
Artificial Intelligence, Machine Learning and Large Language Models

February 19th, 2026

EURADOS Annual Meeting – Winter School
Helsinki, Finland

Weibo Li (BfS) | Paolo Ferrari (ENEA) | Giorgia Stendardo (ISS)

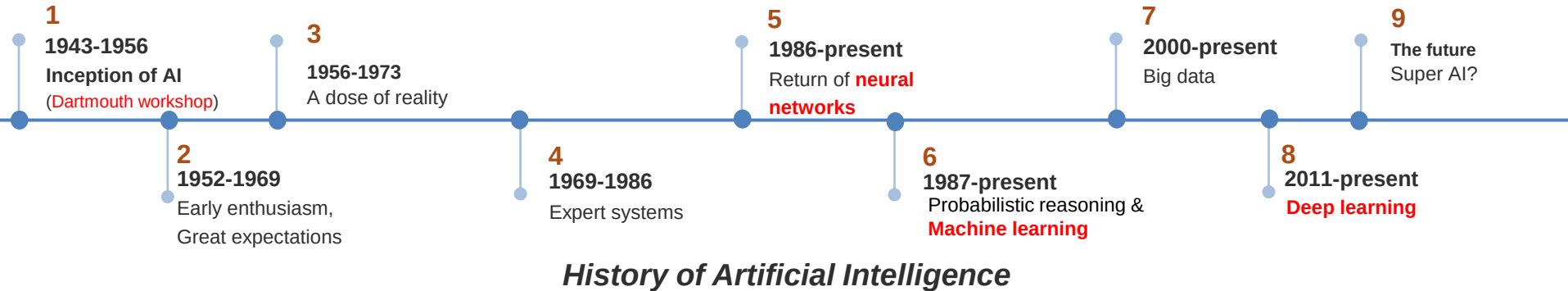
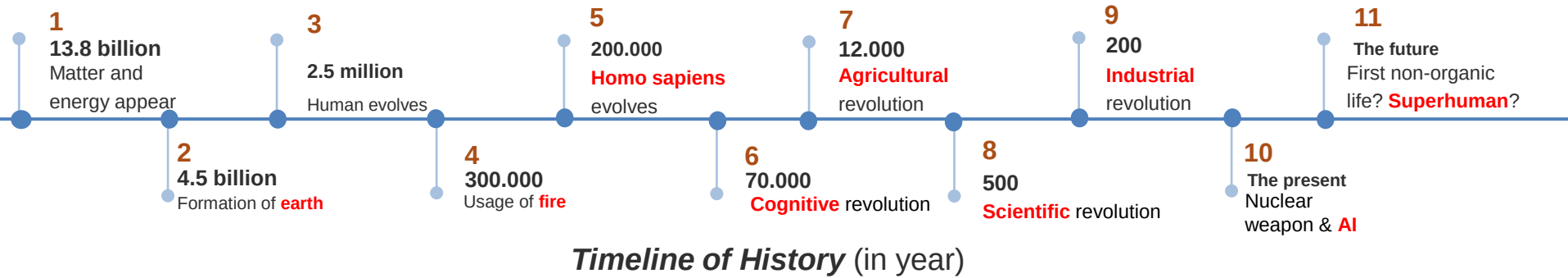
Declaration

- I am the one person who is talking about the AI
- Pictures and figures are taken from the cited professional textbooks
- This presentation is a joint work with Paolo, Giorgia and me



Image from [LinkedIn](#)

A Short Timeline of Humankind and Artificial Intelligence



What Is Artificial Intelligence (AI)

AI is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable — John McCarthy, 2007

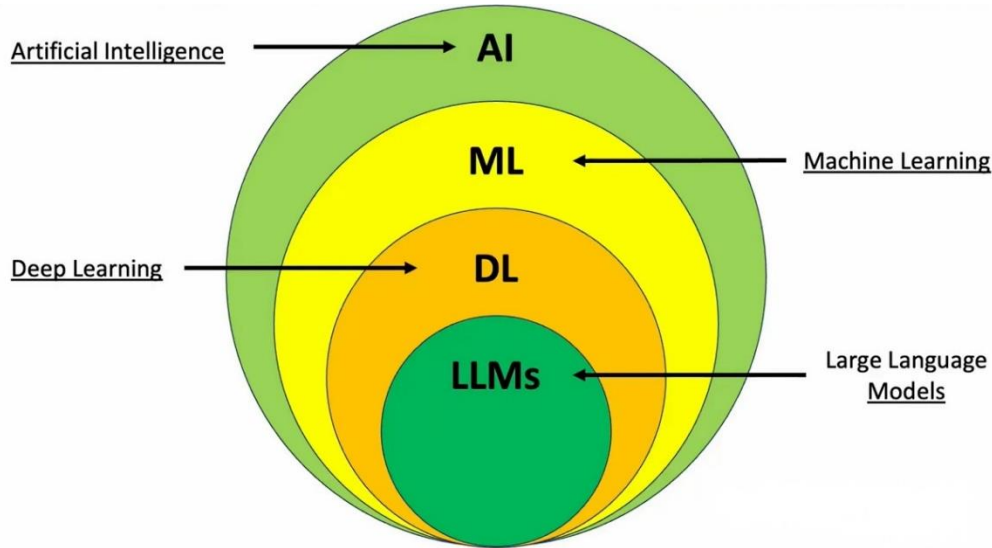
Examples:

- Recognizing images
- Understanding speech
- Playing chess or Go
- Translating languages

Goal: simulate human reasoning and problem-solving

AI, Machine Learning, Deep Learning and LLM

- AI → broad and overarching concept makes machine do like human
- Machine Learning (ML) → learn from data, one subset of AI
- Deep Learning (DL) → use deep neural networks, inspired by neuron
- Large Language Model (LLM) → Language AI application of ML based on DL



What Is Machine Learning?

Machine learning uses data to find patterns and make predictions. ML is the science and art of programming computers so they can learn from data

- [Machine learning is the] field of study that gives computers the ability to learn without being explicitly programmed — Arthur Samuel, 1959

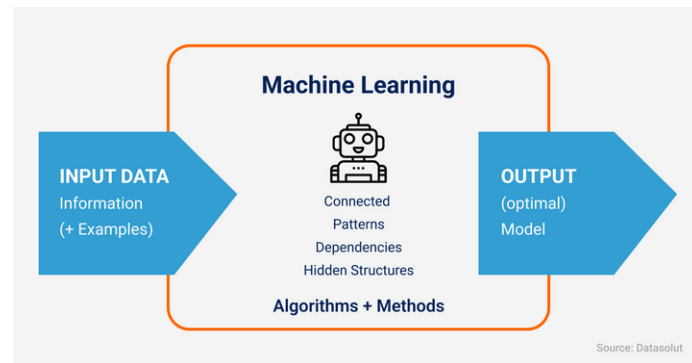
- ***A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P , if its performance at tasks in T , as measured by P , improves with experience E — Tom Mitchell, 1997***

Main types:

