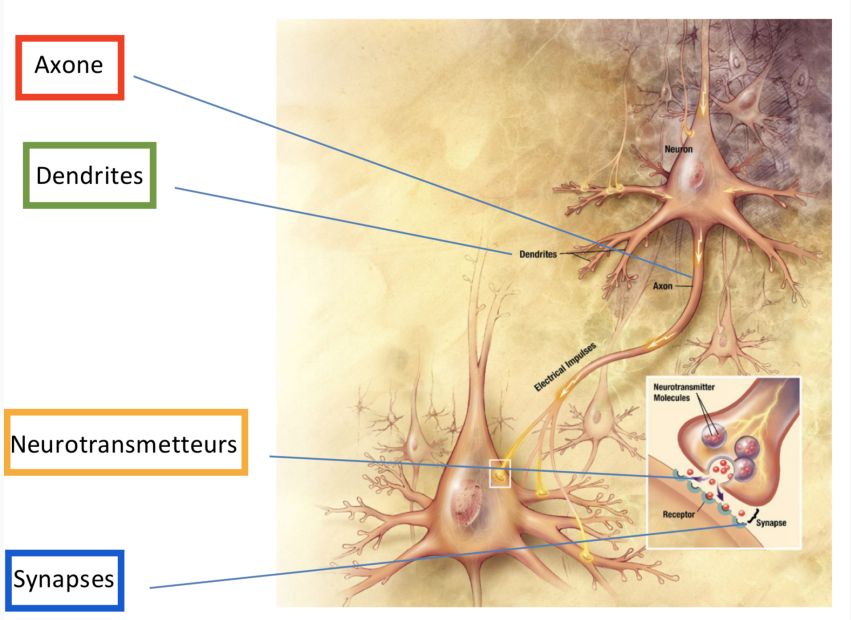
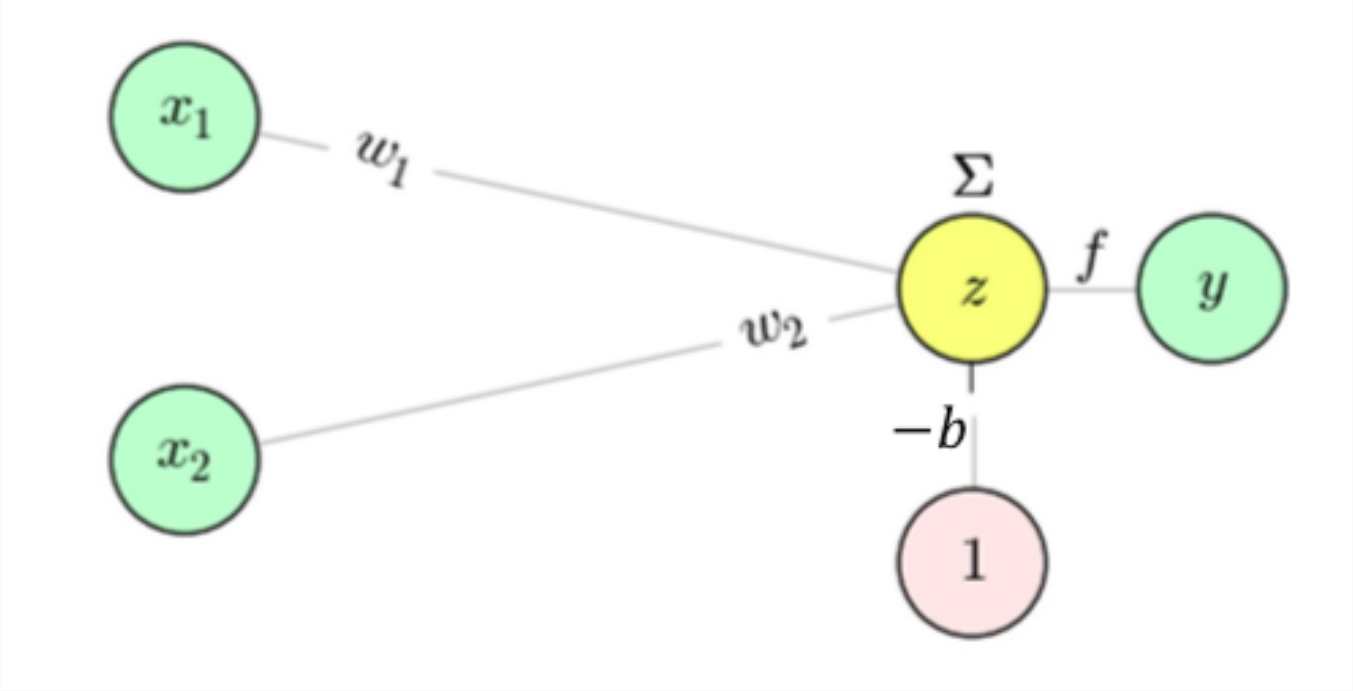


To summarize:

