SNN & NEUROMORPHIC ARCHITECTURES

Hammouda ELBEZ
02-01-2021

Content

1. AI, ML & Neural Networks

2. Neural Networks in general

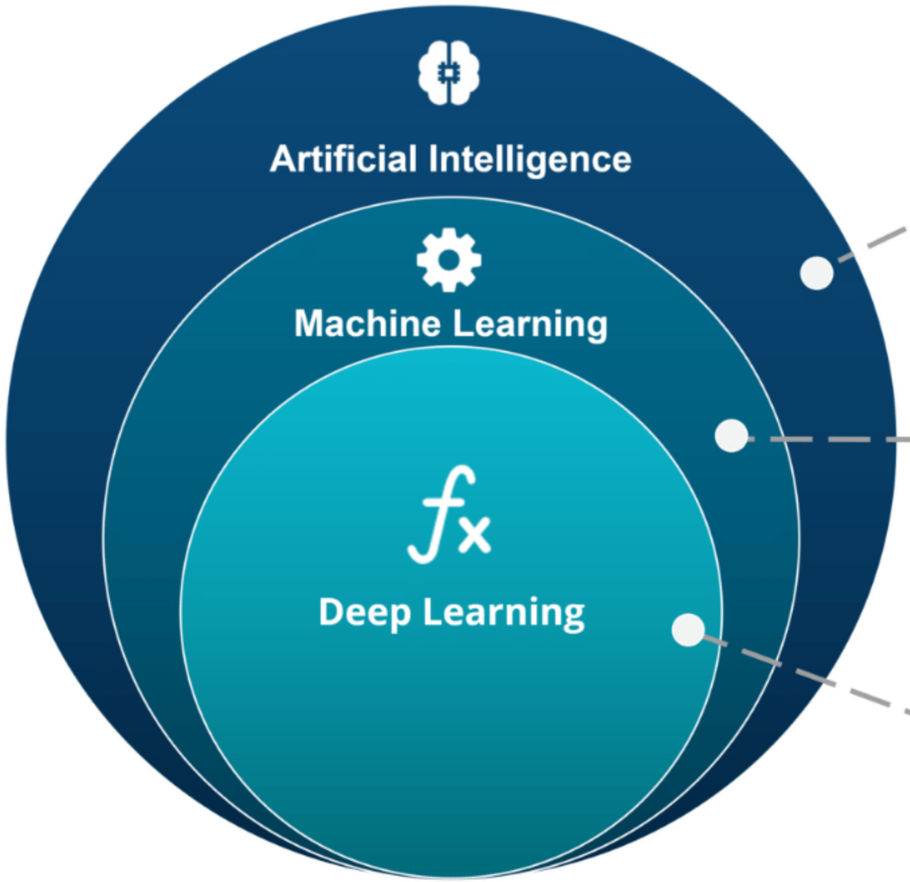
3. CNN Pros & Cons

4. SNN, what is it ?

5. SNN Pros & Cons

6. Neuromorphic Architectures

AI, ML & Neural Networks



ARTIFICIAL INTELLIGENCE

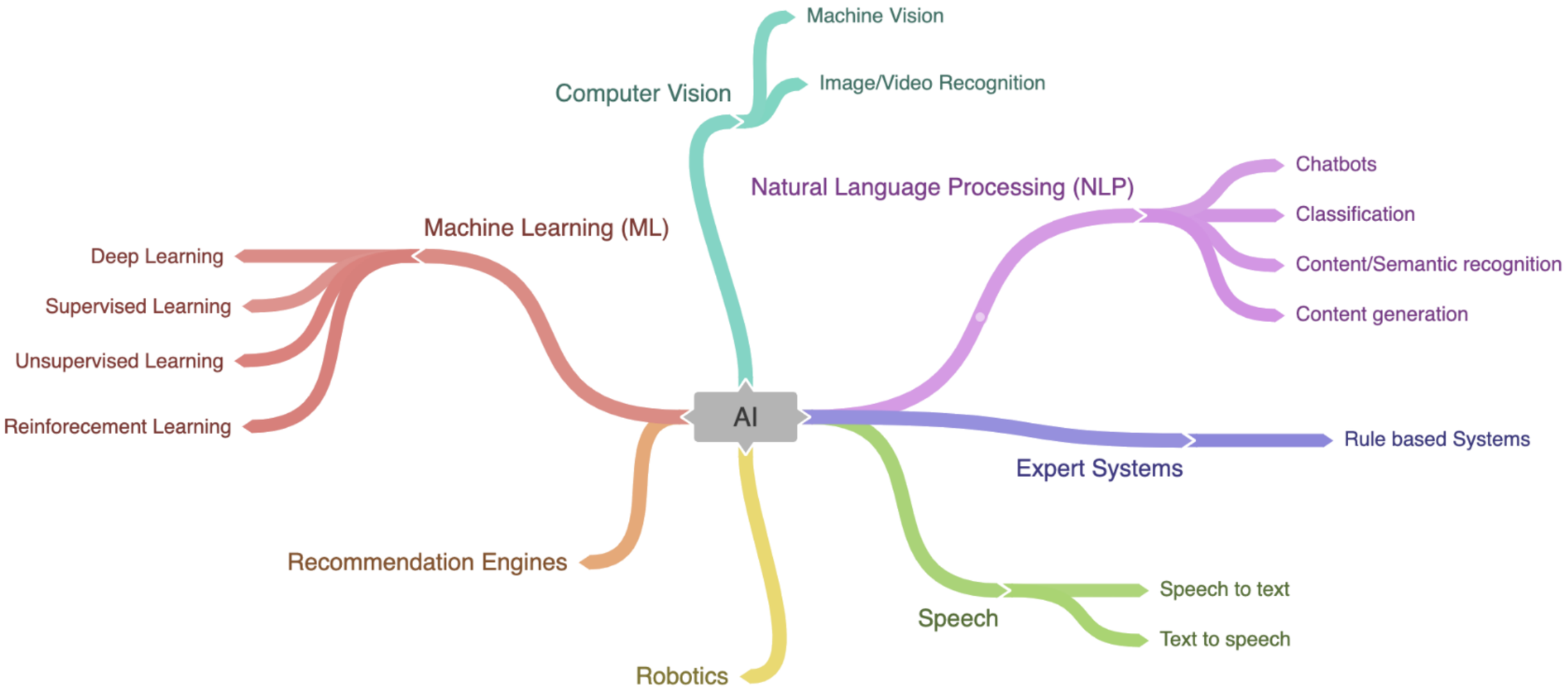
A technique which enables machines to mimic human behaviour

