Introduction to Artificial Intelligence

What is **AI** ? **A brief overview**

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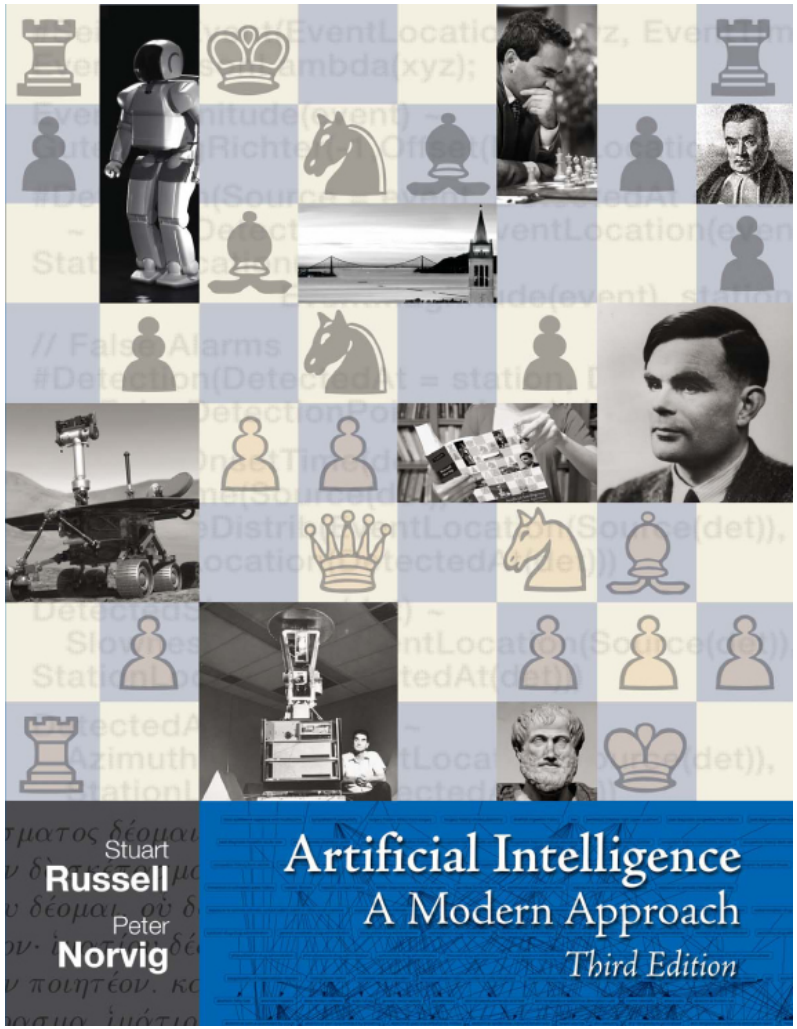
CentraleSupélec Summer School 2019
Artificial Intelligence

Recommended readings - References

- The reference book
  Artificial Intelligence : a modern approach. Russel and Norvig



`http://aima.cs.berkeley.edu/index.html`

Recommended readings - References

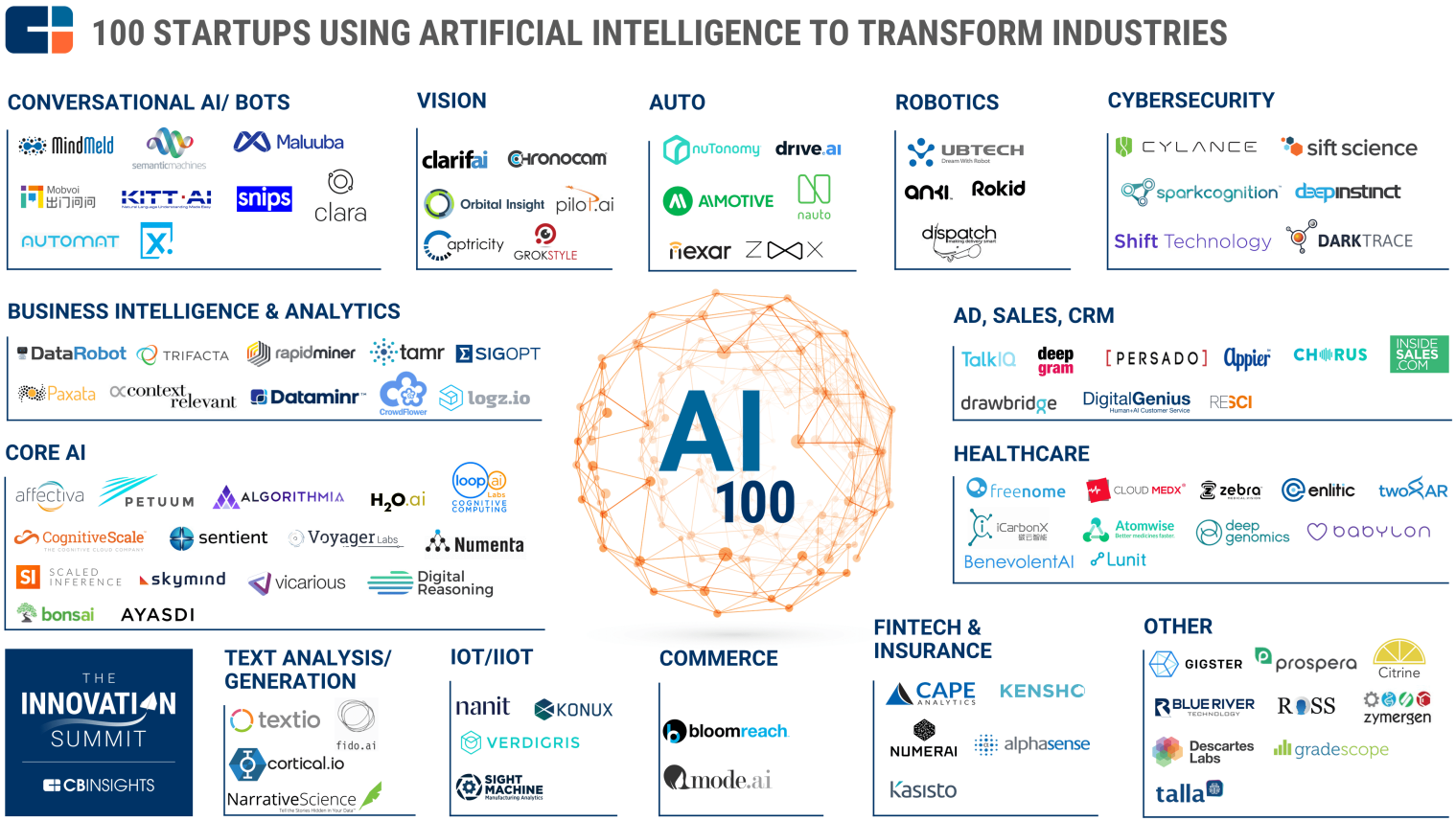
Some courses :