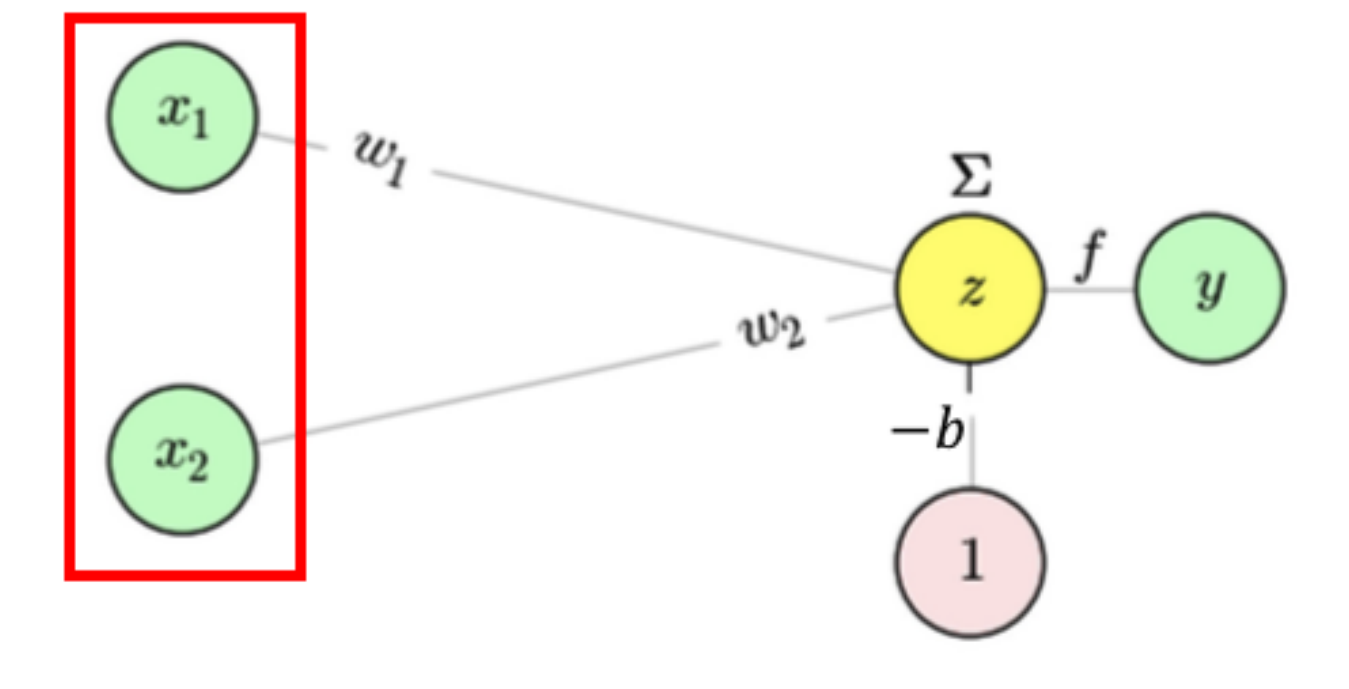
- The outputs of one neuron become the inputs of another.
- A neuron fires when it receives input exceeding a threshold.
- The strength of the signal sent to the next neuron is governed by synapses, which activate once their input crosses a threshold.

Perceptron – Overview



$$y = f(x_1 w_1 + x_2 w_2 - b)$$

Perceptron – Overview



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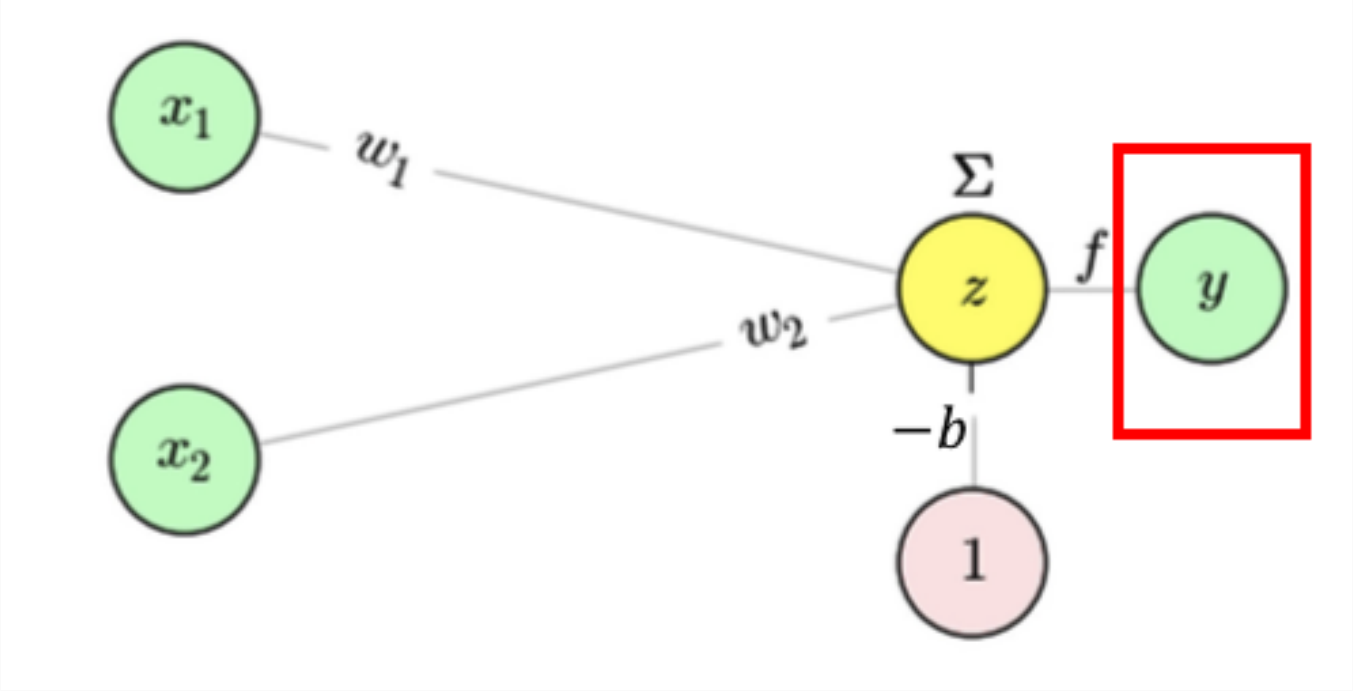