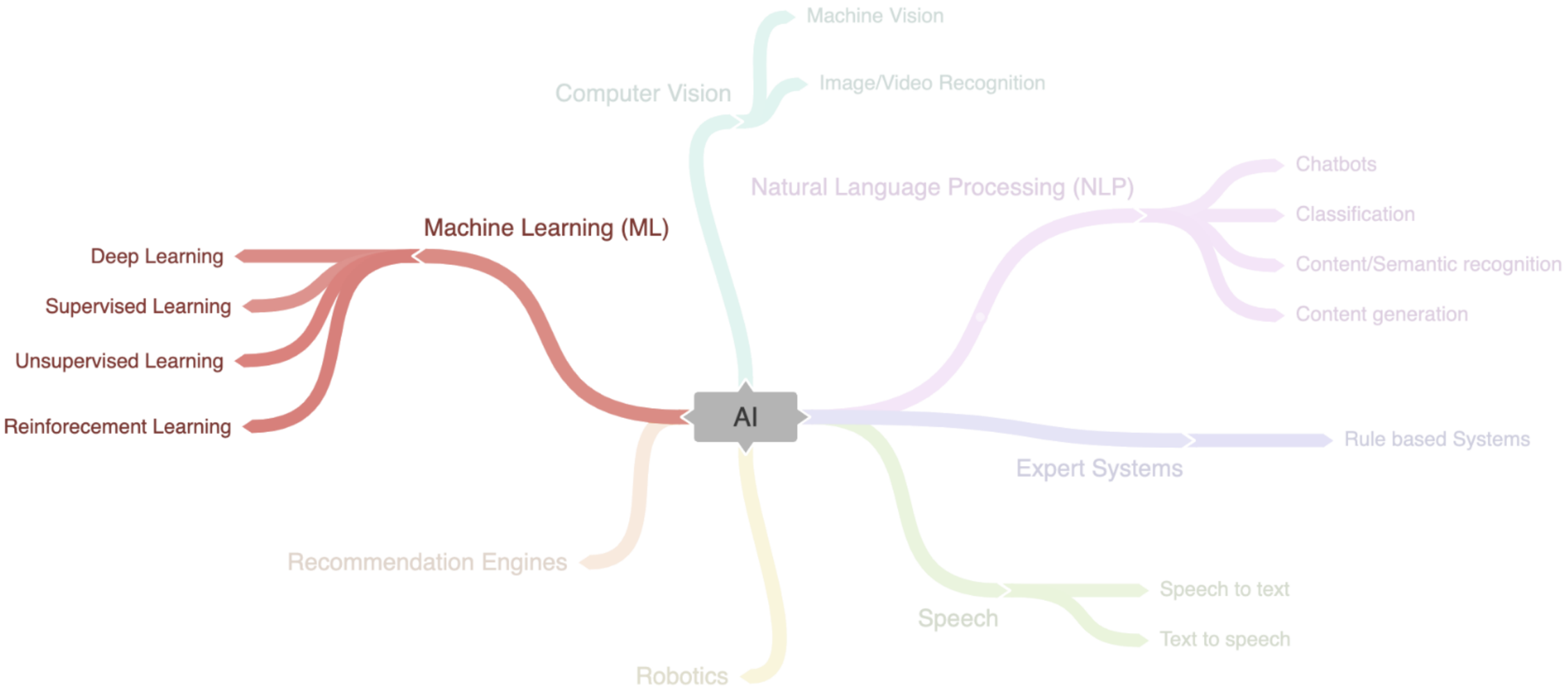
MACHINE LEARNING

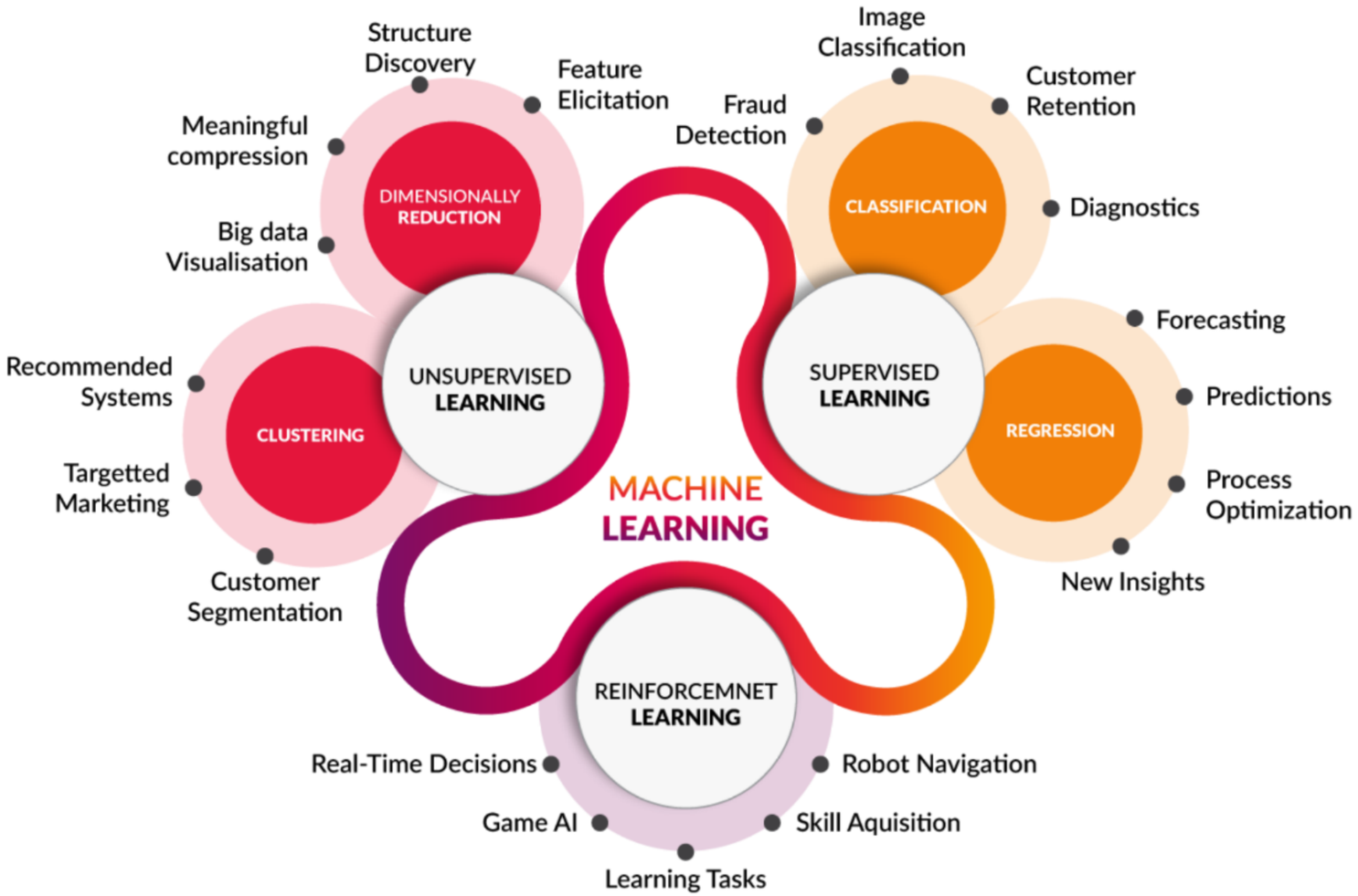
Subset of AI technique which use statistical methods to enable machines to improve with experience

