

Machine learning introduction

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Introduction to machine learning

- **What is the purpose of this session ?**
 - Learning (and recognizing) the most common forms of AI
 - ... And the application domain of each form
 - Being able to implement base mechanisms of a neural network
 - Being able to use high level tools to implement a deep neural network
- **What we will not do**
 - Creating a complete deep learning IA from scratch
 - Creating a IA to dominate the world

Introduction to machine learning

- **Introduction**
- **I - From neuron to multi-layer network**
 - The biological neuron
 - The formal neuron
 - Multi-layer networks
- **II - Deep learning**
 - Deep neural networks
 - Generative antagonist networks
 - Libraries for deep learning : TensorFlow and Keras
- **Github : <https://github.com/gaysimon/ARTISAN2022>**

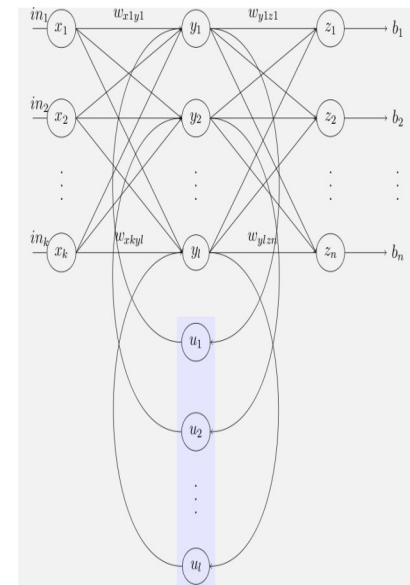
Introduction to machine learning

- **What is (artificial) Intelligence ?**
 - Learning capacities (Beckmann, 2006)
 - Abilities to adapt to a context (Piaget, 1953)
 - Ability to solve problems using new solutions (Gardner, 1989)
- **Artificial Intelligence aims at reproduce these properties on an artificial system**
- **Several approaches where created to reach this goal**

