Machine learning introduction

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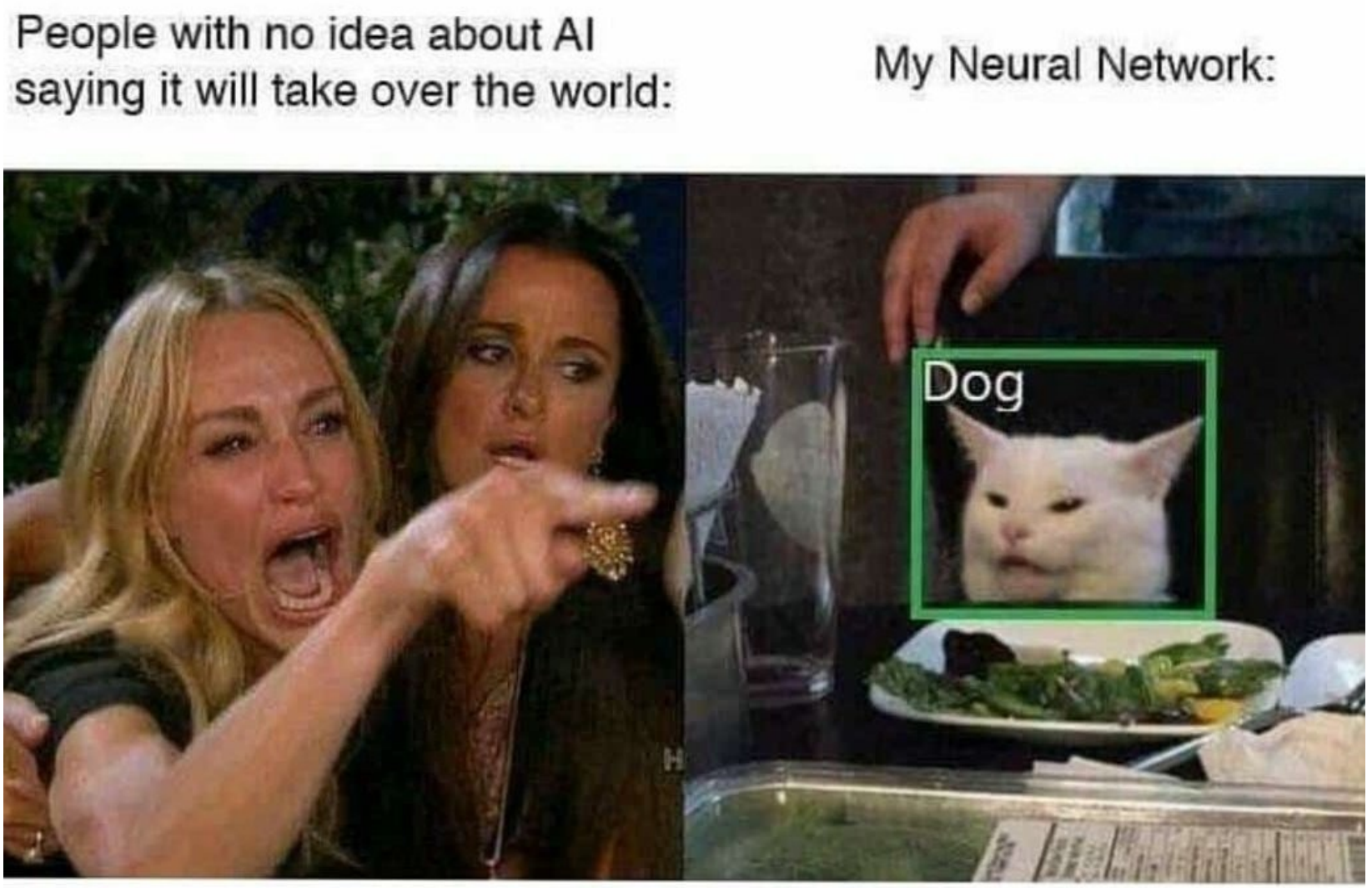
Introduction to machine learning

- **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 basic 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 AI from scratch
  - Creating a AI to dominate the world

Introduction to machine learning



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 reproducing these properties on an artificial system**