- Supervised – learn from labeled data
- Unsupervised – discover patterns
- Reinforcement – learn by trial and feedback

How Machine Learning Works

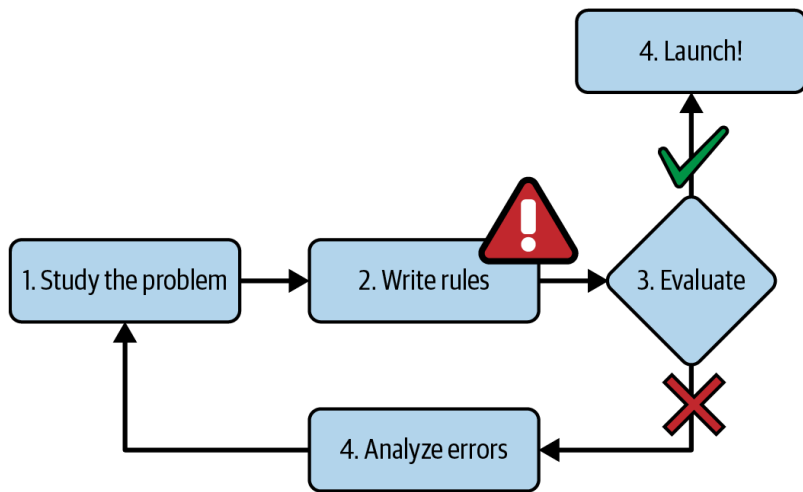
1. Data collection
2. Preprocessing / feature extraction
3. Model training
4. Evaluation
5. Prediction & feedback



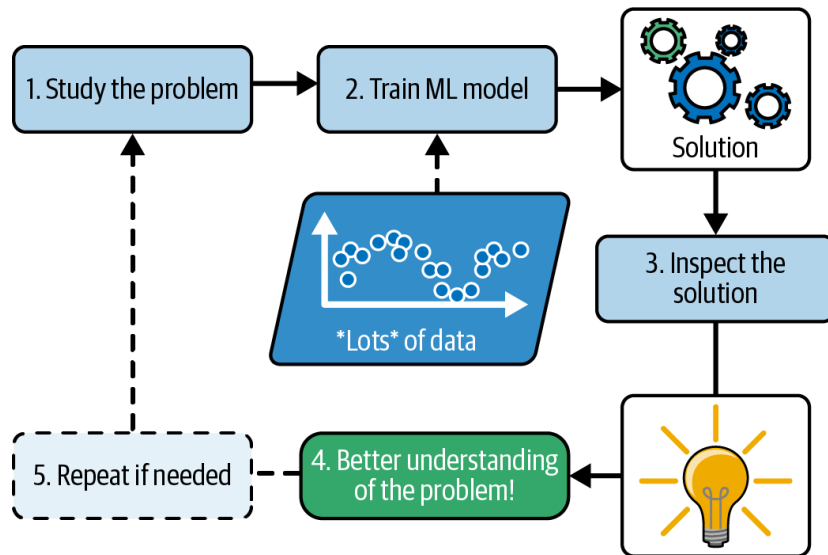
Data → Model → Prediction → Improve

<https://omq.ai/lexicon/machinelearning/>

How Machine Learning Works



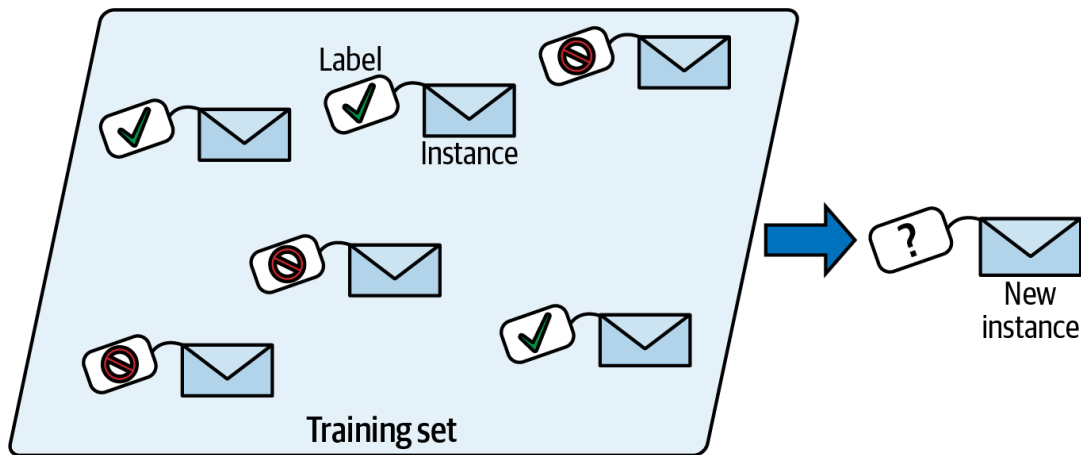
Traditional programming



Machine learning

Images from Géron. Hands-on Machine Learning with Scikit-Learn and PyTorch. 2025

Supervised learning



Labeled data

Learning tasks:

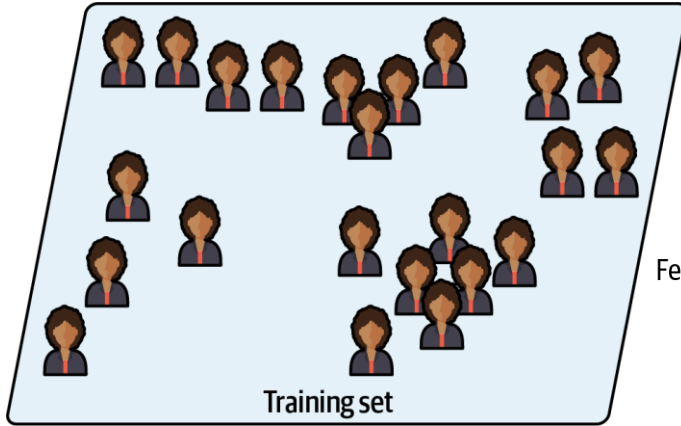
- Classification
- Regression

In internal dosimetry

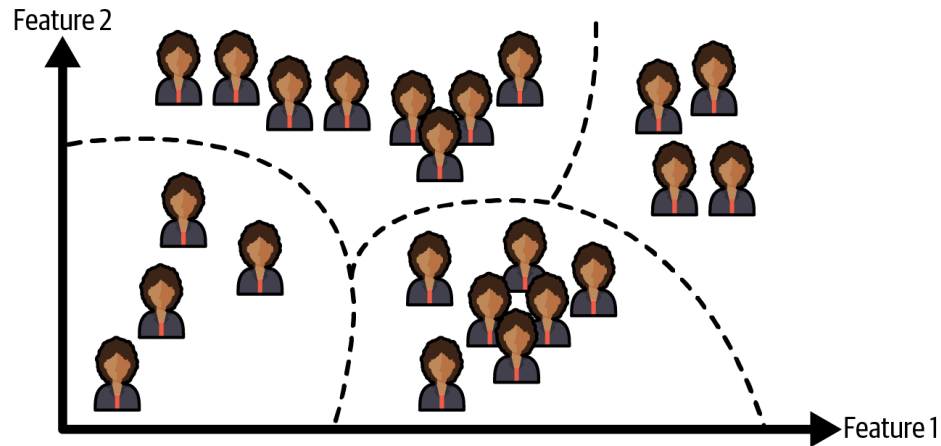
- Predict absorbed dose from limited TAC
- Estimate biokinetic model parameters by training a model on data