DEEP LEARNING

Subset of ML which make the computation of multi-layer neural network feasible


AI
Computer Vision
Machine Vision
Image/Video Recognition
Natural Language Processing (NLP)
Chatbots
Classification
Content/Semantic recognition
Content generation
Machine Learning (ML)
Deep Learning
Supervised Learning
Unsupervised Learning
Reinforecement Learning
Expert Systems
Rule based Systems
Speech
Speech to text
Text to speech
Recommendation Engines
Robotics


Machine Vision
Computer Vision
Image/Video Recognition
Chatbots
Natural Language Processing (NLP)
Classification
Machine Learning (ML)
Content/Semantic recognition
Deep Learning
Content generation
Supervised Learning
Unsupervised Learning
AI
Rule based Systems
Reinforecement Learning
Expert Systems
Recommendation Engines
Speech to text
Speech
Text to speech
Robotics


MACHINE LEARNING
UNSUPERVISED LEARNING
SUPERVISED LEARNING
REINFORCEMNET LEARNING
DIMENSIONALLY REDUCTION
CLUSTERING
CLASSIFICATION
REGRESSION
Structure Discovery
Feature Elicitation
Meaningful compression
Big data Visualisation
Recommended Systems
Targetted Marketing
Customer Segmentation
Image Classification
Customer Retention
Fraud Detection
Diagnostics
Forecasting
Predictions
Process Optimization
New Insights
Real-Time Decisions
Robot Navigation
Game AI
Skill Aquisition
Learning Tasks

Types of learning

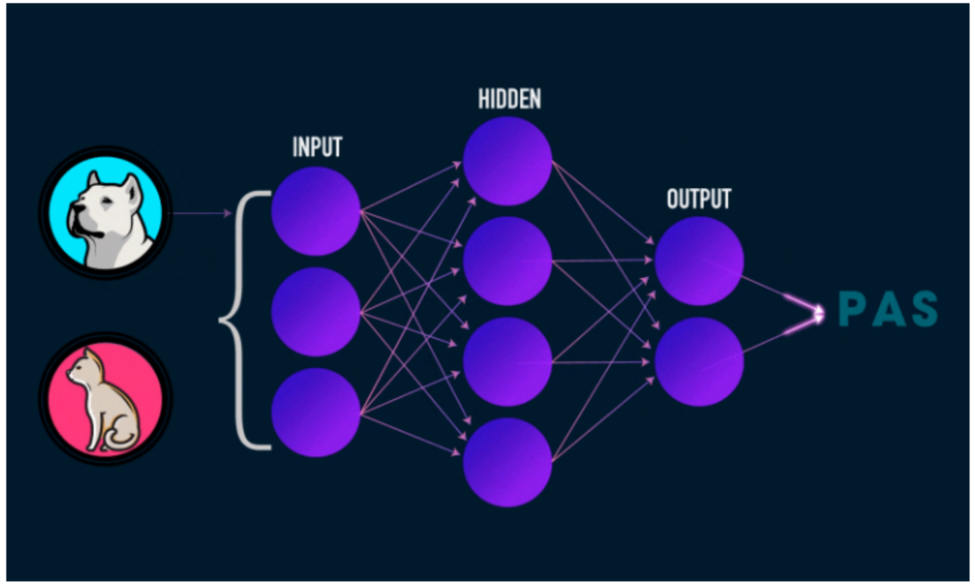
Supervised Learning

Unsupervised Learning

Neural Networks

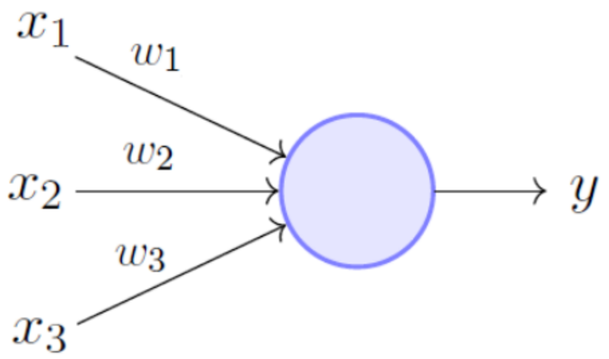
Neural Networks

1. "Neural networks (NNs), are computing systems vaguely inspired by the biological neural networks that constitute animal brains" - wikipedia



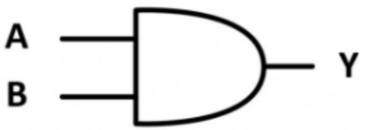
Neural Networks : 1st generation

- Perceptron
- Linear Classification
- Learning is done by updating the weights based on some learning rule



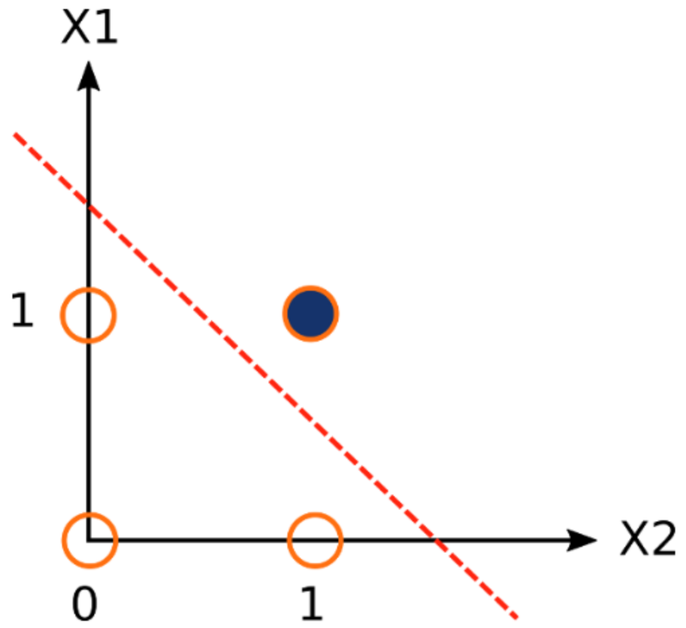
Perceptron Model (Minsky-Papert in 1969)