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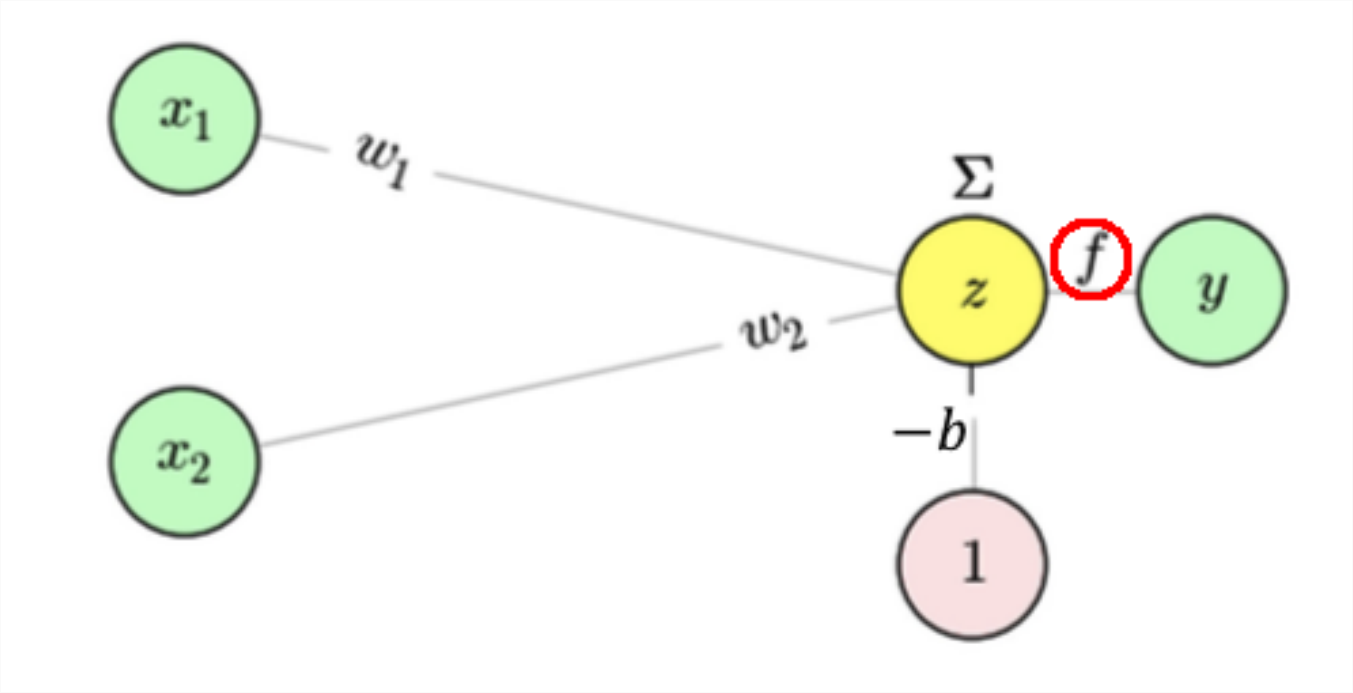