Images from Géron. Hands-on Machine Learning with Scikit-Learn and PyTorch. 2025

Unsupervised learning

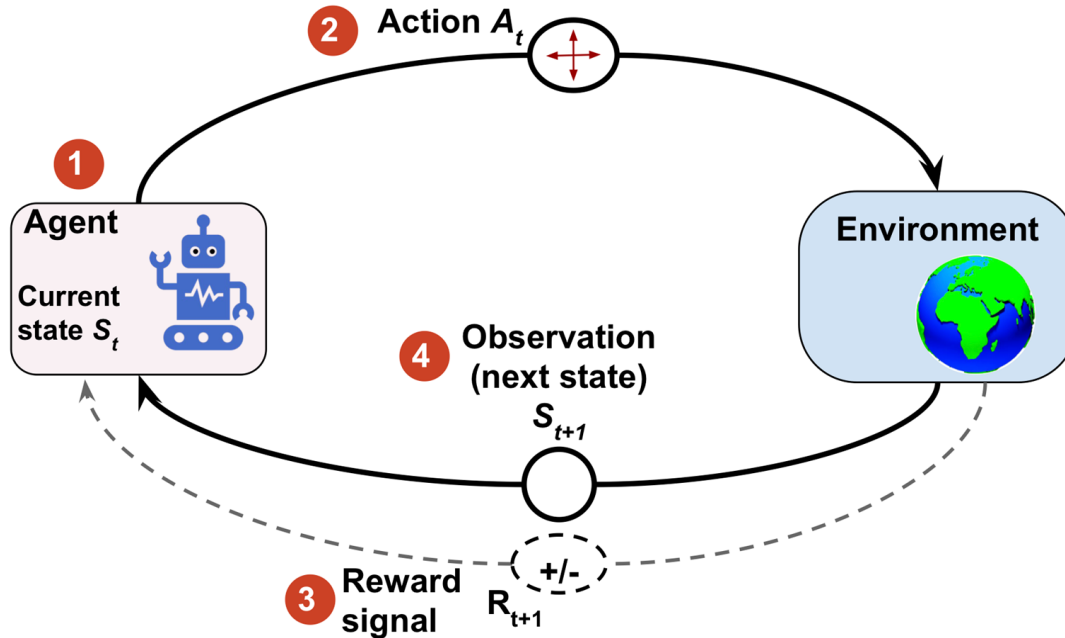


- Cluster analysis and discover the pattern
- Dimensionality reduction
- Association rule



Images from Géron. Hands-on Machine Learning with Scikit-Learn and PyTorch. 2025

Reinforcement learning



Iterative learning and feedback, for example: An AI agent (= learning system) observes the environment, selects and performs the actions, and gets rewards in return. The agent must learn and find the policy to get the most reward over time



Images from Reschke Liu and Mirjalili, 2022

https://en.wikipedia.org/wiki/AlphaGo_%28film%29

What Is Deep Learning

- Deep Learning uses *neural networks* with many layers
- Inspired by the brain neuron, learns complex patterns

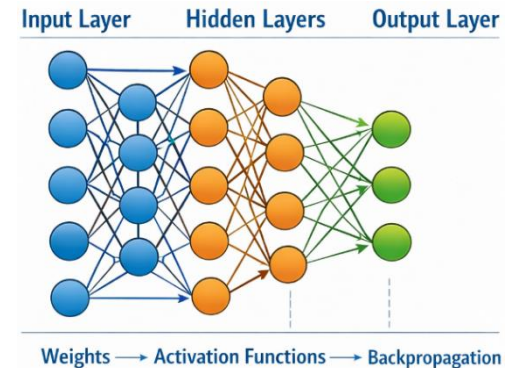
Examples:

- Convolutional neural networks (CNNs) – images
- Recurrent neural networks (RNNs) – time-series
- Transformers – text

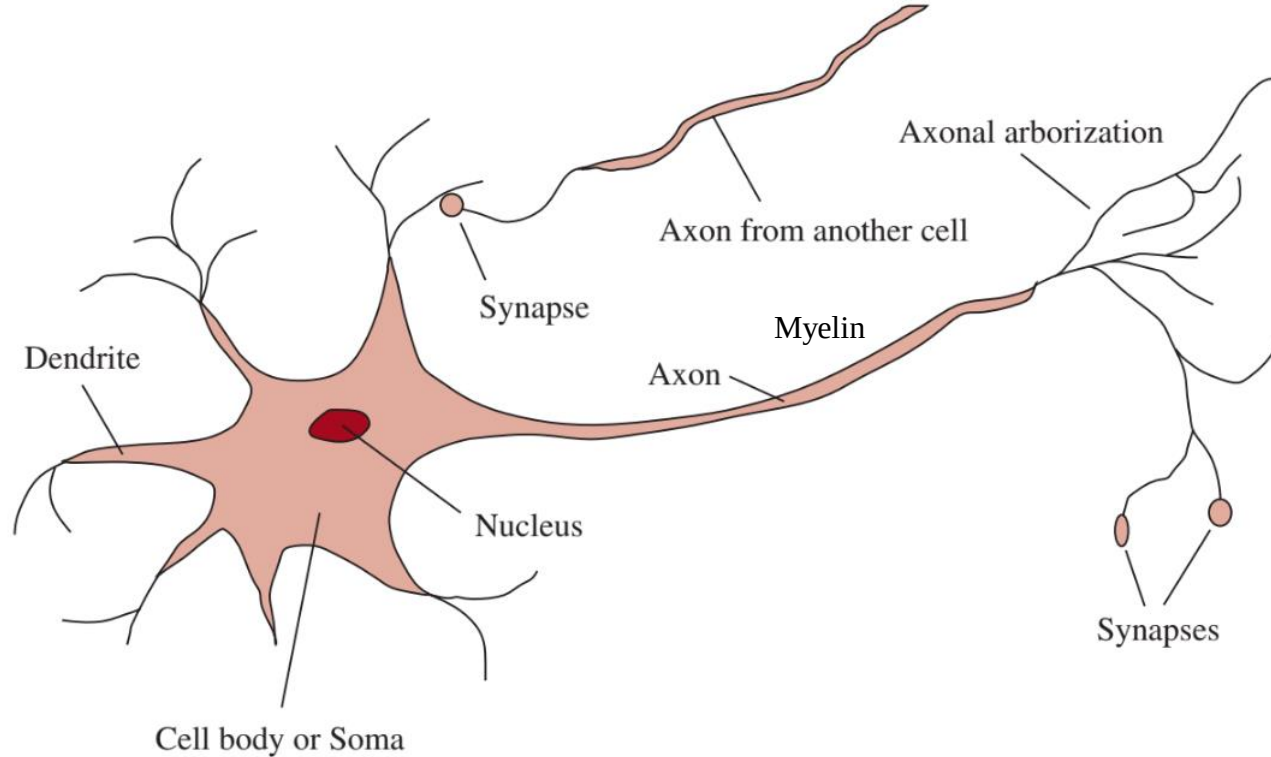
What Is a Neural Network?