- **Several approaches were created to reach this goal**

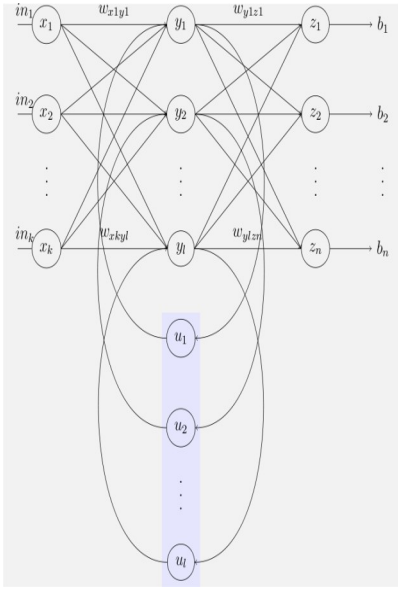
Introduction to machine learning

- **Since the begining of AI, two main approaches emerged :**
  - **Symbolic AI:** algorithms manipulating symbols and logic rules (inference and deduction)

```
mother_child(trude, sally).

father_child(tom, sally).
father_child(tom, erica).
father_child(mike, tom).

sibling(X, Y)      :- parent_child(Z, X), parent_child(Z, Y).

parent_child(X, Y) :- father_child(X, Y).
parent_child(X, Y) :- mother_child(X, Y).
```

```
?- sibling(sally, erica).
Yes
```

  - **Connectionist AI:** algorithms made of elements connected with values, and learning mechanisms modifying these values to converge to a solution



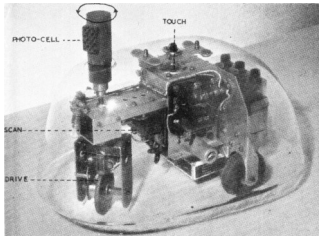
Introduction to machine learning

- **History of artificial Intelligence**
- **Antiquity: myths of artificial persons...**
  … but also first automatons

- **Middle-age and renaissance**
  - Mechanical knight (Leonardo da Vinci)
  - Vaucanson's automatons (18th)
  - The first robot ? Tea serving doll automaton (17th)

- **20th century**
  - First electromecanical 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)**



http://cyberneticzoo.com/cybernetic-time-line/

Introduction to machine learning

- **1956 : Effervescence and optimism.**
  - First neural networks (1957), Logic programming (symbolic AI, 1958), K-means (1967)...

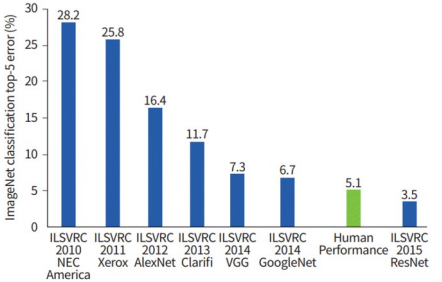
- **1974 : crash of AI**
  - Facing the lack of results, funds are canceled in laboratories all around the world

- **Beginning of 80s : renewed interest due to expert systems**
  - **Total reign of symbolic approaches**
  - Reinforcement Learning (1988), Multi-Agent 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 believes 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
  - Expert 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

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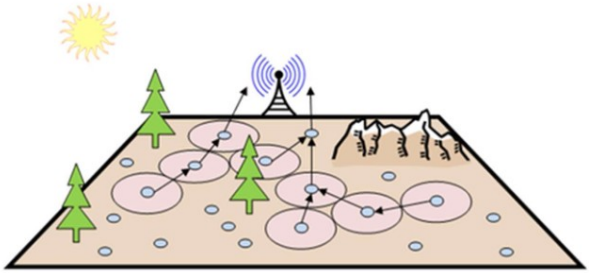

- **Emergence: multi-agent systems**
  - Partially inspired by social insects (ants, bees...)
  - Systems based on interacting simple entities
  - Complex global behavior emerges from simple individual behaviors of entities (*The whole is more than the sum of parts*)