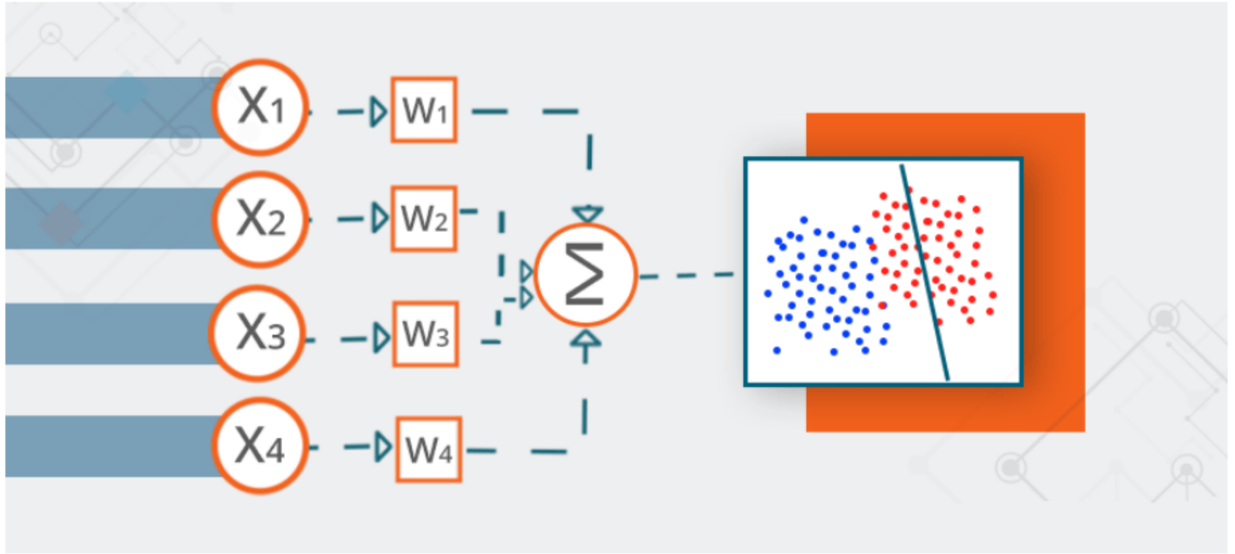
Inputs		Output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1