Introduction to machine learning

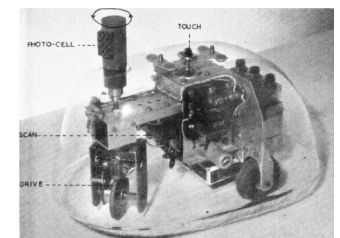
- Since the beginning of AI, two main approaches emerged :
 - **Symbolic AI:** algorithms manipulating symbols and logic rules (inference and deduction)
 - **Connectionist AI:** algorithms made of elements connected with values, and learning mechanisms modifying these values to converge to a solution

```
frère_ou_sœur(X,Y) :- parent(Z,X), parent(Z,Y), X \= Y.  
parent(X,Y) :- père(X,Y).  
parent(X,Y) :- mère(X,Y).  
mère(trude, sally).  
père(tom, sally).  
père(tom, erica).  
  
?- frère_ou_sœur(sally, erica).  
oui.
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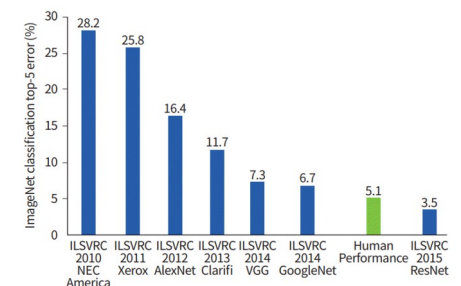
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- **History of artificial Intelligence**
- **Antiquity: myths of artificial persons...
... but also first automatons**
- **Middle-age and renaissance**
 - Mechanical knight (Leonard da Vinci)
 - Vaucanson's automatons (18th)
 - The first robot ? Tea serving doll automaton (17th)
- **20th century**
 - First electromechanical mobile systems (1912)
 - Karel Čapek : Rossum's Universal **Robots** (1921)
 - emergence of *cybernetics* en 1942
 - First forms of Machine Learning (1951)
 - Logistic Regression (1944?), K-nearest neighbors
- **1956: Artificial Intelligence officially becomes a research domain (Dartmouth conference)**



Introduction to machine learning

- **1956 : Effervescence and optimism.**
 - First neural networks (1957), Logic programming (symbolic AI, 1958), K-means (1967)...
- **1974 : crash of AI**
 - Facing the lack of results, funds are canceled in laboratory all around the world
- **Beginning of 80s : renewed interest due to expert systems**
 - Total reign of symbolic approaches
 - Reinforcement Learning (1988), Multi-Agents Systems (middle of 80s)
 - First multi-layer neural systems (but nobody cares)
- **Middle of 90s : lack of progress in expert systems → Second crash of AI**
- **1997 : Chess computer Deep Blue defeats world champion Kasparov** : Strongly renewed interest in research and industry
 - Developmental robotics (middle 90s) and intelligence (middle 2000s)
 - Emergence of neural networks with high number of layers (~2010) (but nobody believe in it)
- **2012 : A deep learning model breaks all records at ILSVRC**
 - Total reign of connectionism approaches



Introduction to machine learning

- **Different types of AI**

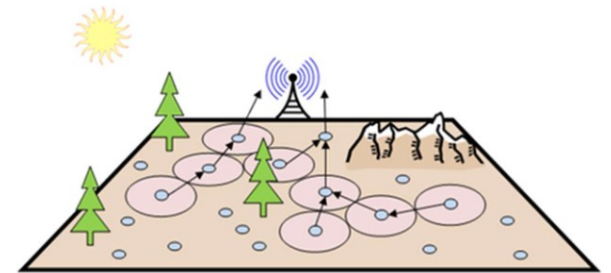
!! there is no official classification

- **Symbolic: inference and deduction from symbols and rules**
 - Logic programming
 - Experts Systems
- **Connectionism: adjustment of numerical values and connections between entities**
 - Neural networks
 - Logistic regression
 - Genetic algorithms
 - Reinforcement learning
 -
- **Emergence: solving problems through interaction between simple entities**
 - Multi-agent systems

Introduction to machine learning

- **Emergence: multi-agent systems**

- Partially inspired by social insects (ants, bees...)
- Systems based on interacting simple entities
- Complex global behavior emerge from simple individual behaviors of entities (*The whole is more than the sum of parts*)



- **Applications**

- Simulation of complex phenomena (crowd, fire propagation, ...)