- Stanford CS 221 Course : Artificial Intelligence : Principles and Techniques
  `http://cs221.stanford.edu/`
- Berkeley CS 188 : Intro to AI
  `http://ai.berkeley.edu/home.html`
- And many others...

Recommended readings - References

Other interesting readings

- AI 100 : One Hundred Year Study on Artificial Intelligence
  `https://ai100.stanford.edu/`



The community - Conferences

- IJCAI : International Joint Conference on Artificial Intelligence
  `https://ijcai-17.org/`
- ECAI : European Conference on Artificial Intelligence
  `http://www.ecai2016.org/`
- AAAI : Association for the Advancement of Artificial Intelligence
  `http://www.aaai.org/`

What is Artificial Intelligence for you ?

Short survey

Which movie is the more related to Artificial Intelligence from your point of view ?

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Short survey

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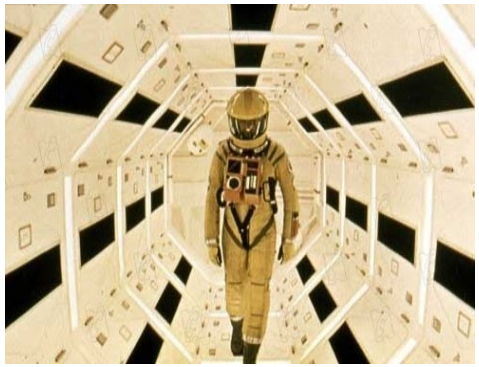



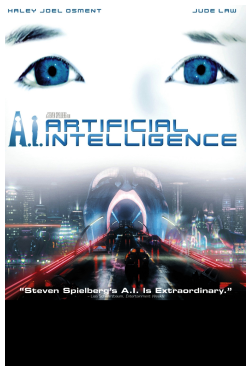

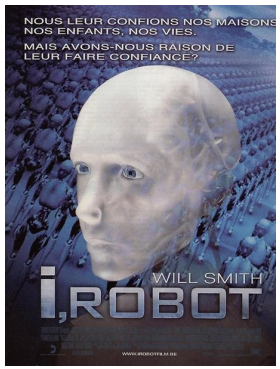


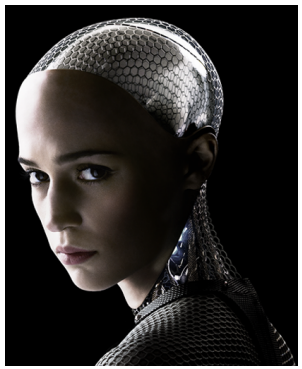

What is Artificial Intelligence for you ?

Short survey

Which picture is the more related to Artificial Intelligence from your point of view ?

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Short survey

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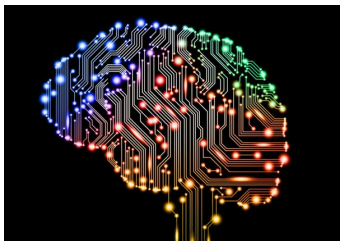
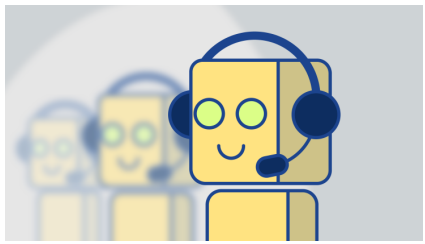
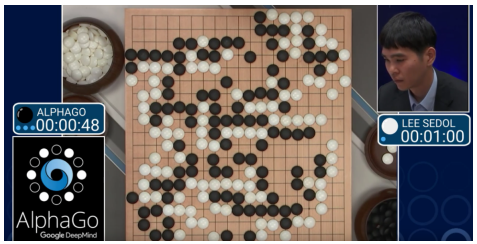
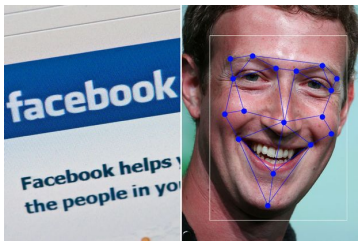





An attempt to define AI

Artificial Intelligence is

A sub-branch of computer science aiming at building intelligent programs or intelligent systems.