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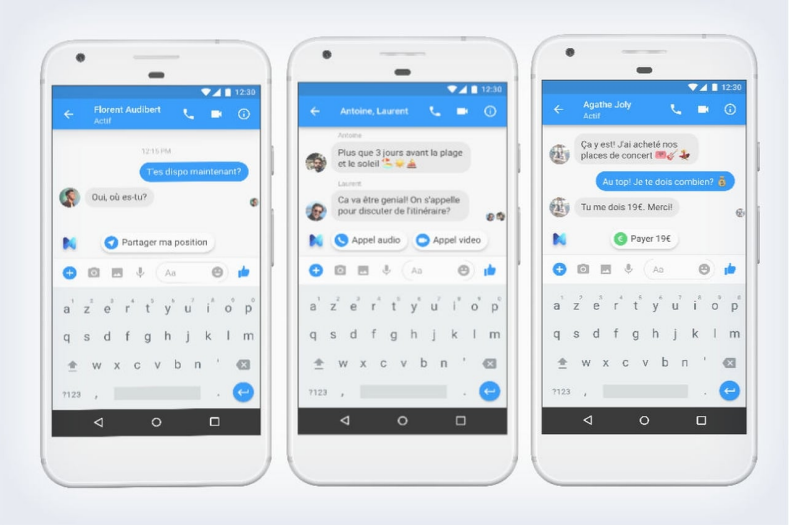
In theory, f is the Heaviside step function:

$$f(z) = \mathbb{1}_{\mathbb{R}_+}(z) = \begin{cases} 1 & \text{if } z \geq 0, \\ 0 & \text{if } z < 0. \end{cases}$$

Outline : Applications

Applications (I/II)

- Event detection in text



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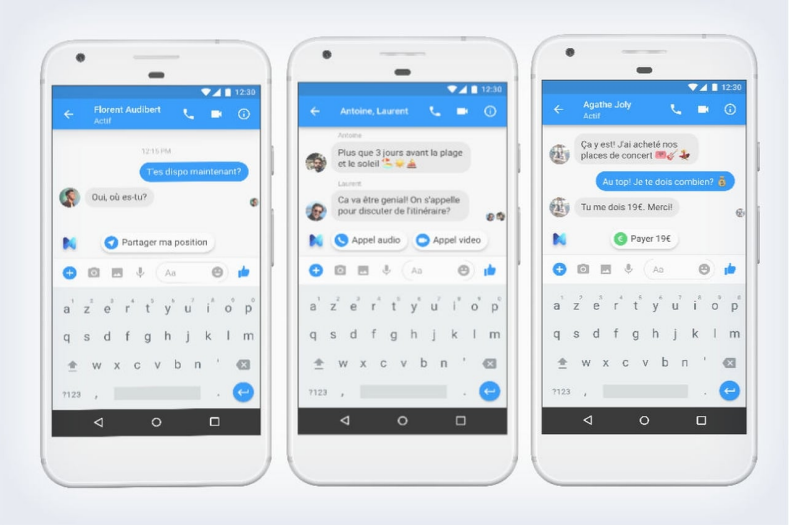

- Automatic processing of user opinions

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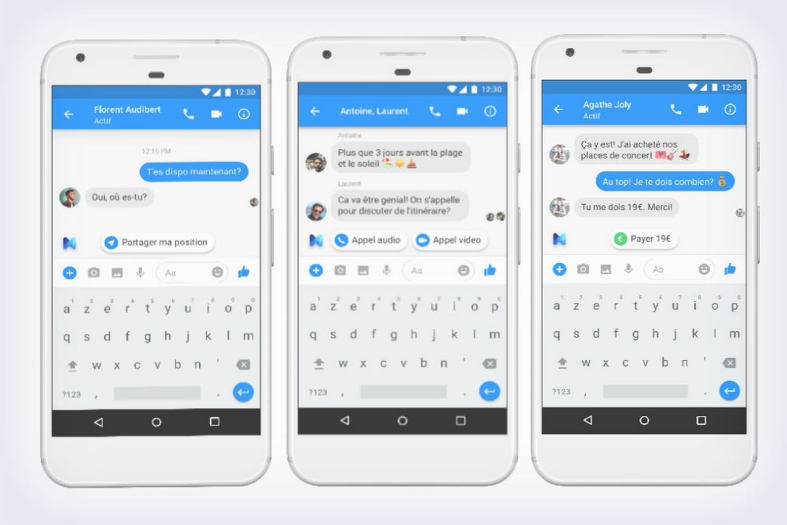
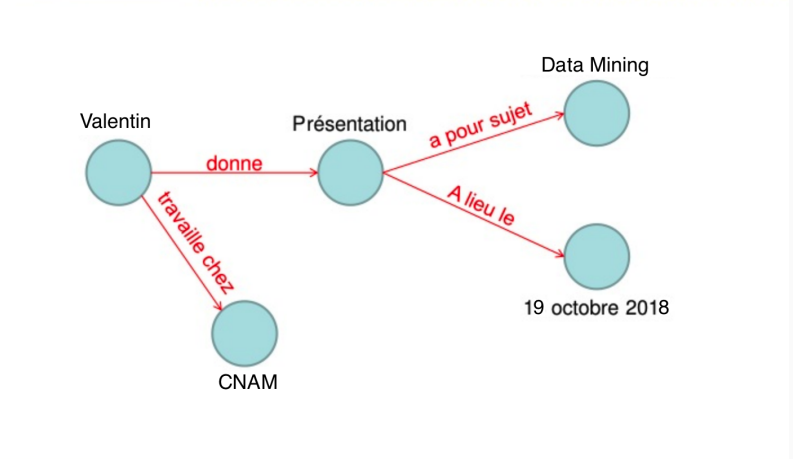