- System of nodes (**neurons**) connected by weights
- Each neuron applies **weights**, activation, and outputs results
- Network adjusts weights via **backpropagation**

Structure: Input → Hidden Layers → Output



Neuron structure and neurons chains



Russell & Norvig 2022

The membrane potential & the action potential

The resting membrane potential is given by an unequal distribution of ions across the neuronal membrane. It is about -70 mV (mainly due to anions)

Extracellular zone

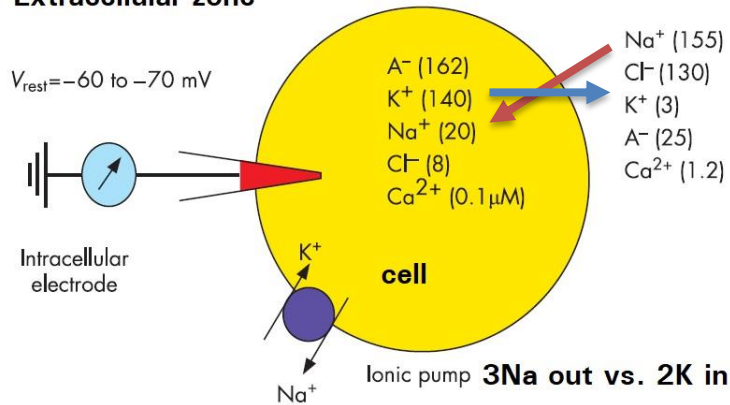
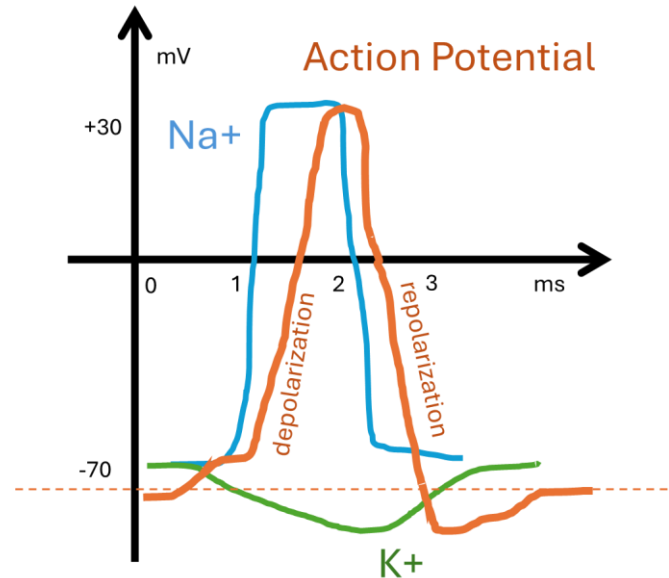
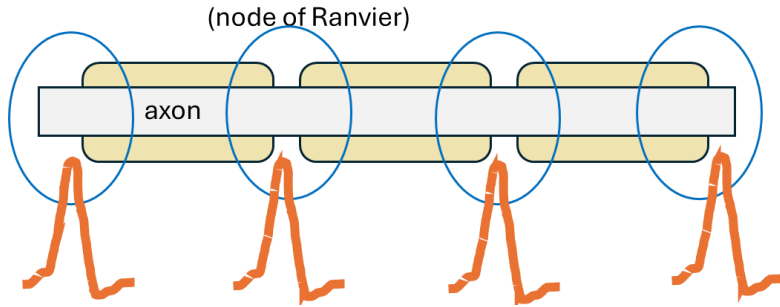


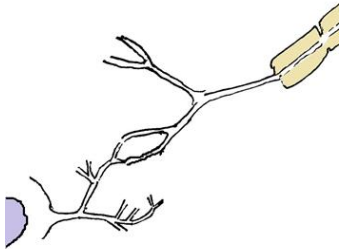
Image taken from: Barnett & Larkman, The action potential, Practical Neurology. 2007



The action potential generation and propagation



- The axon is covered by myelin but the nodes of Ranvier contains Na^+ channels allowing the “saltatory electrical conduction” of the **signal**
- The signal is transmitted from the membrane through **axon terminal** of the “emitting” cell to the dendrites of the “receiving” cell



But what triggers an action potential?

In the central nervous system, **synaptic events** received over the dendritic tree of a neuron are integrated into a **signal** that may be sufficient to promote the generation of **action potentials** in the axon of the neuron

The brain plasticity

It refers to the brain's ability to reorganise, adapt, and change during the course of a person's life in response to a variety of experiences, learning, injuries, and environmental factors. The **plasticity** of the brain serves as the **foundation** for our ability to learn, gain new skills, and recover from traumas

Brain plasticity is defined by the **rewiring of neuronal connections** and the development of **new neural pathways**

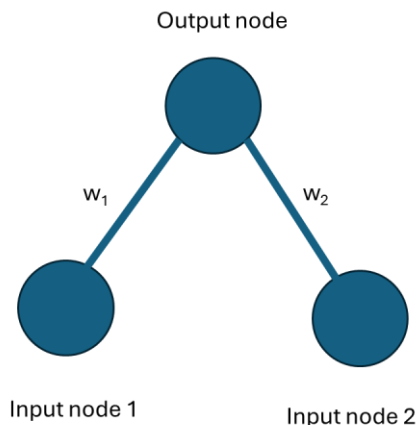
When we gain **new** knowledge, learn **new** skills, or engage in activities that stretch our cognitive capacities, our brain adapts to accommodate these **new** experiences.

Learning a new language, playing a musical instrument, or participating in sophisticated problem-solving tasks can all help to **encourage** the **creation of new brain networks**.