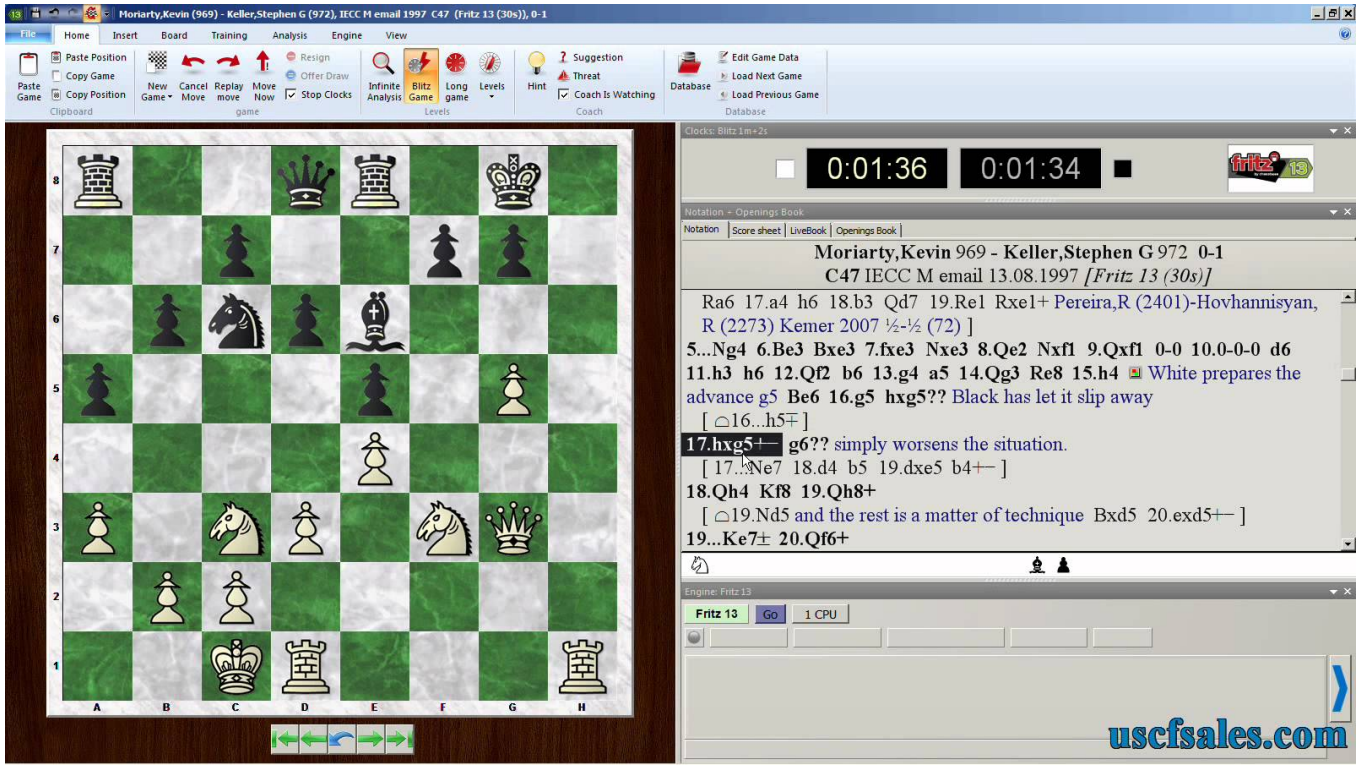
- What is a **program** or a **system** ?
- What is **intelligence** ?

Instead of **what is AI**, a good question is **what can AI do for us ?**

Some tasks that required intelligence

Example : Games

Decision making



Humans against machines

One of the great and well-known *success* of AI : **when the machines win the human games**.

1997: Deep Blue (chess)

2011: IBM Watson (Jeopardy!)

2016 : AlphaGo (Go)

Some tasks that required intelligence

Exemple : Robotics

Perception, decision-making, action, communication, learning

Projet Cog MIT (`http://www.ai.mit.edu/projects/humanoid-robotics-group/cog/`)

Some tasks that required intelligence

Example : Driving a car

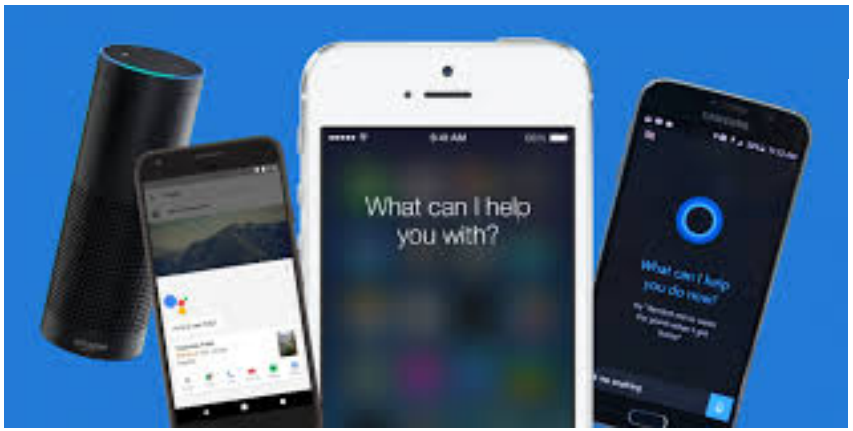
Perception, recognition, decision-making, action, learning