- Automatic processing of user opinions

- Recommending items to a user

Applications (II/II)

- Detection of relationships between entities in a text



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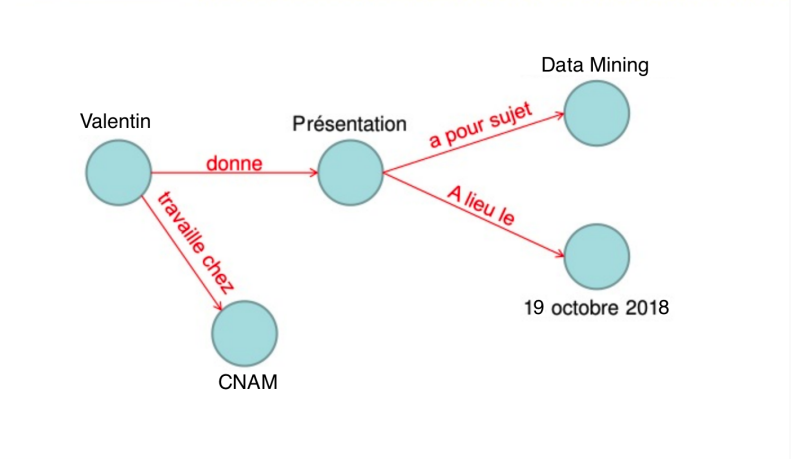
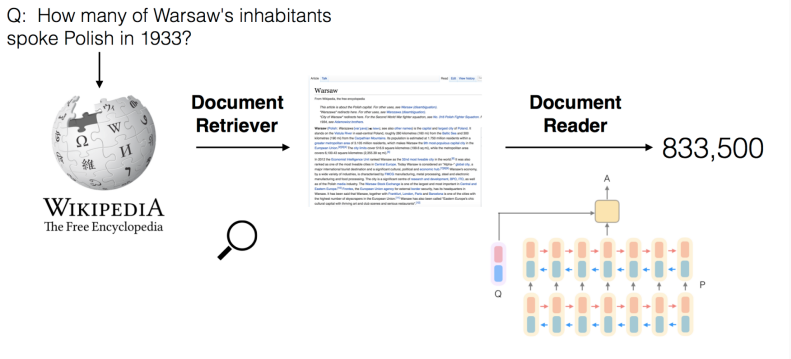


- Question answering



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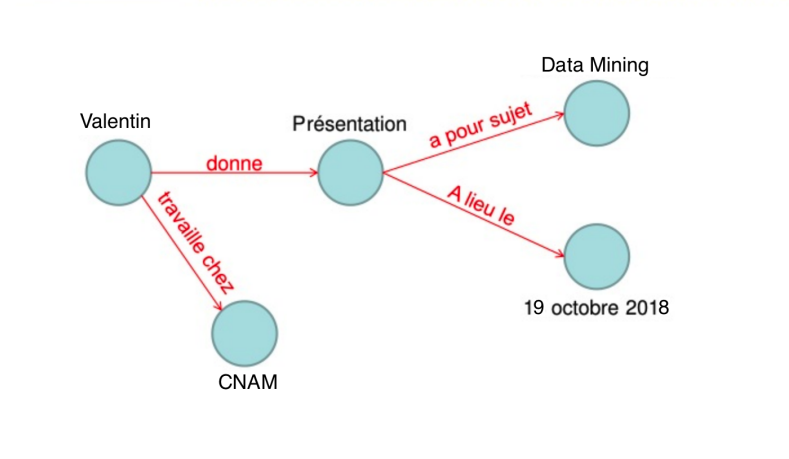

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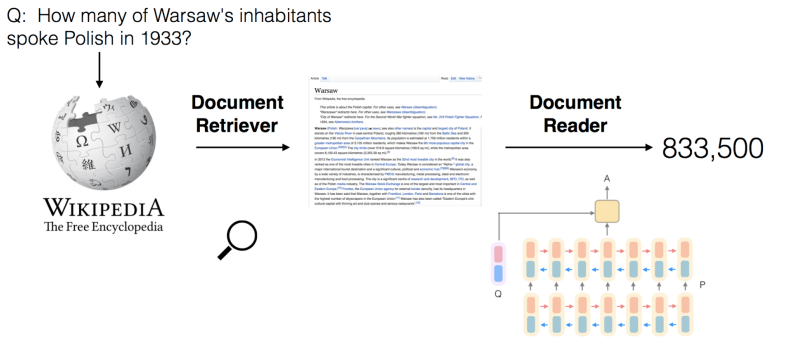
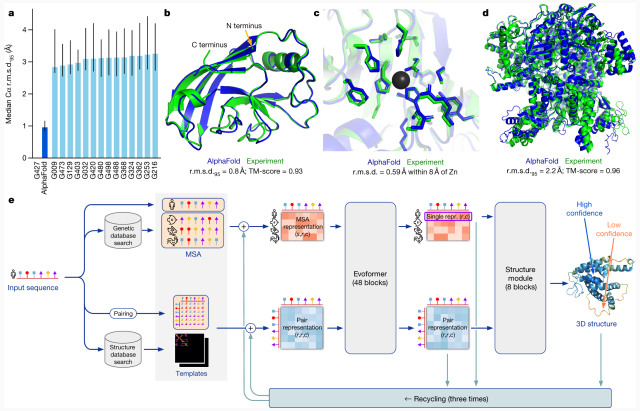


- IE module for a conversational agent

Meaning of the Job: Why Doing It?