- Optimization of systems, communication routing
- Cinema and video games (simulation of large armies, e.g. The Lord of the Rings)



Introduction to machine learning

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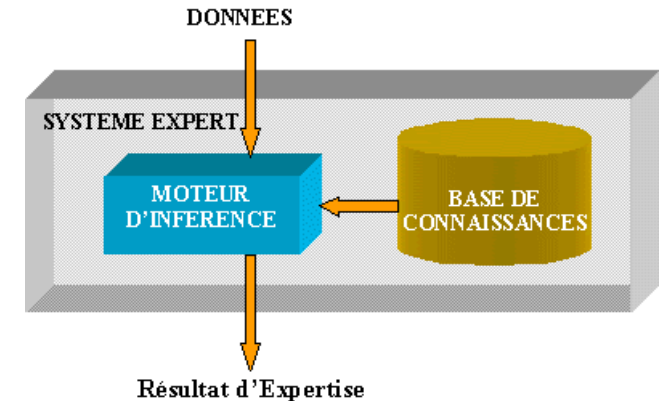
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- **Symbolic AI**

- Set of rules provided by the conceptor
- Relies on the manipulation of symbols
- Most known model: The expert system
 - Aims at reproducing the knowledge of an expert human in a specific domain
- Logic programming languages
 - PROLOG
- No learning (in most models)

- **Applications**

- Widely used to assist decisions in specific domains (e.g. medical fields, diagnostic...)



Introduction to machine learning

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Introduction to machine learning

- **Connectionist AI: a whole family**

- **Supervised learning:** the model is trained on a dataset with known results, then exploited on data with unknown results.
- **Unsupervised learning:** models that can be used with datasets with unknown results. The model must converge toward an optimal solution
- **Reinforcement learning:** The system can interact with its environment and is actively involved in the learning process: the system (or *agent*) perform action and learn from obtained results.

Introduction to machine learning

- **Connectionist AI: supervised learning**

- Learns from a dataset with known results
 - Requires to first create a dataset of labeled data

- Mathematical approaches:

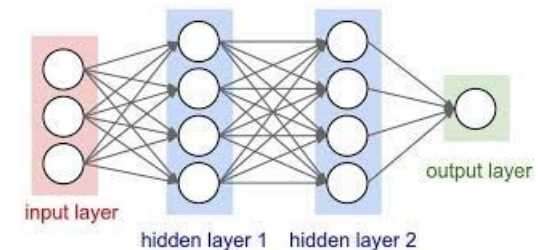
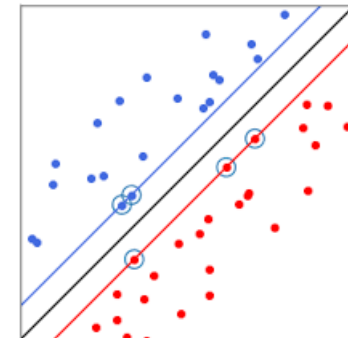
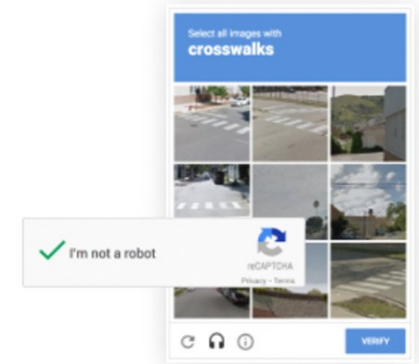
- K-NN
- Logistic regression
- Decision trees
- SVM

- Biologically inspired models:

- Artificial neuron networks

- **Applications**

- Classification and recognition of data, images, text, sound...
- Translation, decision assistance...
 - Note : even a deep learning model cannot 'understand' these data
- ... as soon as a sufficient training dataset is available



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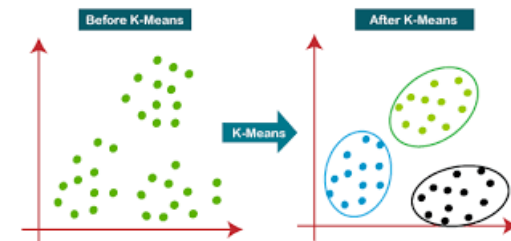
Introduction to machine learning

- **Connectionist AI: unsupervised learning**

- Learning on data with unknown results
 - These approaches are used to organize data
 - The system converge to an optimal organization (or clustering) of data

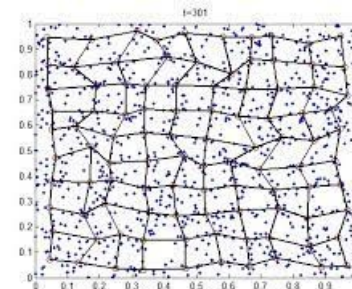
- Mathematical approaches:

- K-means
- Hierarchical clustering



- Biologically inspired approaches:

- Unsupervised neural networks

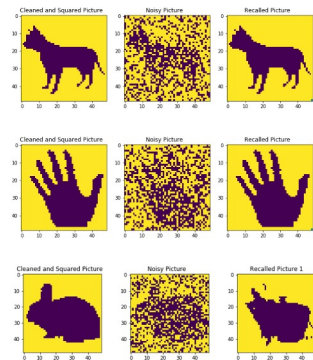
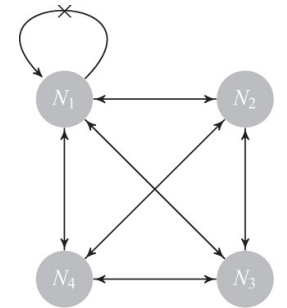


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- **Some well-known unsupervised neural networks:**

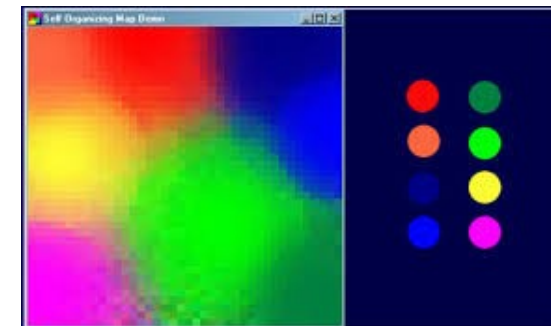
- **Hopfield networks: associative memory**

- Recursive and asynchronous network
- Trained on input data: the network will define a stable configuration for each data
- When presenting an incomplete or noisy data, the network will converge to the closest configuration, reconstructing the original data
- Used to study biological memory principles



- **Self-organizing maps (or Kohonen maps)**

- Inspired by brain's cortex principles
- 2-dimensions networks