Some tasks that required intelligence

Exemple : Virtual assistant - NLP - Automatic Translation [a]

a. e.g. Google Translate supports 90 langages and 200 millions of users

Perception, recognition, decision-making, action, learning

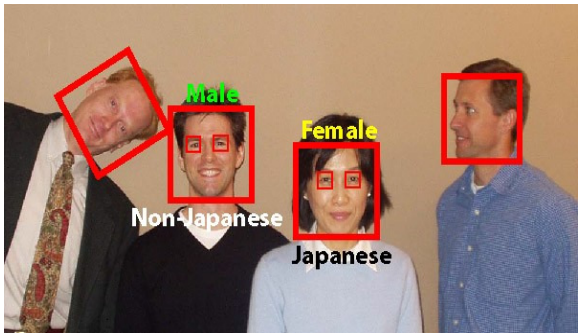


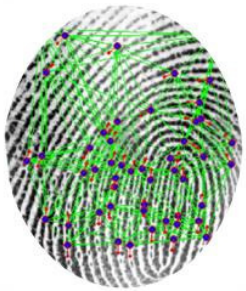
Some tasks that required intelligence

Visual recognition [a] - Image interpretation

a. Optical character recognition : *Operational in the mail sorting domain since 2000 (Paper Y. LeCun, CNN 1989).*

Decision-making, perception, recognition, learning



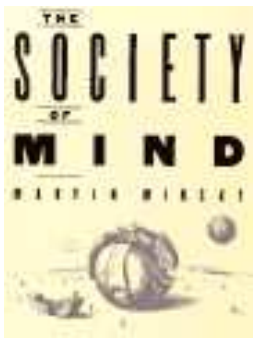


Fingerprint Analysis Software

Artificial Intelligence : definition from a founding father

Marvin Minsky :
"The science of making machines do things that would require intelligence if done by men"

http ://web.media.mit.edu/~ minsky/



Definition related to what human do !

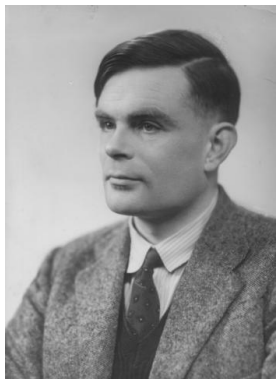
- Intelligence ?
- What means making machines do things ?

"The things that are very easy for humans (for instance grasping an object) are very difficult to reproduce for machines whereas things that are difficult for humans (as playing expert chess) are easy for machines. "

What is *intelligence* ?

Several answers

- According to Turing
  Ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of an human.



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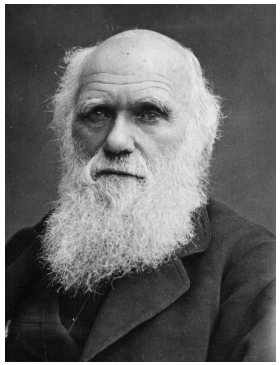
- According to Darwin
  Ability to survive and reproduce



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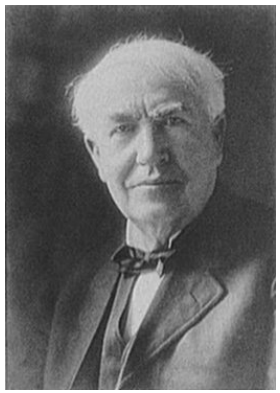
  Ability to survive and reproduce
- According to Edison
  Ability to make things that work



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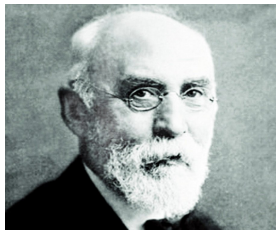
- According to Edison
  Ability to make things that work
- According to Lorentz
  Collective intelligence



Artificial Intelligence : several definitions

Thinking like humans	Thinking rationnaly
The exciting new effort to make computers think... machine with minds, in the full and litteral sense.(Haugeland,1985) *The automation of activities that we associate with human thinking, activities such as decision-making, problem sloving, learning.*(Bellman, 1978)	*The study of mental faculties through the use of computational models* (Charniak and Mc Dermott, 1985) *The study of the computation that make it possible to perceive, reason and act*(Winston, 1992)
Acting like humans	**Acting rationnaly**
The art of creating machines that perform functions that require intelligence when performed by humans (Kurzweil, 1990) *The study of how to make computers do things at which, at the moment, people are better*(Rich and Knight, 1991)	*Computationbal intelligence is the study of the design of intelligent agents*(Poole et al, 1998) *AI... is concerned with intelligence behavior in artifacts*(Nilsson, 1998)

Thinking humanly : cognitive sciences

The human brain = an information processing machine. Systems should solve problems the same way humans do.

- Study of human brain and human behavior ?
- Requires scientific theories of internal activities of the brain
- Reproduction of these scientific theories and comparison with human behavior
- Validation :
  - Predicting and testing the behavior of human subjects top-down : cognitive sciences).
  - Direct identification from neurological data (bottom-up : Cognitive neuroscience).

Example

General Problem Solver (Newell and Simon,1967) : model of the human information processing approach. An universal problem solving system

Acting like an human : The Turing test (1950)

Idea

The Imitation game : do not define AI but test it !