- Scientific advancement



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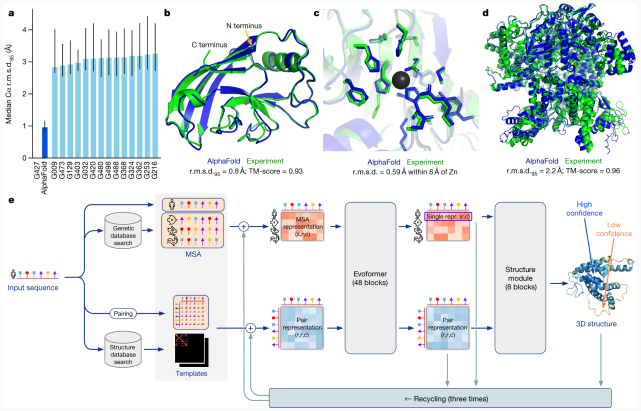

- Prevention and management of natural disasters

Meaning of the Job: Why Doing It?

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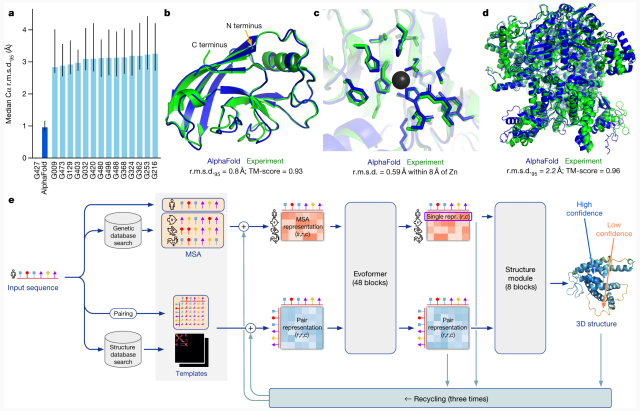
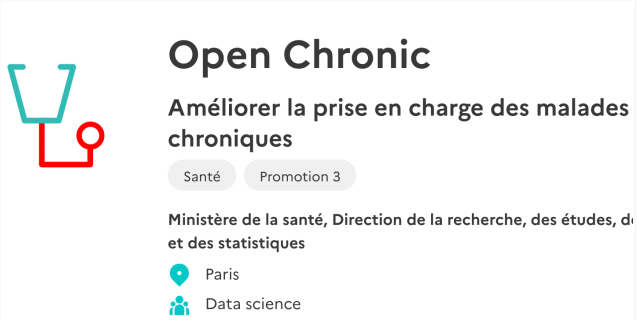


- Prevention and management of natural disasters

- Impact on public health



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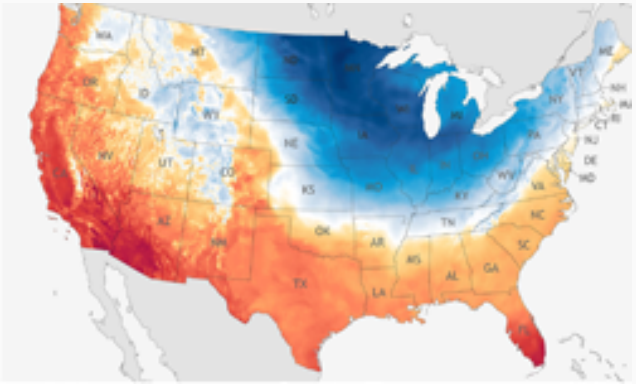

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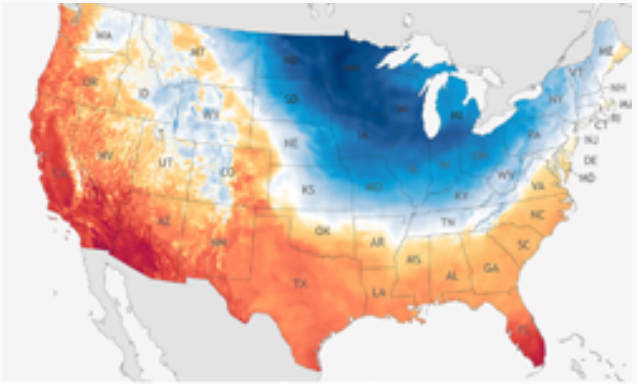
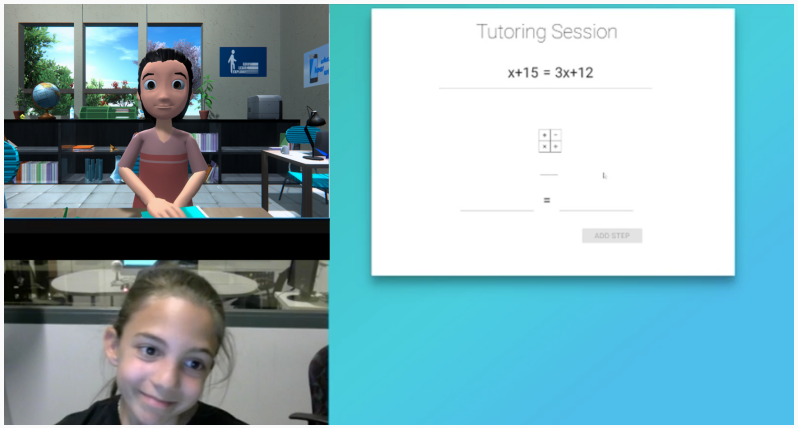