Physical activity has also been found to improve brain plasticity by increasing the production of neurotrophic substances that **promote neuron growth and connections**

Extracted from: P. Marmarosh, Brain Plasticity: The Remarkable Adaptability of the Human Mind, Neurosci. Psych. Open Access. (2023) 6(4), 101–103

A simple artificial neural network made by 3 elements



- Each element is a **node/neuron** of the network
- Each node i is associated to a **state variable** n
- A **weight** w_{ik} is associated between two nodes i and k
- A **transfer function** f determines the state of the node as a function of the weights and of the state variables of the linked incoming nodes

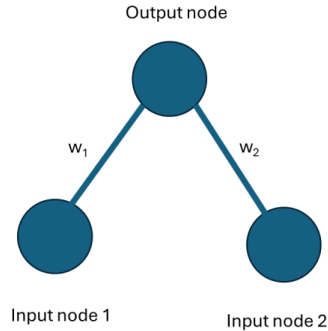
The **Perceptron** was developed by Frank Rosenblatt and co. in 1960

The state variable of the output node is then:

$$n_{output} = f\left(\sum_{i=1}^2 w_i n_i\right)$$

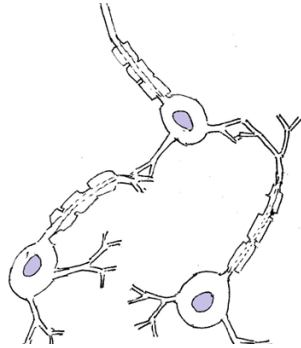
(Frank Rosenblatt & co. 1957)

Comparison with biology



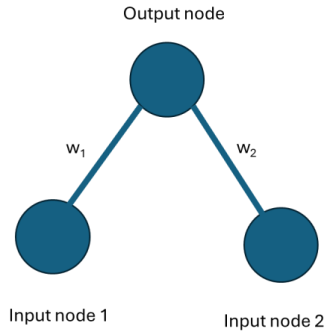
- Consider the case in which n can take only 0 or 1 value
- 1 means active node, 0 means resting node
- The output node state n_{output} is given by:

$$n_{output} = \sum_{i=1}^2 w_i n_i$$



The **synaptic events** received over the dendritic tree of a neuron are integrated into a **signal** that can activate the neuron inducing the generation of **action potentials** in its axon

Simulating Boolean Algebra functions



$$n_{output} = \sum_{i=1}^2 w_i n_i - 0.6$$

- Consider that to activate a node you have to pass a threshold, let say 0.6
- Thus the output is active only if the summation > 0.6

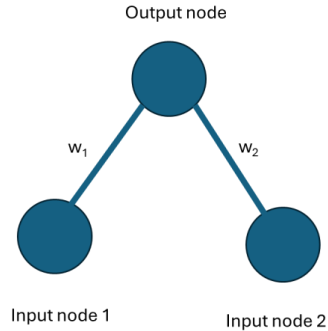
AND

Inp1	Inp2	w1	w2	sum	thr	n	out
1	0	0.5	0.6	0.5	0.6	-0.1	0
0	1	0.5	0.6	0.6	0.6	0.0	0
1	1	0.5	0.6	1.1	0.6	0.5	1
0	0	0.5	0.6	0	0.6	-0.6	0

OR

Inp1	Inp2	w1	w2	sum	thr	n	out
1	0	0.7	0.7	0.7	0.6	0.1	1
0	1	0.7	0.7	0.7	0.6	0.1	1
1	1	0.7	0.7	1.4	0.6	0.8	1
0	0	0.7	0.7	0	0.6	-0.6	0

Perceptron cannot simulate XOR an upgrade is needed

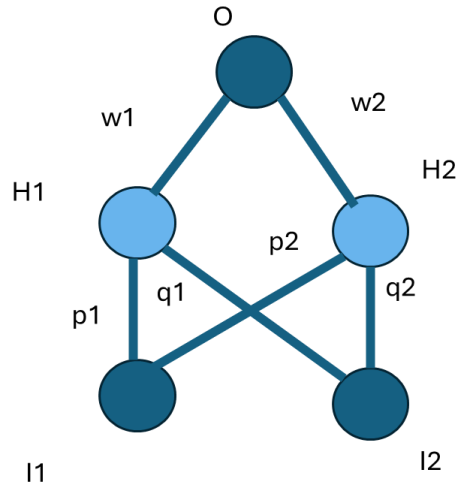


- The input nodes can be active or not and if they are both active their linear combination should give a result that is the opposite of that obtained when they are both inactive

XOR Table

Inp1	Inp2	out
1	0	1
0	1	1
1	1	0
0	0	0

Solving the XOR with *a hidden layer addition*



I1	I2	p1	q1	sum	thr	n	H1
1	0	0.7	-0.7	0.7	0.6	0.1	1
0	1	0.7	-0.7	-0.7	0.6	-0.1	0
1	1	0.7	-0.7	0.0	0.6	-0.6	0
0	0	0.7	-0.7	0	0.6	-0.6	0

I1	I2	p2	q2	sum	thr	n	H2
1	0	-0.7	0.7	-0.7	0.6	-0.1	0
0	1	-0.7	0.7	0.7	0.6	0.1	1
1	1	-0.7	0.7	0.0	0.6	-0.6	0
0	0	-0.7	0.7	0	0.6	-0.6	0

H1	H2	w1	w2	sum	thr	n	O
1	0	0.7	0.7	0.7	0.6	0.1	1
0	1	0.7	0.7	0.7	0.6	0.1	1
0	0	0.7	0.7	0	0.6	-0.6	0

What Are Large Language Models (LLMs)?

- LLM is the underlying technology of ChatGPT and others
 - LLM is one of many models in the field of *Language AI*, a subfield of AI focusing on developing technologies capable of understanding, processing and generating human language, interchangeable with *natural language processing*
- Deep neural networks trained on huge text datasets
 - Based on *transformer* architecture
 - Learn statistical patterns of language