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

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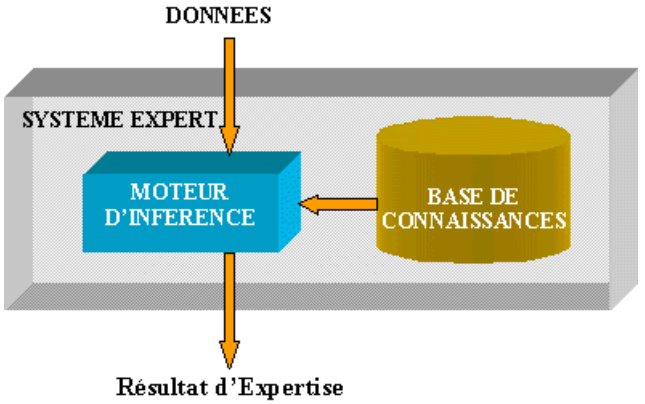

- **Symbolic AI**
  - Set of rules provided by the conceptor
  - Relies on the manipulation of symbols
  - Most known model: The expert system
    - Aims at reproducing the knowledge of an expert human in a specific domain
  - Logic programming languages
    - PROLOG
  - No learning (in most models)
- **Applications**
  - Widely used to assist decision making in specific domains (e.g. medical fields, diagnostic...)

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  - ….

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Introduction to machine learning

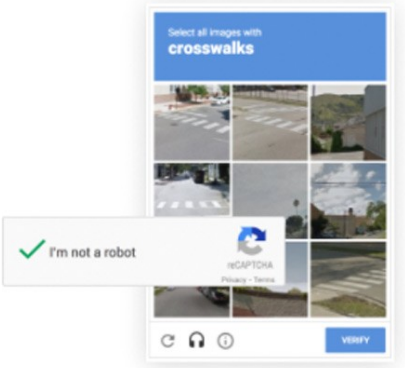
- **Connectionist AI: a whole family**

  - **Supervised learning:** the model is trained on a dataset with known results, then exploited on data with unknown results.

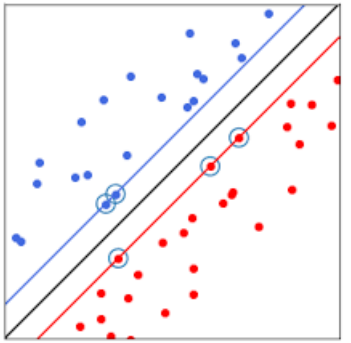
  - **Unsupervised learning:** models that can be used with datasets with unknown results. The model must converge toward an optimal solution

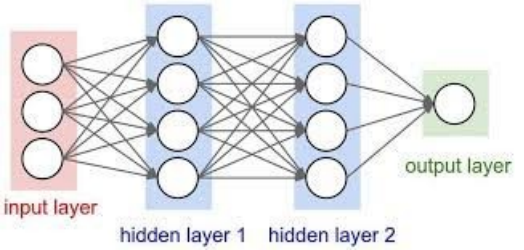
  - **Reinforcement learning:** The system can interact with its environment and is actively involved in the learning process: the system (or *agent*) performs action and learns from obtained results.

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

Introduction to machine learning

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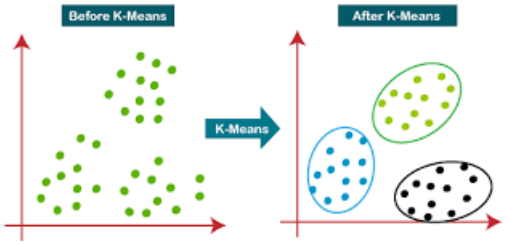
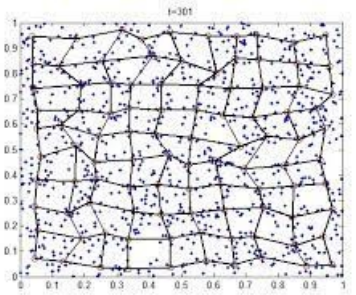
Introduction to machine learning

- **Connectionist AI: unsupervised learning**
  - Learning on data with unknown results
    - → These approaches are used to organize data
    - → The system converges to an optimal organization (or clustering) of data
  - Mathematical approaches:
    - K-means
    - Hierarchical clustering

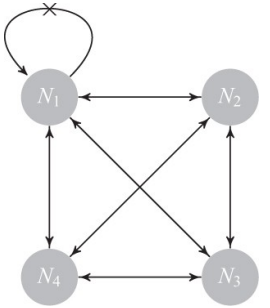


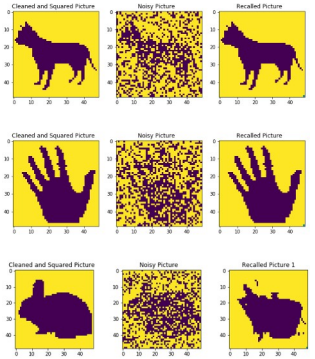
  - Biologically inspired approaches:
    - Unsupervised neural networks