- Boost to education and research



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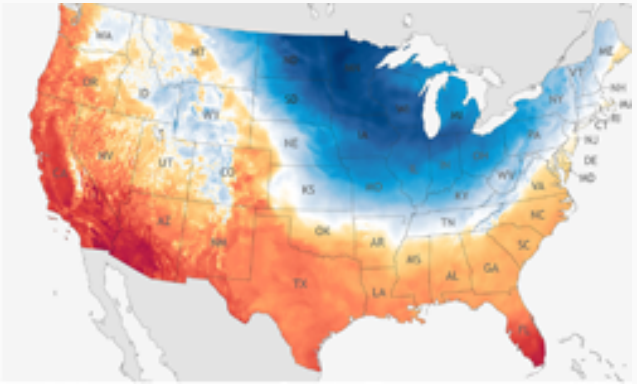

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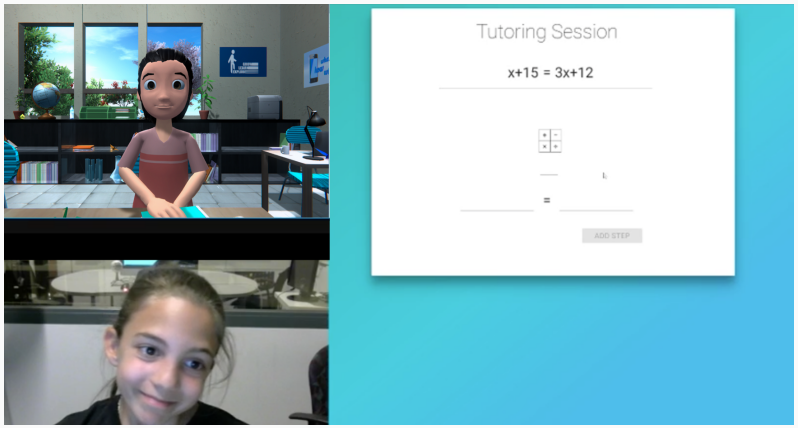
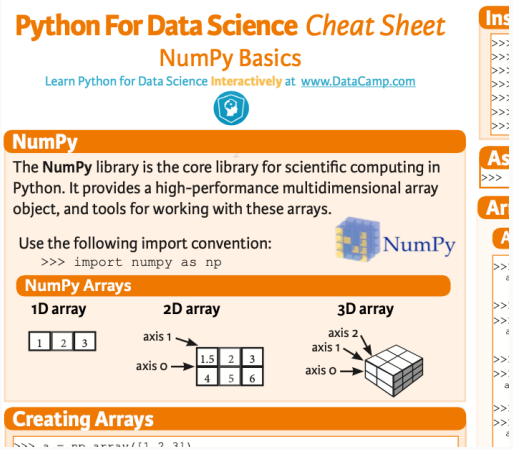