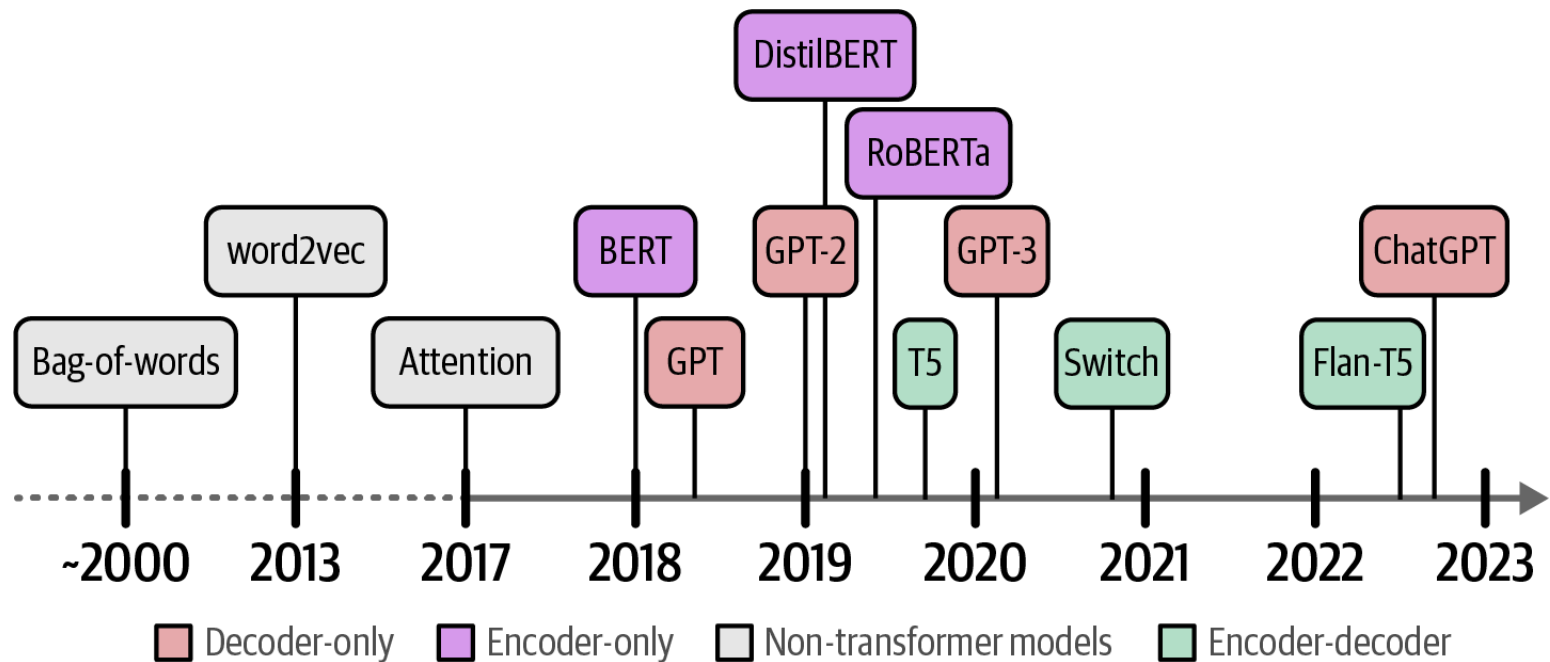
Examples: GPT-4, Claude, Gemini, LLaMA



Gemini



A History of Language AI und Evolution of LLMs

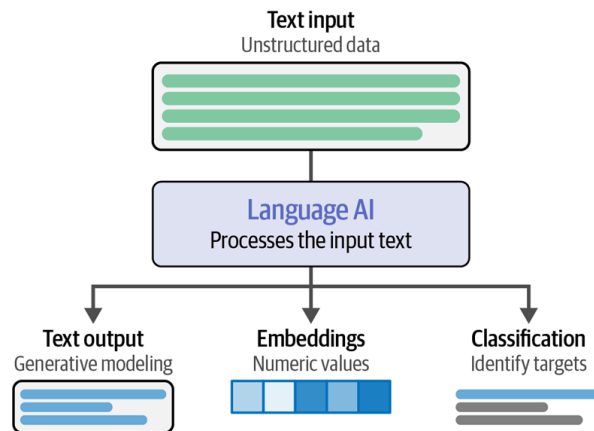


Alammar & Grootendorst. Hands-on Large Language Models. 2024

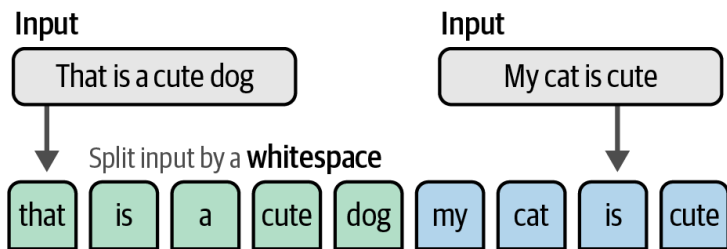
How Language AI (LLM) Work?

The key question is how to represent the language in a structured manner that can be used by computer

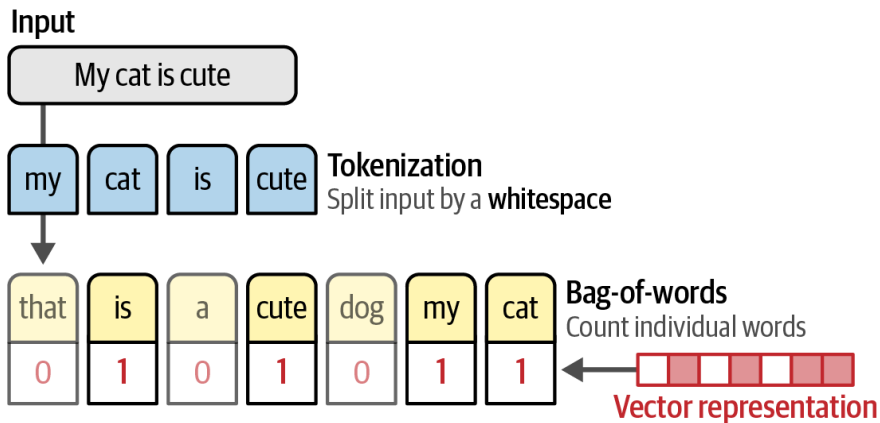
1. **Bag-of-words:** **token** and **embeddings**
2. **Encoding & decoding with attention**
3. **Transformer:** **Encoding-only model** (BERT)
Representative model
Decoding-only model (GPT-1)
Generative AI
4. **Generative AI -> LLM**
5. Moving definition of LLM: “**Large**” is “**arbitrary**”