- The self organizing map can remap data from a N-dimension space to a 2-D map, while respecting (as much as possible) distance between data.
- Used for complex data analysis and organization



Mapping RGB 3-D space
on a 2-surface

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Introduction to machine learning

- **Connectionist AI: Reinforcement learning**

- Embodied intelligence: an artificial agent interact with an environment
- The agent perceives its environment, acts and analyzes changes
 - The learning process is supervised by the agent itself
- Goal oriented approaches

A predefined reward is attributed when performing a specific task or action

- Reinforcement Learning (1988)
- Q-Learning (1989)

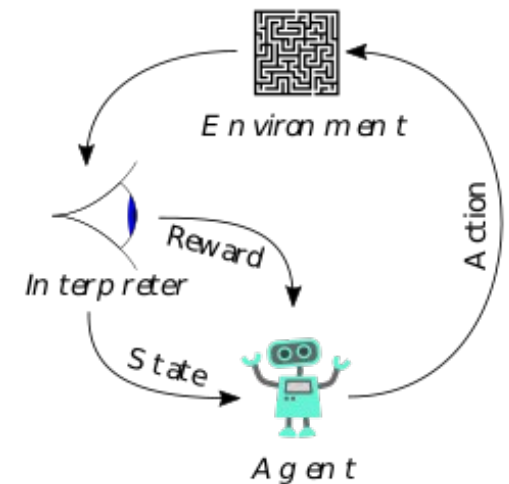
- Behavior oriented approaches :

Used to study living beings development and behavior emergence

- Developmental robotics (middle of 90s)
- Developmental learning (middle of 2000s)

Introduction to machine learning

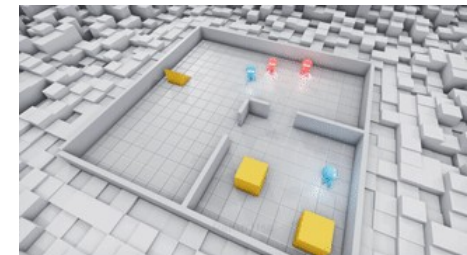
- **Reinforcement learning (RL): goal oriented approaches**
 - The agent can perform a set of actions and perceive the current state of the environment
 - Rewards are given when reaching a certain state or performing a specific task
 - The agent learns to link states and to define best states to cover to maximize future rewards
- **Q-Learning: a variant of reinforcement learning**
 - Consider the best actions to perform instead of state to reach (useful when we do not know how to reach a state)
- **Applications :**
 - Robot control, trading, virtual bots, diagnostic (medical fields)...



Learning to Walk via Deep Reinforcement Learning, T. Haarnoja et al., 2019



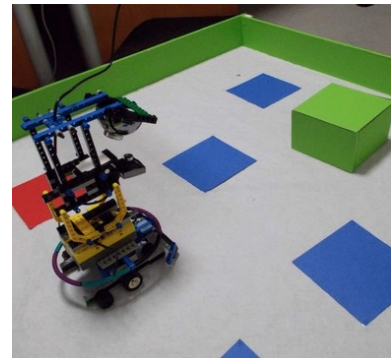
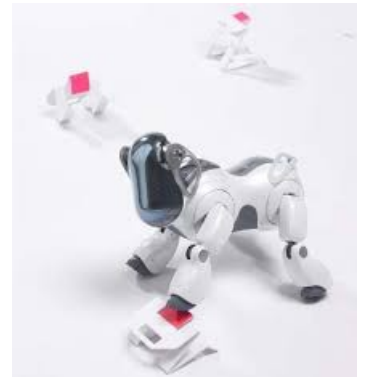
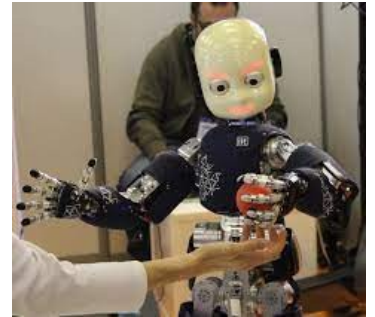
Control of a Quadrotor with Reinforcement Learning, J. Hwangbo et al., 2017



Emergent Tool Use From Multi-Agent Autocurricula, B. Baker et al., 2019

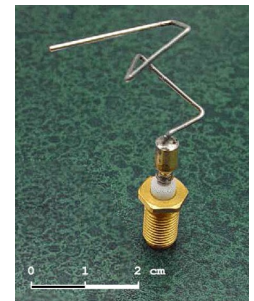
Introduction to machine learning

- **Reinforcement learning (RL): behavior oriented approaches**
 - **Developmental robotics**
 - Fundamental research domain: understanding sensorimotor development stages on humans (and sometime animals)
e.g. crawling, hand-eye coordination, standing up, grab an object...
 - **Developmental learning**
 - Fundamental domain research: understanding the emergence of environment interpretation and behavior emergence on more simple agents through their whole 'life'
 - No external reward, agents are fully autonomous and self-motivated
 - Inspired by psychology theories of cognition (ex Piaget, Gibson)



Introduction to machine learning

- **Reinforcement learning (RL)**
 - **A peculiar model: genetic algorithms**
 - Inspired by species evolution
 - “learning” (optimization) through generations of a population of genes
 - **Principle :**
 - The problem is encoded as a set of parameters: genomes
 - A population is created with random genomes
 - Genomes are evaluated, best genomes are combined to create next generation
 - The genomes are optimized at each new generation
 - **Applications :**
 - Optimisation, routage, object design and architecture, electronic circuits, finance and economics...



Spacecraft antenna

Introduction to machine learning