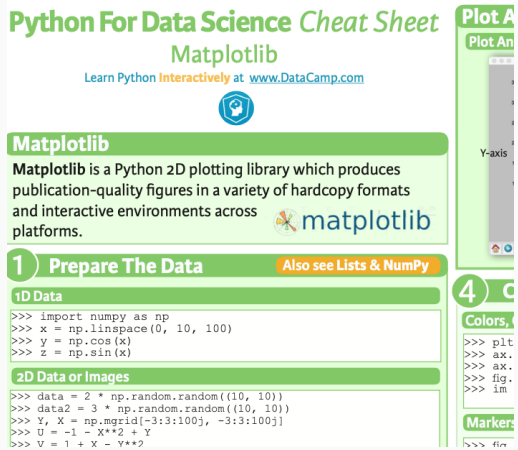
- Participatory democracy

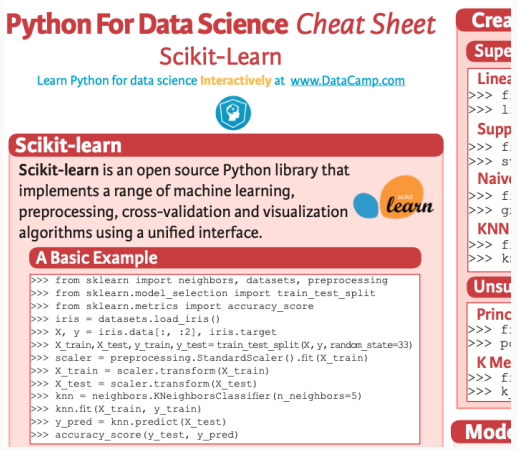
Outline : Ressources

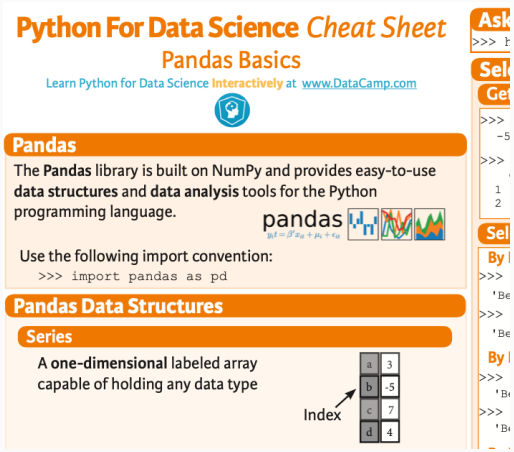
Material

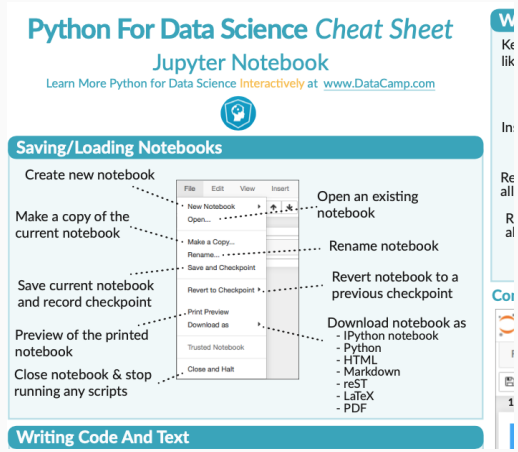
- Computer
- Jupyter Notebook and Anaconda:
  https://www.anaconda.com/download/
- The notebooks and cheatsheets available online:

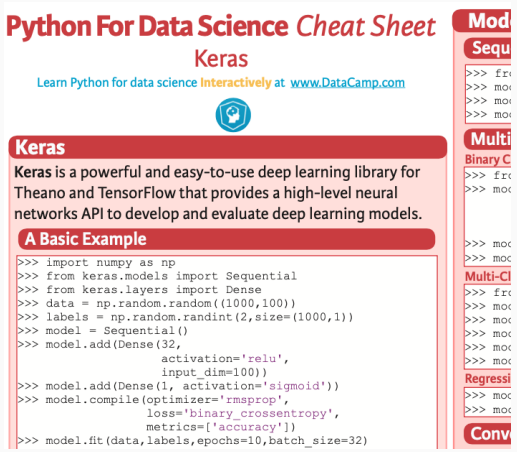












Ressources

- El Calendario y las slides en el github
- Books:
  - Deep learning, Goodfellow, Bengio, Courville (https://www.deeplearningbook.org/)
  - Neural networks and Deep learning, Nielsen (http://neuralnetworksanddeeplearning.com/)
  - Dive into Deep Learning. Zhang, Lipton, Li, Smola (https://d2l.ai/)
- Otros
  - CS231n - Stanford: Deep Learning for Computer Vision (http://cs231n.stanford.edu/)
  - CS224N: Natural Language Processing with Deep Learning (https://web.stanford.edu/class/cs224n/)
  - Deep learning – New York University (https://atcold.github.io/pytorch-Deep-Learning/)
  - CS224W: Machine Learning with Graphs (http://web.stanford.edu/class/cs224w/)
- Canal Discord: https://discord.gg/hUJqa4AHCd

Keras

A high-level Python library for Deep Learning, running on top of TensorFlow and other backends.

- Vision: Keras tutorial for fine-tuning a pre-trained VGG16, which can be used with: pre-trained CNNs available in Keras
- Text and audio:
  Tutorial RNN-LSTM Seq2seq for machine translation
- Text: Use of pre-trained word embeddings

PyTorch

A Python library for Deep Learning, a competitor to TensorFlow.

- Vision: Tutorial for fine-tuning a pre-trained ResNet18
- Audio: Speech Recognition with Wav2Vec2
- Text: RNN-GRU Seq2seq tutorial for machine translation

HuggingFace Transformers

A Python library for **Transformer** models (a class of deep neural networks).

Hugging Face

- Many pre-trained models for images, audio, multimodal data, text, ...
- From classical classifiers to generative models and embeddings, up to large models (e.g. Llama3-70B).
- Related libraries: `Diffusers`, `Datasets`, `Accelerate`, `PEFT`, `bitsandbytes`, `TRL`, ...

Outline : The course

Evaluations

This class will be evaluated with 4 or 5 tasks to exectute at home.

Careful: ponderations of the tasks vary wrt its difficulty!

Questions?

References i