Principle

An Interrogator converses with a man and a machine via a text-based channel. If the interrogator fails to guess which one is the machine, then the machine is said to have passed the Turing Test.

Requirements

NLP, Knowledge Representation, Automatic Reasoning, Learning, Interaction

Interesting Idea : Decoupling of what to solve from how to solve.

The Turing Test

- An annual challenge since 1991 : "The loebner prize [a]"
- Other applications :
  - Bot Challenge : AWS Chatbot Challenge
  - The Visual Turing Challenge : VQA, Visual Dialog, TQA
    - http://demo.visualdialog.org/
    - https://arxiv.org/abs/1410.8027
    - http://vuchallenge.org/
  - Use in commercial services (more and more chtabots on web sites)

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a. http://www.loebner.net/Prizef/loebner-prize.html, http://www.aisb.org.uk/events/loebner-prize

Turing test criticisms

The Chinese room [Searl,80]

- A man in an insulated room
- In the room, there are some questions - answers written in Chinese.
- The man does not speak chinese
- It receives written questions, he copies the answers and sends them.

- The man does not understand Chinese !

Turing test is not reproducible, constructive or amenable to mathematical analysis.

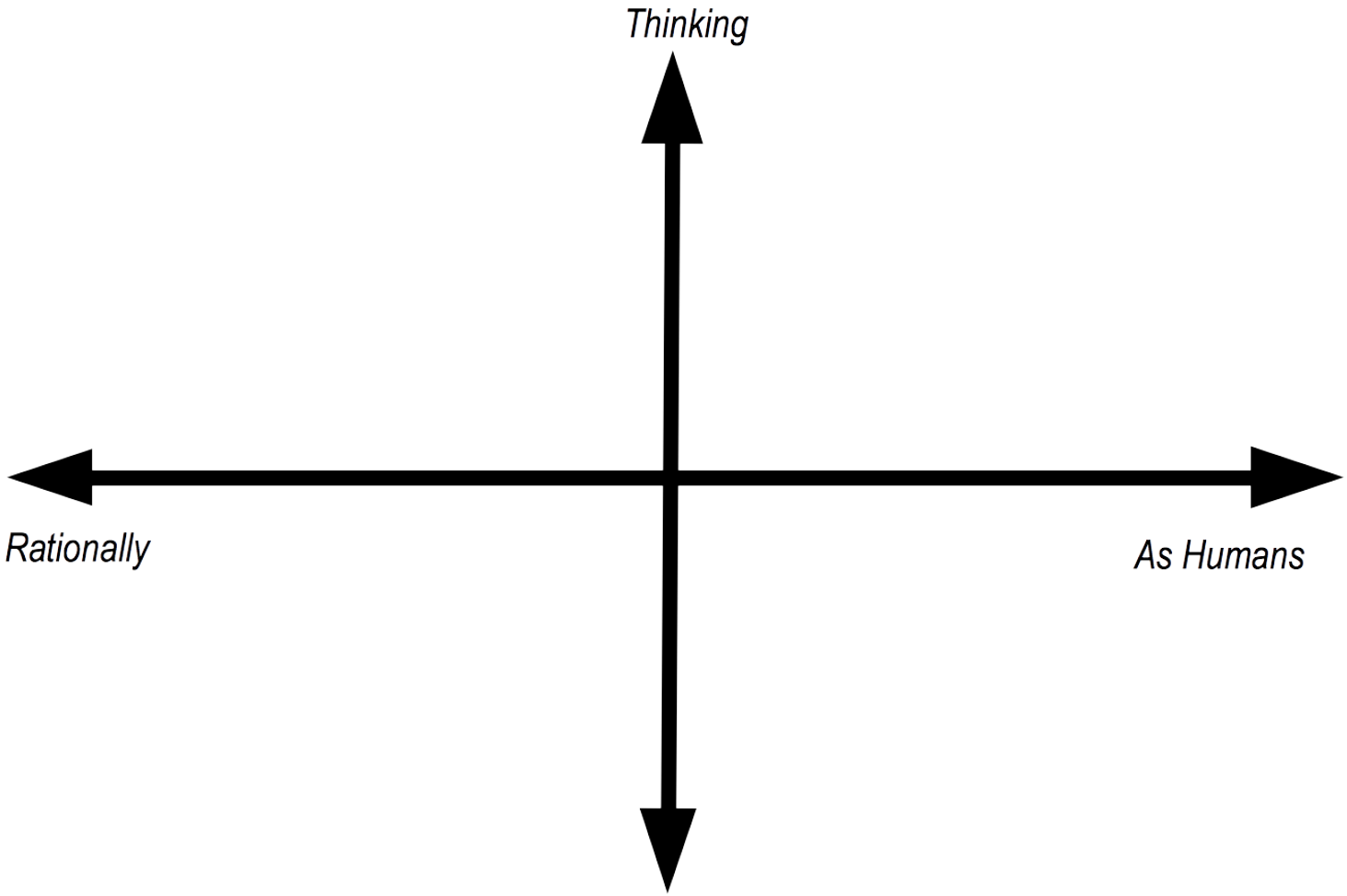
Thinking rationally : Laws of Thought

- Aristotle and the *right* thinking and irrefutable reasoning : Logics.
  - e.g. : *All humans are mortal, Socrate is an human, thus Socrate is mortal.* (syllogism)
- Rational thinking is based on logic inferences (Logics)
  - Notations for statements about all kinds of objects in the world and the relations among them.
- Main difficulties :
  - Not all intelligent behavior is mediated by logical deliberation.
  - Not easy to take informal knowledge and state it in the formal logical notations (uncertainty).
  - Big difference between solving a problem in principle and solving it in practice (complexity).