Bag-of-Words: Token and Embeddings



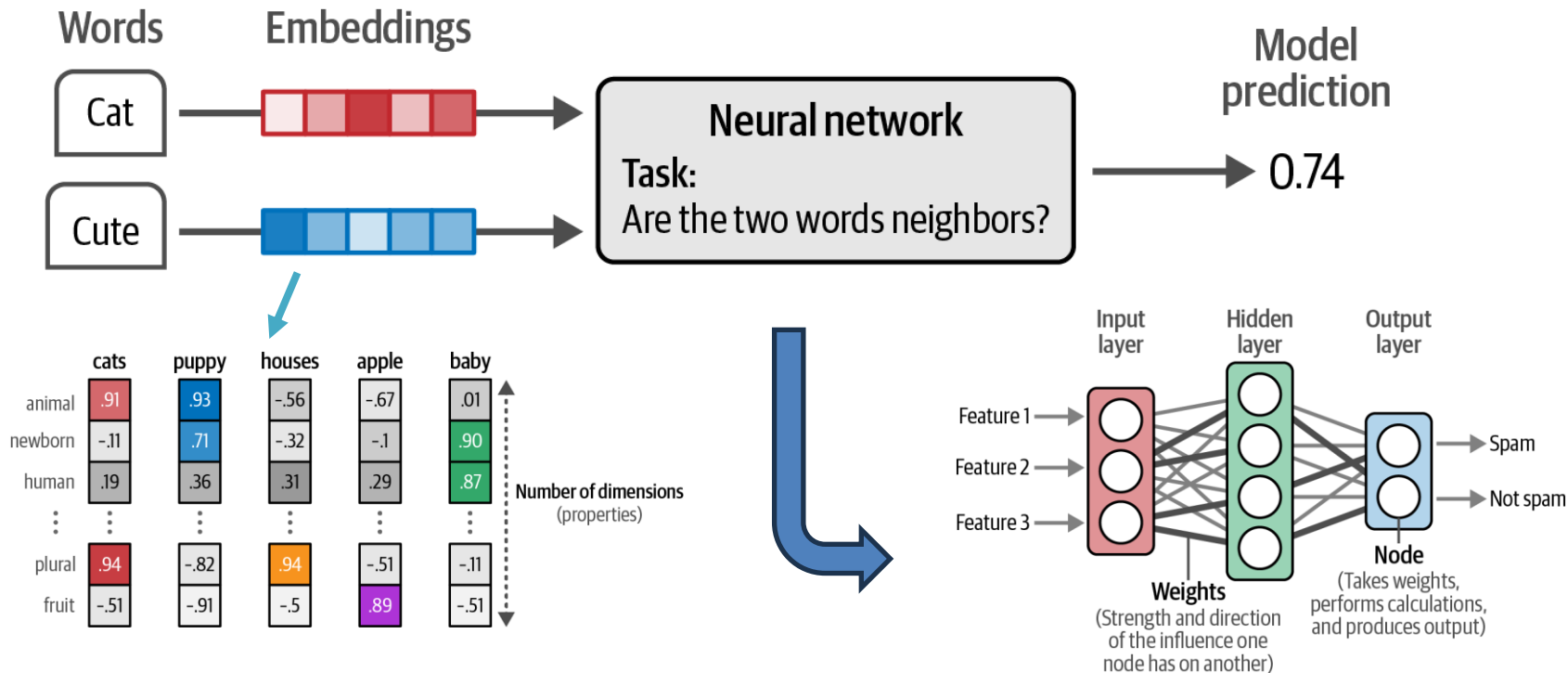
Tokenization



Vector representation

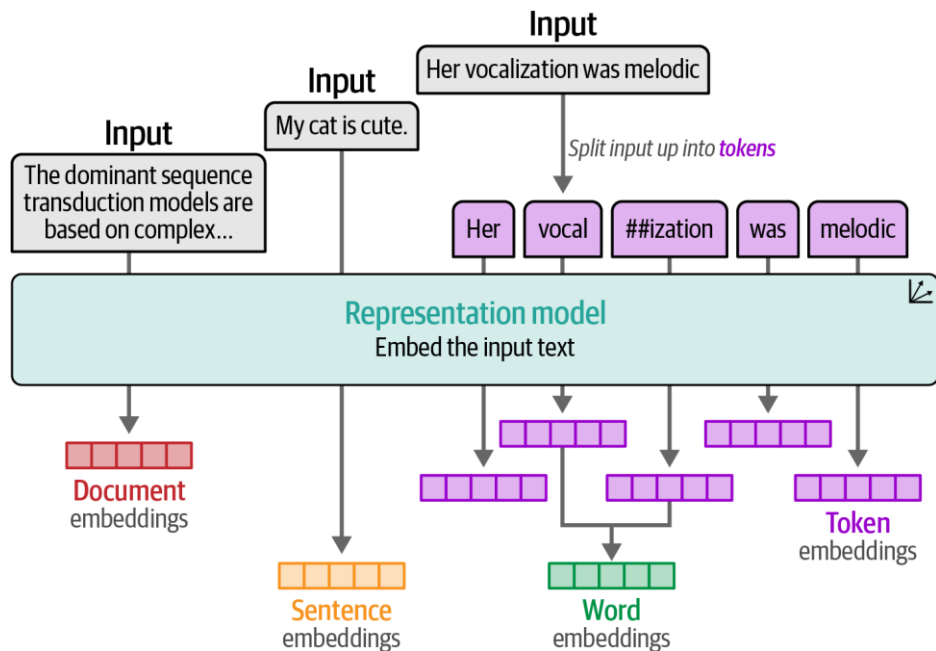
Bag-of-Words: Token and Embeddings

Using RNNs
Not for
classification



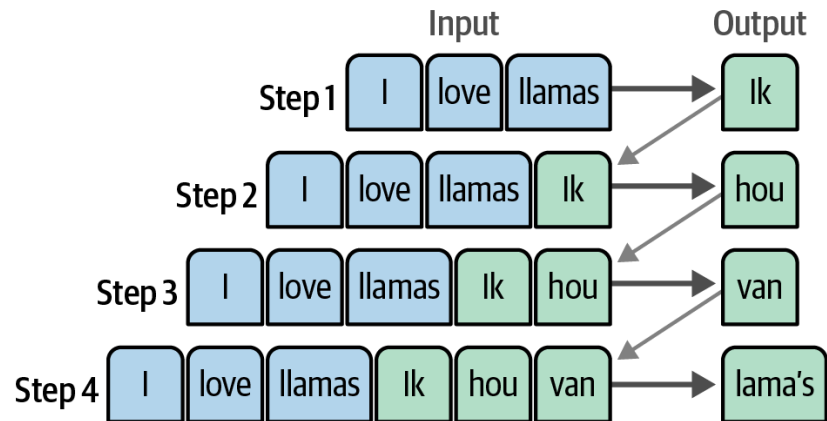
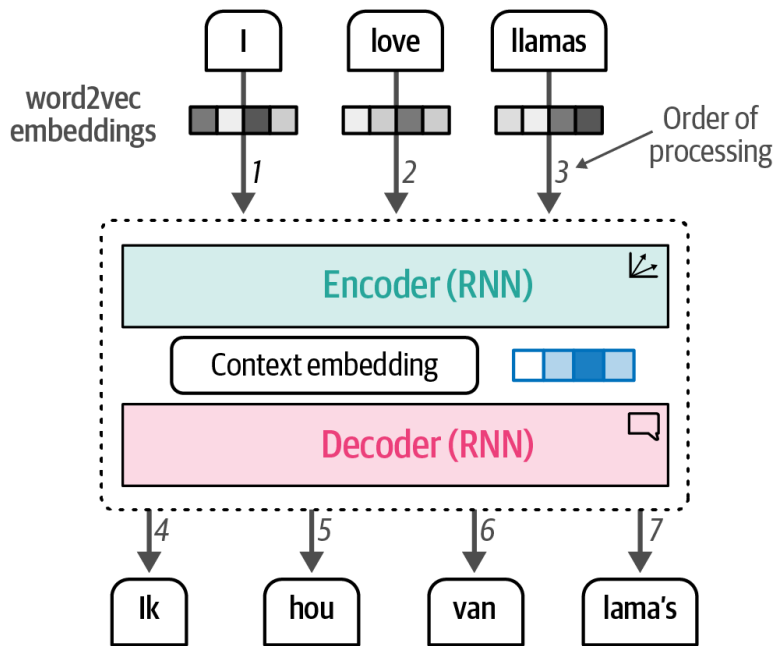
Alammar & Grootendorst. Hands-on Large Language Models. 2024

Bag-of-Words: Type of embeddings



- **Token** embeddings
- **Word** embeddings
- **Sentence** embeddings
- **Document** embeddings