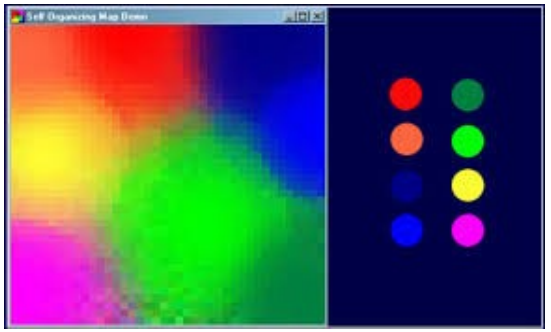
Introduction to machine learning

- **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**

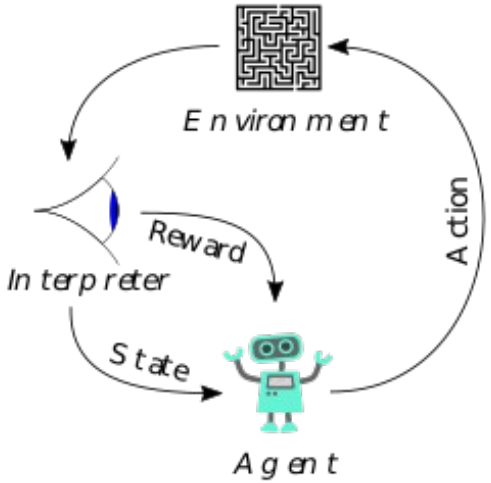
  - Embodied intelligence: an artificial agent interacts with an environment
  - The agent perceives its environment, acts and analyzes changes
    → The learning process is supervised by the agent itself
  - Goal oriented approaches

    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

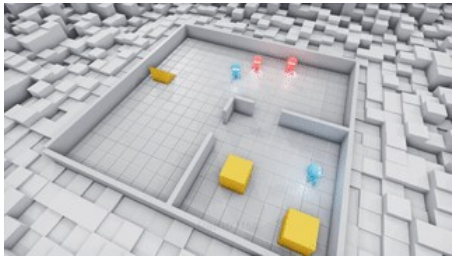


- **Q-Learning: a variant of reinforcement learning**
  - Consider the best actions to perform instead of state to reach (useful when we do not known how to reach a state)

- **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

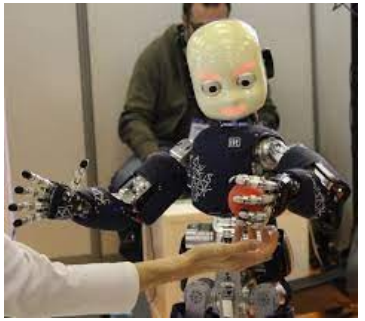


Emergent Tool Use From Multi-Agent Autocurricula, B. Baker et al., 2019

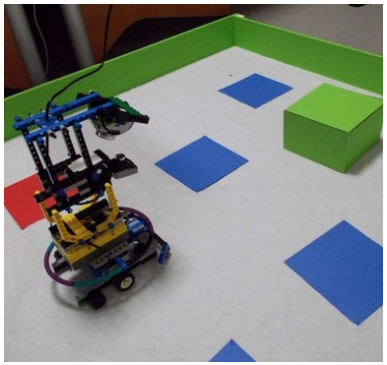
Introduction to machine learning

- **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...

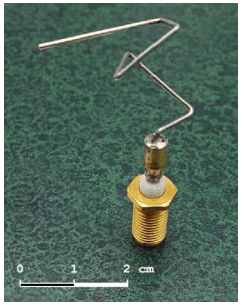


  - **Developmental learning**
    - Fundamental domain research: understanding the emergence of environment interpretation and behavior emergence on more simple agents through their whole ‘life’
    - No external reward, agents are fully autonomous and self-motivated
    - Inspired by psychology theories 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 :**
    - Optimization, routing, object design and architecture, electronic circuits, finance and economics...



Spacecraft antenna

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