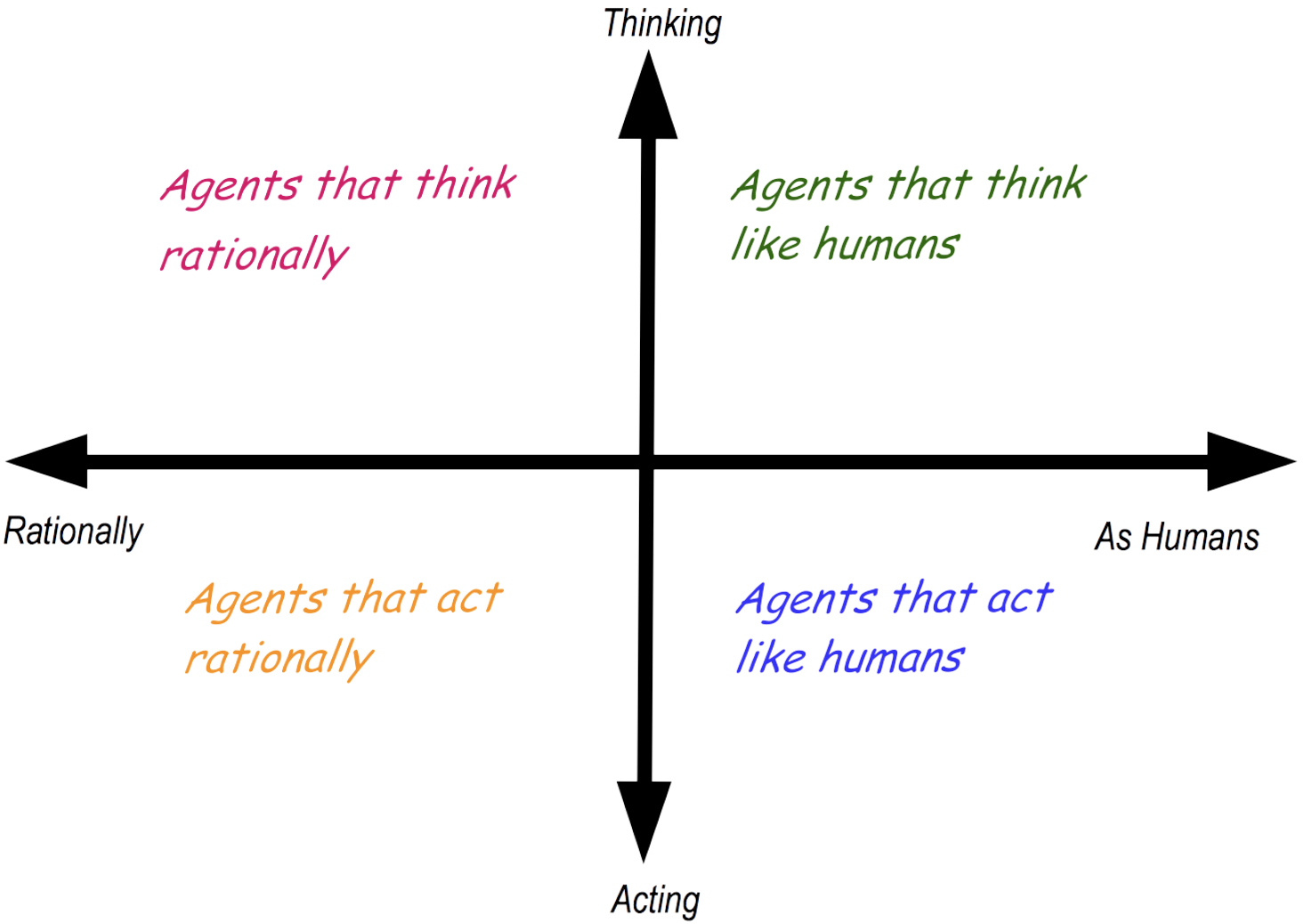
Acting rationally : The rational agent approach

- Rational behavior :
  - doing the right thing : that which is expected to maximize **goal achievement** given the available information.
- Does not necessarily involve thinking (e.g. : blinking reflex) but in the service of a **a rational action, a goal**.
- Goals are expressed in terms of the **utility** of outcomes.
- Being rational means **maximizing your expected utility**
- Rather than *Artificial Intelligence*, we could speak of *Computational rationality*.