Y = A.B

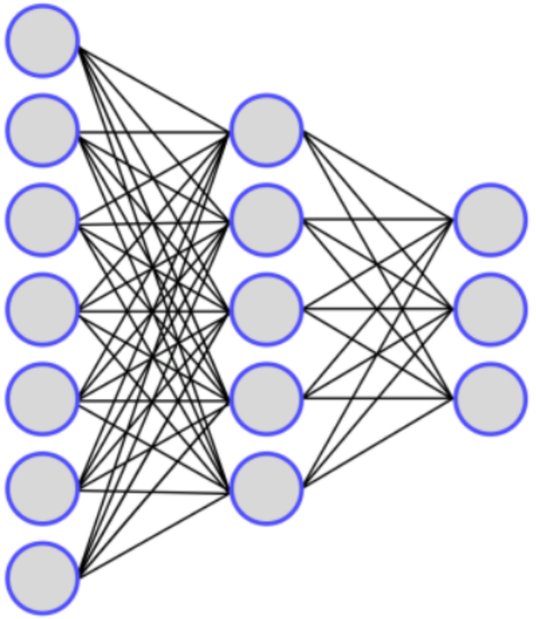
Neural Networks : 1st generation

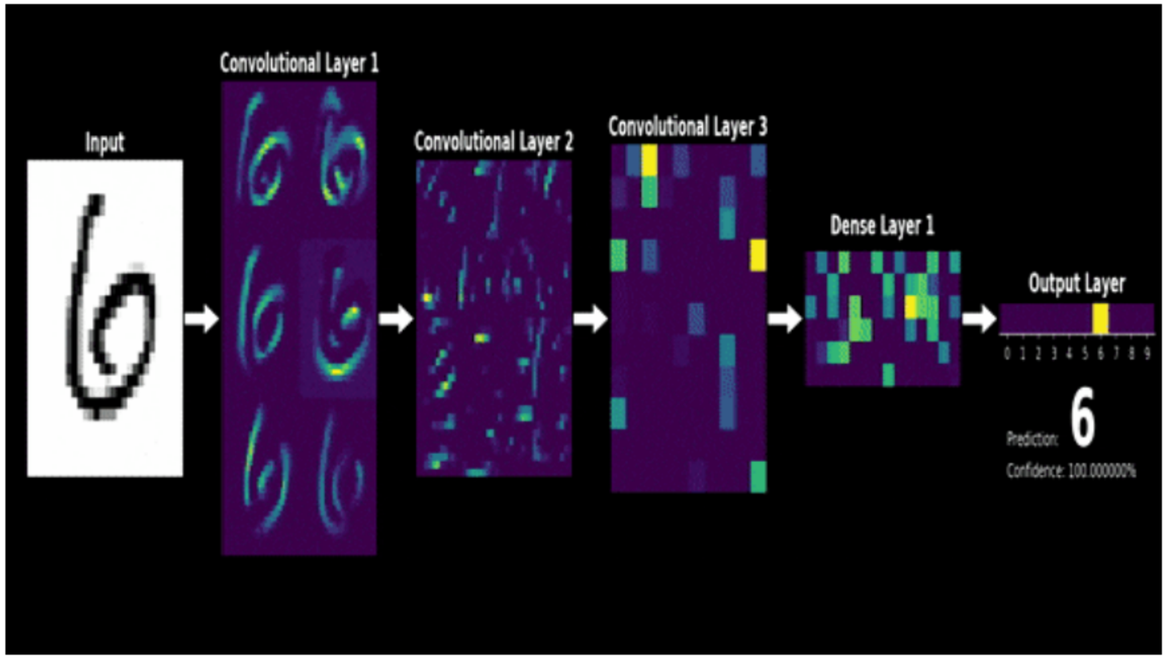




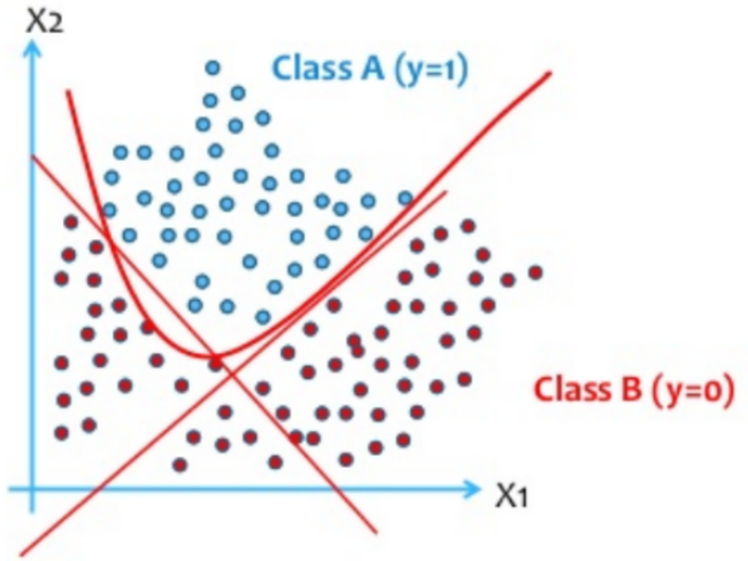
Neural Networks : 2nd generation

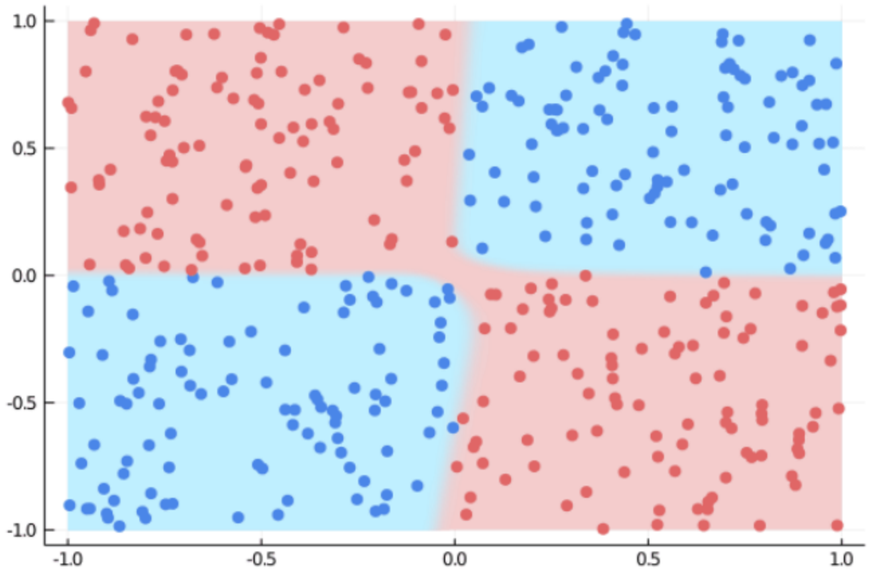
- Convolutional neural network (CNN)
- Non-linearity
- **"shallow"** neural network is a term used to describe NN that usually have only one hidden layer



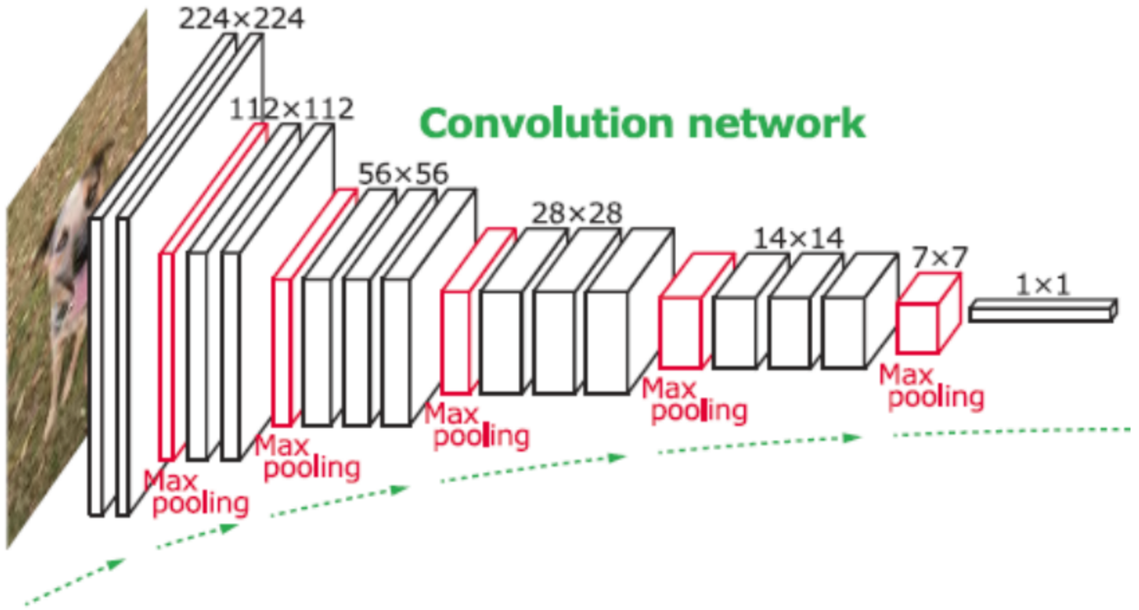


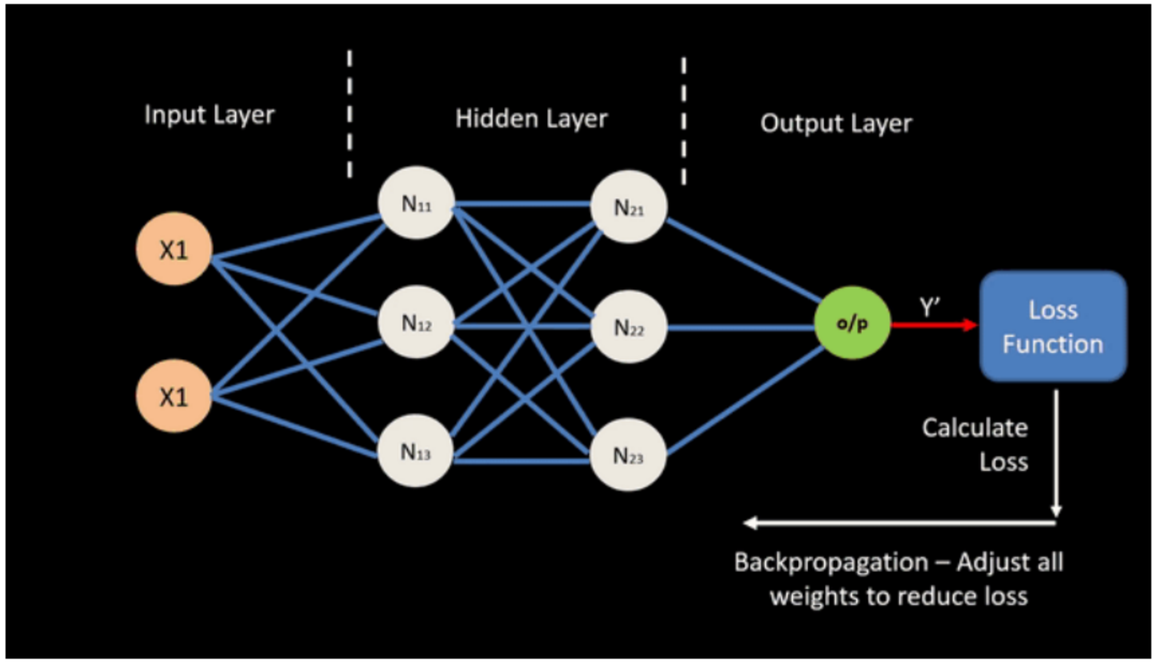
Neural Networks : 2nd generation





Neural Networks : Deep Neural Networks





CNN pros & cons

Pros:

- A huge interest in Convolutional Neural Networks (CNNs) and Deep learning
- Applications in different fields
- The best performance in many applications