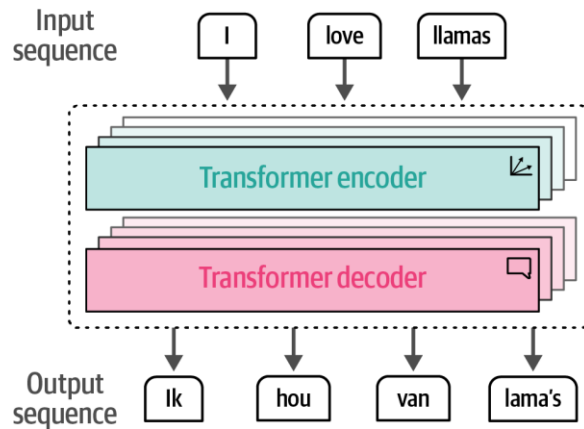
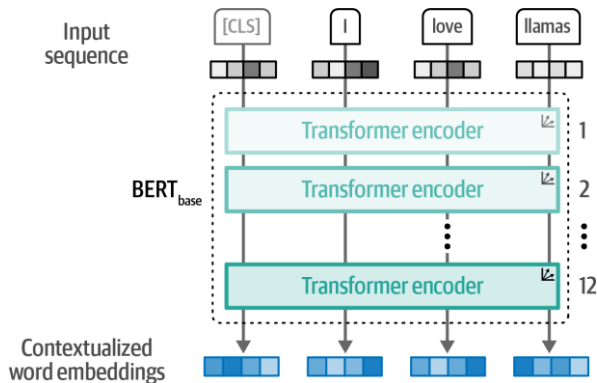
Encoding and decoding with attention



- **Attention** allows a model to **focus** on parts of the input sequence that relevant to one another and **amplify** their signals
- **Attention** selectively determines which word is most important in a given sentence

Transformer: Encoding-only and Decoding-only

Representative model

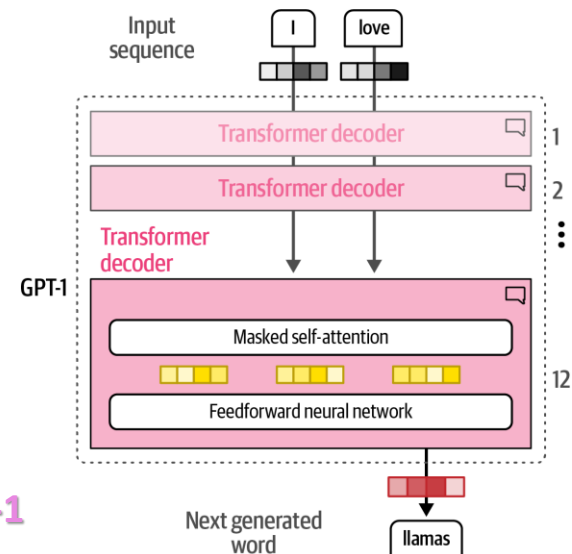


Transformer model

BERT

GPT-1

Generative AI model



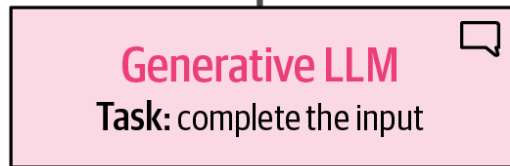
Alammar & Grootendorst. Hands-on Large Language Models. 2024

Decoding-only model: Generative AI refers to -> LLM

Large Language Model

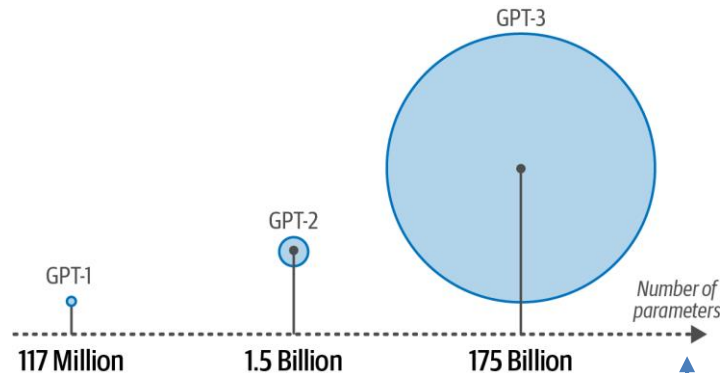
User query
(prompt)

Tell me something about llamas



Output
(completion)

Llamas are domesticated South American camelids, widely used as pack animals by Andean cultures since pre-Hispanic times. With their fluffy coat, long neck, and distinctive facial features...



Parameter is a numerical value that represents the model's understanding of language

The word "**large**" is arbitrary and changing over the times

Alammar & Grootendorst. Hands-on Large Language Models. 2024

What LLMs Can Do?

- Summarize and explain texts
- Translate languages
- Answer questions
- Generate code and reports
- Domain-specific fine-tuning
- Interaction between patients and healthcare system (medicine)
- Converting different scripts/formats between programs, such as Python <-> R <-> Fortran <-> SAAM II (biokinetic modeling code)
- Application in radiation protection

Opportunities & Challenges in Radiation Protection and Medicine

Contribution from experts

- **Artificial Intelligence in radiation dosimetry** - Hans Rabus
- **Large language models for practice optimization in nuclear medicine theranostics** - Kuangyu Shi
- **AI as the future of Monte Carlo modelling: Energy-shifting, a new generic approach for fast radiotherapy dose calculation** - Chi-Hieu Pham
- **AI in radiation protection in diagnostic radiology** - Mika Kortensniemi
- **Artificial Intelligence in Internal Dosimetry: Mechanisms, Models, and Multiscale Applications** - Shaheen Dewji
- **What might the future look like for AI in dosimetry?** - Daniele Giuffrida

Contribution within EURADOS

- CR39 detector **image segmentation** using Meta's Mask R-CNN - Jeppe Brage Christensen
- Development of ANN-based Dose Conversion Models for **Retrospective Dosimetry** in External Exposure Scenarios - Hyoungtaek Kim
- Compressing **Radiation-Transport Simulations** using neural networks - Felix Lehner
- Estimating **uncertainty** and demonstrating reproducibility in a practical machine learning model - Max Taylor

Challenges - LLM

- **ChatEurados?**
- Interaction between patients and healthcare system
- ChatGPT aiding PBPK modeling documentation

The Future of AI

- **Multi-modal** models (text + image + data)
- **Real-time digital twins**
- Transparent, **explainable AI**
- Collaboration **between humans and AI**

AI won't replace experts — but experts using AI will replace those who don't

Chance for EURADOS

- EURADOS AM 2022 Winter School gave one talk on AI
 - The emerging role of **artificial intelligence** in internal radiation dosimetry
- EURADOS 22nd webinar
 - Dosimetry for radiopharmaceuticals in therapy and **AI applications**
- **AI tasks in several working groups**
- AI application was **not explicitly written** in EURADOS SRA 2020
- AI application **will be proposed** in the updating SRIA

*This winter school and the discussion thereafter can build the basis for the EURADOS AI strategy as a **EURADOS Report** and a **strategy paper***

*Build a EURADOS chatbot -> **ChatEURADOS***

Literature

- Russell & Norvig. ***Artificial Intelligence A Modern Approach***. 4th 2022
- Géron. ***Hands-on Machine Learning with Scikit-Learn and PyTorch***. 2025
- Mueller, Reinhardt & Strickland. ***Neural Networks. An introduction***. 2nd 1995
- Alammam & Grootendorst. ***Hands-on Large Language Models***. 2024
- Eagleman. ***The Brain***. 2015