The approaches of AI



The approaches of AI



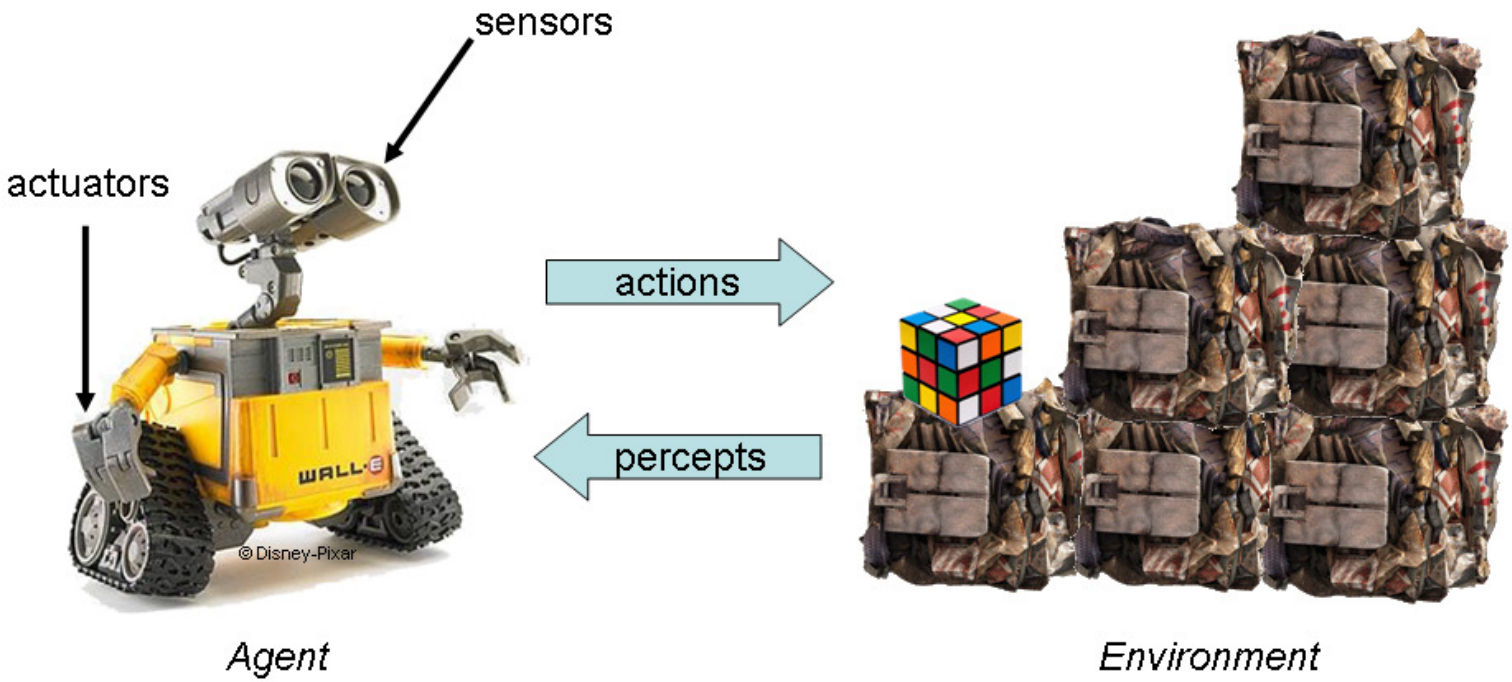
Rational Agent

Definition

An agent is an entity that perceives and acts in its environment.

- A rational agent selects actions that maximize its expected utility.
- The characteristics of the **percepts, environment** and **action space** dictate the way of selecting rational agents.

What is an intelligent agent ?



An intelligent agent is an entity that perceives its environment through sensors and acts on it through actuators.

What is an intelligent agent ?

- For an human :
  - Sensors : eyes, ears, skin, tongue, nose...
  - Actuators : the members : arms, legs, mouth, hands..
- For a robot :
  - Sensors : camera, microphone, touch interface ...
  - Actuators : artificial legs and arms, clamps...
- For a softbot :
  - Sensors : data, strings...
  - Actuators : operators,...

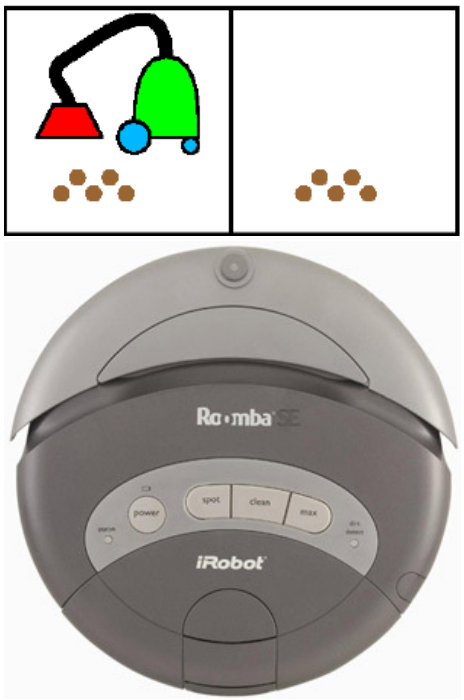
Definitions

- Perception (percepts) : Agent perceptual input at a time.
- Percept sequence : complete history of what has been perceived
- Agent behavior = agent function f that maps the given percept sequence $\mathcal{P}^*$ into a sequence of discrete actions $\mathcal{A}$.

$$f : \mathcal{P}^* \rightarrow \mathcal{A}.$$

- Concrete implementation : agent program.
  Run on a complete architecture to compute f.

Classical example : the vaccum agent



$\mathcal{AS} = (\mathcal{P}_1, \mathcal{A}_1, f)$ with :

- $\mathcal{P}_1 = Loc \times State$ with $Loc = \{A, B\}$ et $State = \{clean, dirty\}$
  $\mathcal{P}_1$ is a set of couples (Location, State).
- $\mathcal{A}_1 =$
  $\{move\ right, move\ left, suck, do\ nothing\}$

Classical example : the vaccum agent

Séquence de perceptions	Action
$(A, propre)$	$droite$
$(A, sale)$	$aspirer$
$(B, propre)$	$gauche$
$(B, sale)$	$aspirer$
$(A, propre)(A, propre)$	$droite$
$(A, propre)(A, sale)$	$aspirer$
⋮	⋮

FIGURE – Excerpt of the table for the agent function

Rational Agent

Definition

An agent is an entity that perceives and acts in its environment. A rational agent, for each possible percept sequence, does whatever actions that maximize its expected performance measure

How to measure the performance ?