Cons:

- Huge energy consumption
- The need for a lot of Data for training
- Interpretability

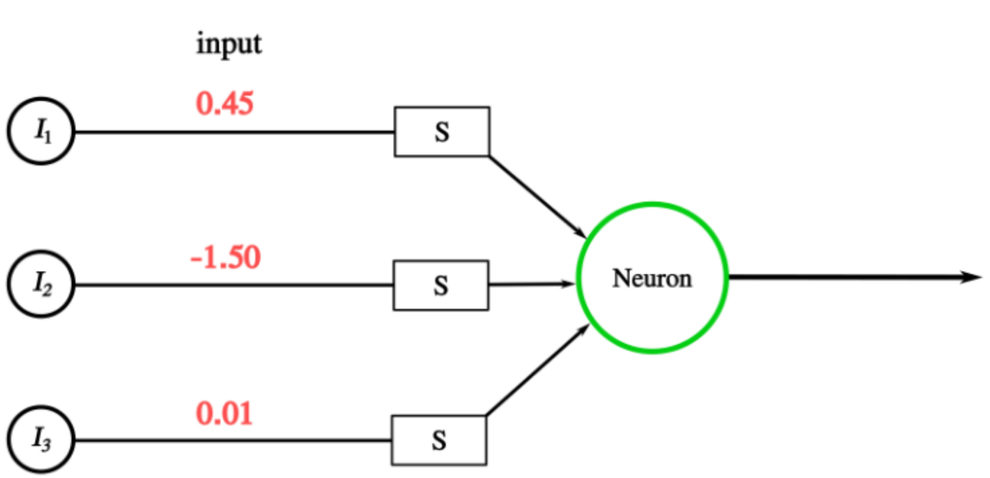
Yann LeCun (AAAI-20)
7-12 Feb 2020

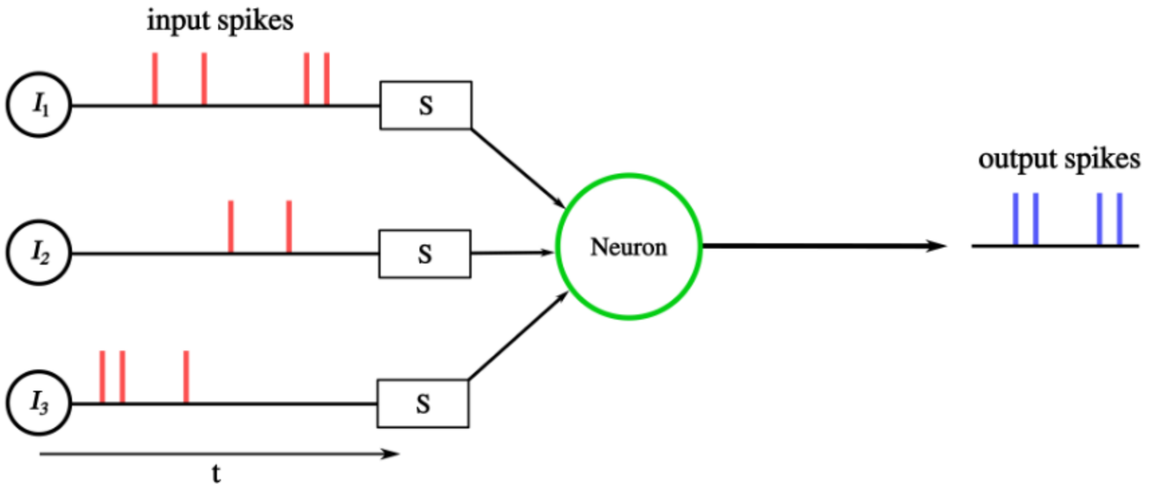
SNN, what is it ?

SNN, what is it ?

- Spiking neural networks (SNNs) are considered as the 3rd generation of neural networks
- SNNs are artificial neural networks that more closely mimic natural neural networks
- SNNs incorporate the concept of time into their operating model
- Spike based activation of SNNs is not differentiable thus making it hard to perform error backpropagation

CNN vs SNN





- Different learning techniques

SNN pros & cons

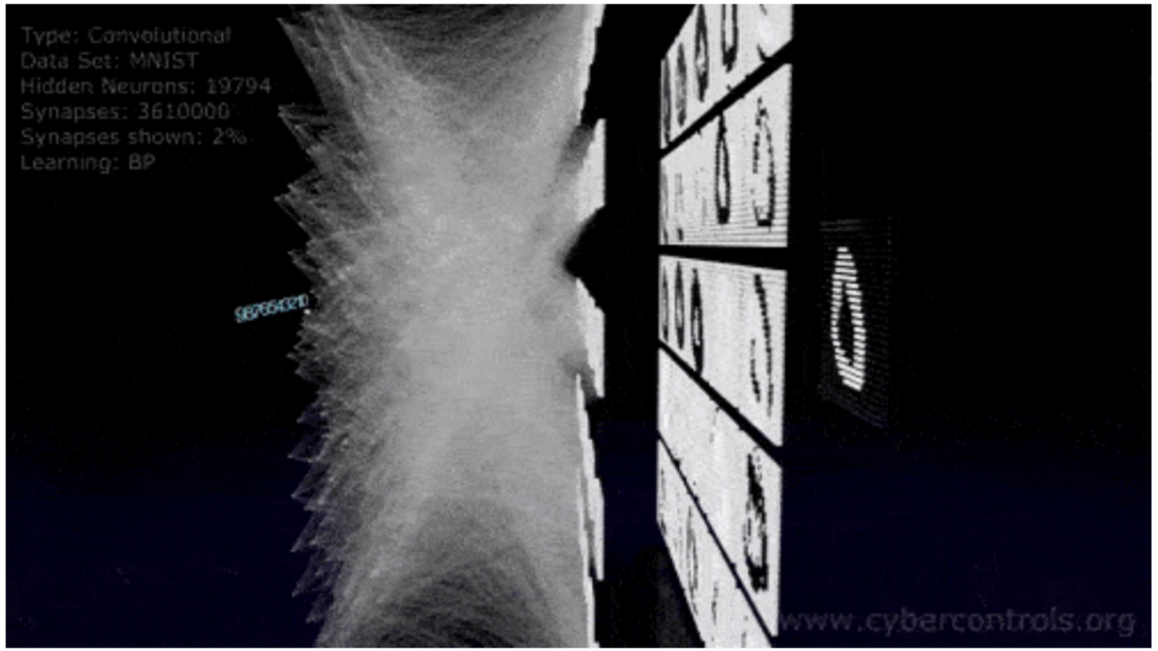
Pros:

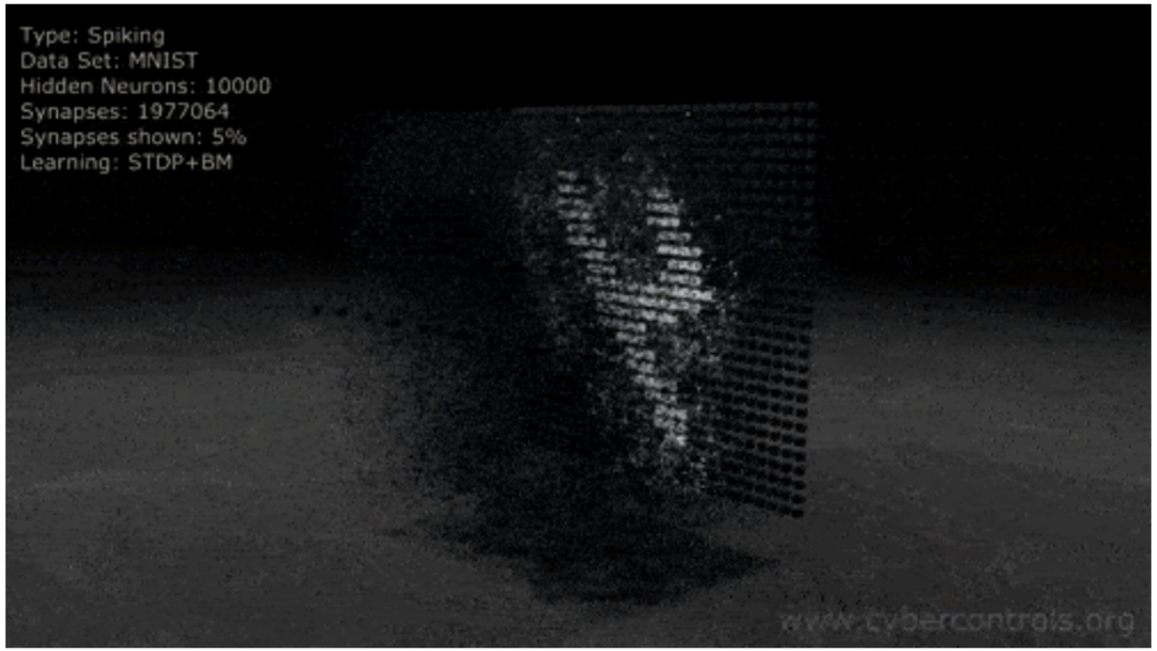
- Low energy consumption
- Suitable for energy constrainted applications
- Possibility to process natural signals
- Produce sparse networks (no calculation unless activity happens)

Cons:

- Low performance compared to DNN (Local Learning rule)
- Lack of a deep understanding of some brain related questions (intelligence, consciousness ..etc)
- Interpretability

CNN vs SNN


Type: Convolutional
Data Set: MNIST
Hidden Neurons: 19794
Synapses: 3610000
Synapses shown: 2%
Learning: BP
www.cybercontrols.org

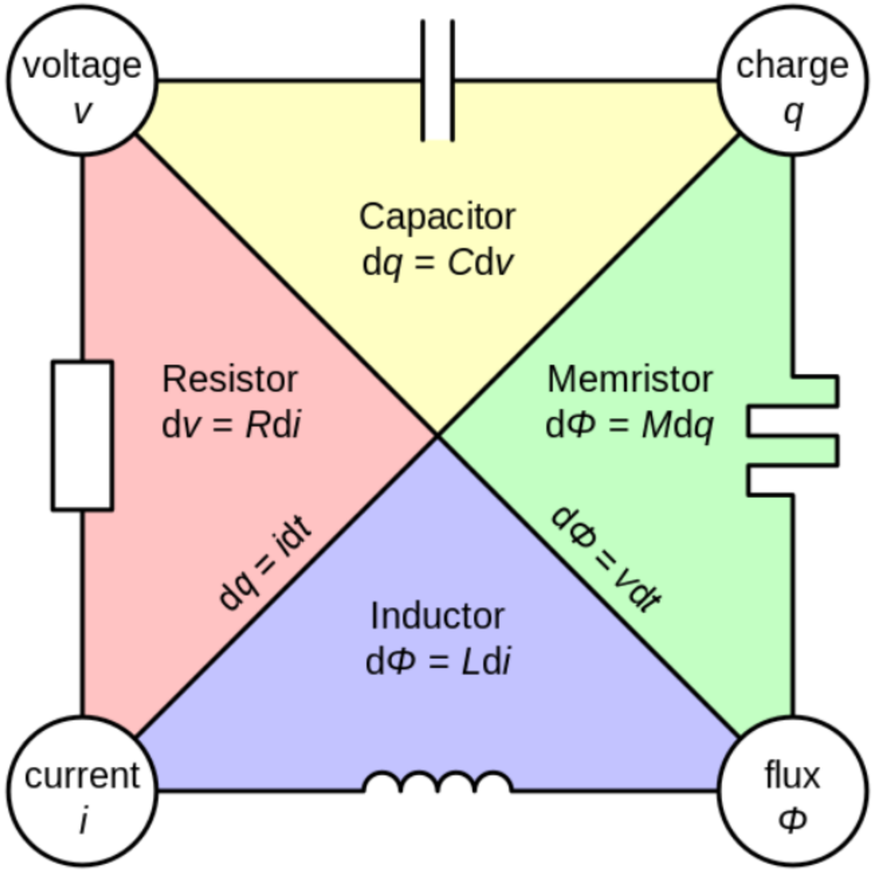

Type: Spiking
Data Set: MNIST
Hidden Neurons: 10000
Synapses: 1977064
Synapses shown: 5%
Learning: STDP+BM
www.cybercontrols.org

Neuromorphic Architectures

Neuromorphic Architectures

- Computer architectures that are similar to biological brains
- Architectures that implement spiking neural networks in hardware
- Neuromorphic architectures are different from Von Neumann one, memory and computation is on the same place
- Computation is done in neurons and memory is in synapses (connections between neurons)
- Neuromorphic architectures have the potential to overcome **Moore's law limitation**
- It is possible to make neurons in different ways, the main two are : CMOS and Memristor

Neuromorphic Architectures : Memristor

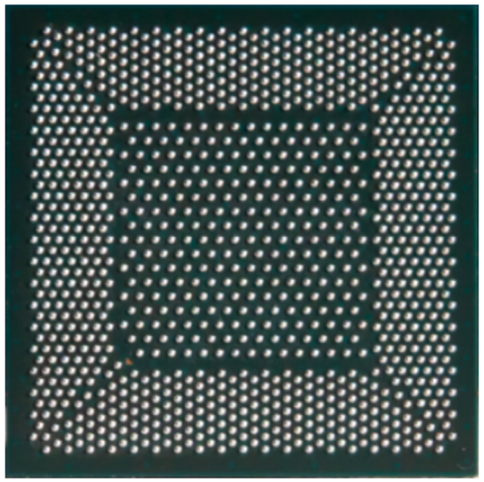


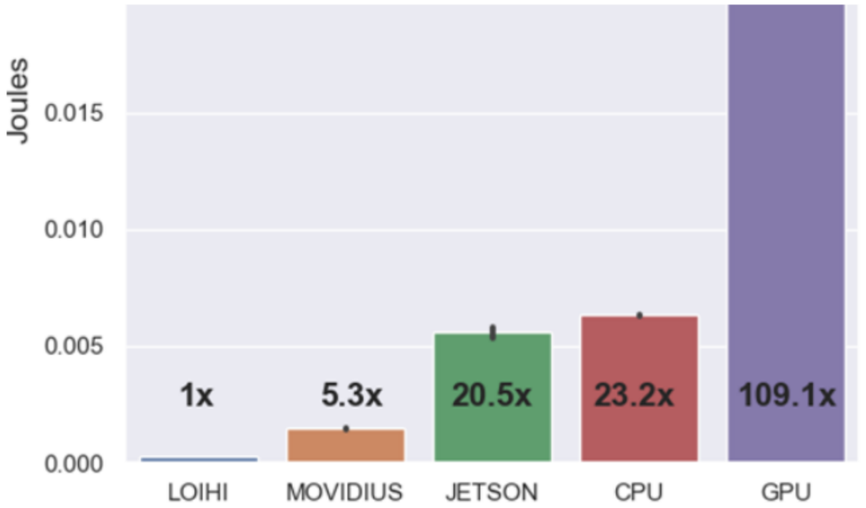
- Memristor is called the missing element
- The memristor was predicted and described in 1971
- 37 years later, a physical implementation of the memristor was reported by HP lab
- Memristor (**Memor**y and Res**istor**) is a Resistor with memory and the ability to modify its resistance value
- In Neuromorphic architectures, with only one Memristor we can represent a neuron

Neuromorphic architectures: Academia & Industry

Neuromorphic Hardware: Intel Loihi chip

- Technology: CMOS
- Neurons: 131,072

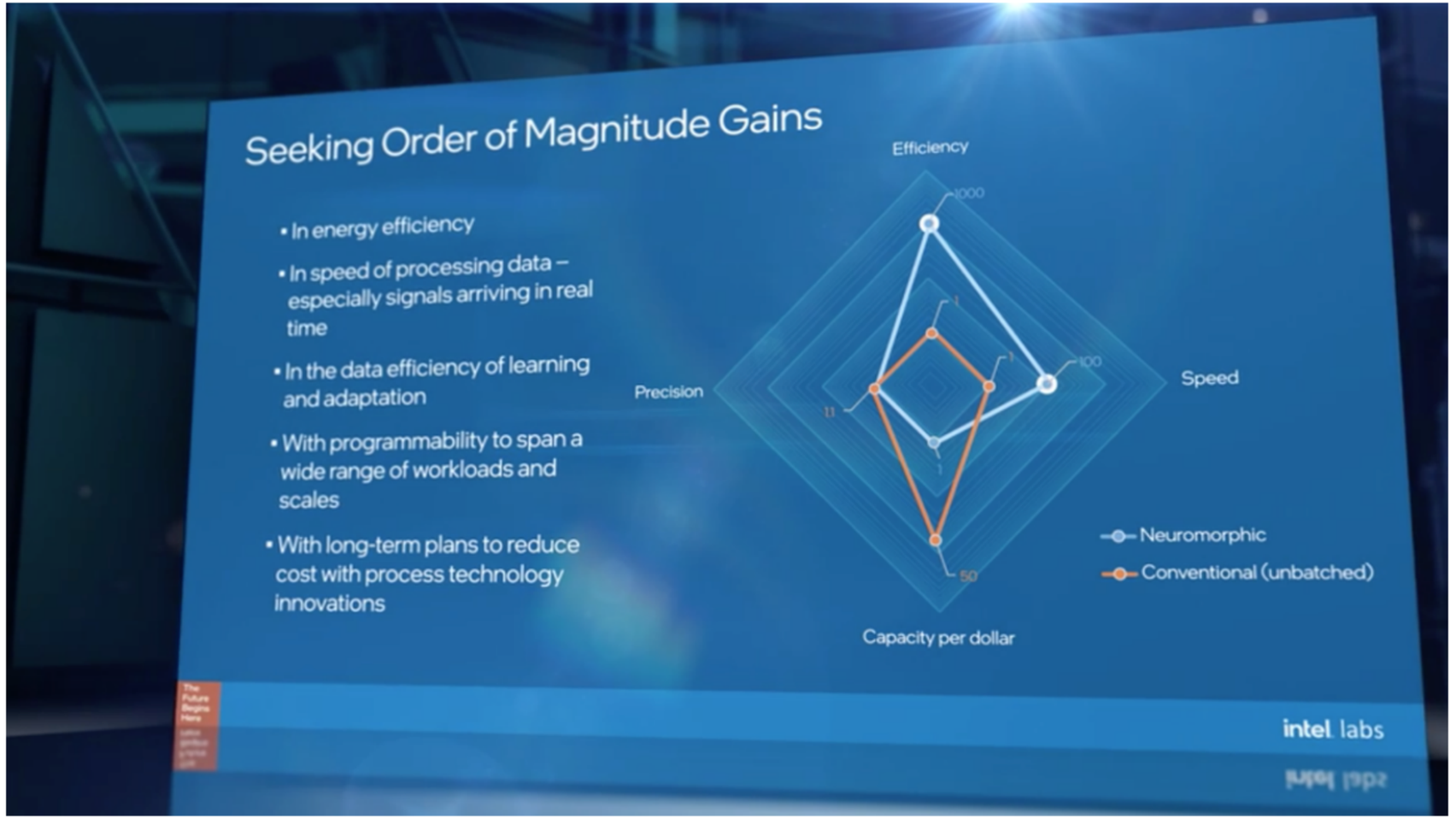




Neuromorphic Hardware: Intel Pohoiki Springs

- Technology: CMOS
- Neurons: 100 million
- 768 Loihi chips
- Pohoiki Springs scales up Loihi chip by more than 750 times, while operating at a power level of under **500 watts**
- Only for researchers

Neuromorphic Hardware: Intel



Neuromorphic Hardware: SPINNAKER

- Designed at the Department of Computer Science, University of Manchester
- 1,036,800 cores
- Each core can have up to 255 neuron
- 7 TB of RAM
- a full-size million-core SpiNNaker will consume around **90 kW**
- Accessible only for researchers (From EU)

Neuromorphic Hardware: SPINNAKER

Conclusion

- SNNs are artificial neural networks that mimic natural neural networks more closely
- SNNs incorporate the concept of time into their operating model, which can be critical for video processing and time related applications
- Neuromorphic architectures have the potential to overcome **Moore's law limitation**
- Neuromorphic architectures can be the key for AI in IOT, Robotics and FANET (drones)

https://www.youtube.com/watch?v=muaG2VETgHU

END