- With some external criteria (e.g. : quantity of sucked dust, cleaned area, noise...)
- Set by the designer
- Depending on the task.

Rational Agent

Rationality

Depends on

- The performance measure (success criteria).
- The knowledge on the environment.
- The possible actions.
- The percept sequences of the agent.

Task Environment

PEAS

The first task to design a rational agent is to specify the task environment (PEAS) :

- Performance measure.
- Environment.
- Actuators.
- Sensors.

Property of the environment

Observable :

- Do the sensors give at a time a complete view of the environment ?

Deterministic vs stochastic :

- The state of the environment depends on the current state and on the action of the agent ?

Episodic :

- Evaluation of the quality of an action into a cycle (perception-action) ? Next and future steps are needed ?

Static :

- Can the environment change during the agent deliberation ?

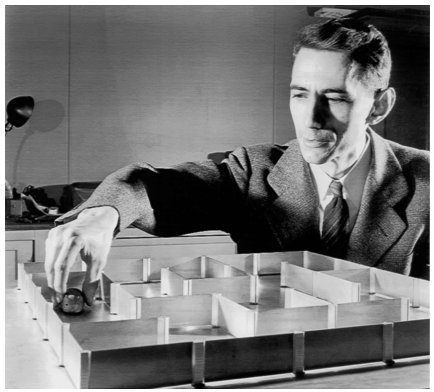
Discrete :

- Discrete states (e.g. :playing chess) or continous (e.g. : walking) ?

AI history : the founding fathers

Shannon (1916-2001)

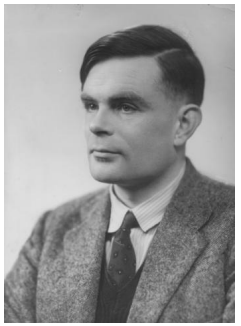
- Information theory.
- One of the AI pionner : The first AI able to play to chess : *Programming computer for playing chess*



AI history : the founding fathers

Turing (1912-1954)

- Computer scientist, Mathematician, Physician, Philosophist
- The turing machine



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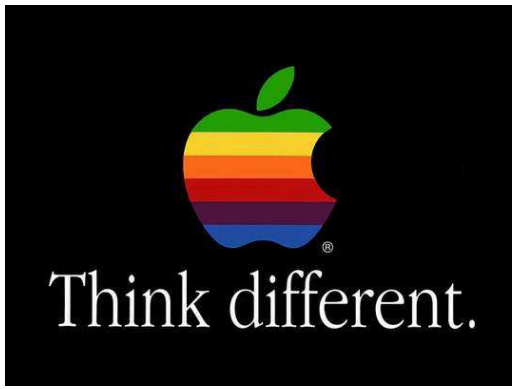

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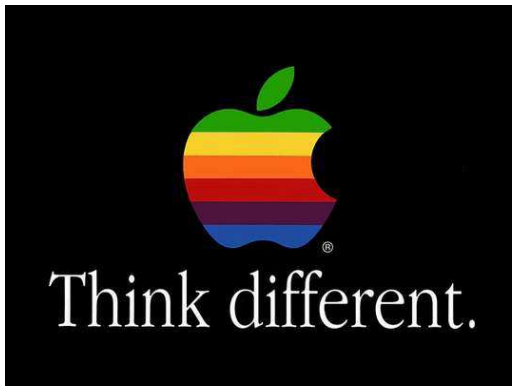


Dip the apple in the brew/Let the sleeping death seep through

AI history : the founding fathers

Newell (1927-1992) and Simon (1917-2001)

- Authors of the *Logic Theorist* : linked lists.
- Chess game programming
- Decision making (Simon, Economy Nobel Prize in 1977)

AI history : the founding fathers

Mac Carthy (1927-2011)

- Coined the term Artificial Intelligence
- Developed the LISP language
- University of Stanford : *http ://www-formal.stanford.edu/jmc/*

History of AI : gestation period

- 1936-1955 : gestation period
  - Artificial neuron [McCulloch and Pitts, 1943] : boolean circuit model of the brain
  - Turing : *Computing Machinery and Intelligence* : Computable functions are defined by a machine
  - Von Neumann : Computer architecture, Automaton
- 1956, the birth : the Darmouth meeting
  - Symbolic reasoning (Logic Theorist) [McCulloch and Pitts]
  - The name Artificial Intelligence is proposed [McCarty]

History of AI : the beginning (1956-1970)

AI as generic methods

- 1952-1969 : the period of euphoria
  - Generic search methods : GPS (General Problem Solver) [Newell and Simon]
  - LISP : high level programming language [McCarty]
  - Adalines [Widrow], Perceptron [Rosenblath]
  - AI that plays chess (Samuel)
  - Symbolic reasoning (Logic Theorist) [McCulloch and Pitts] (Theorem proving)

AI discovers computational complexity. Neural network research almost disappears.

History of AI : the second period (1969-1979)

Importance of knowledge

- J.A. Robinson : complete algorithm for logical reasoning- PROLOG
- Knowledge-based systems - Inference rules
- Knowledge representation : structured representations, other logics
- AI is divided into several fields : Natural language processing, automatic proving , games, knowledge representaton, perception, machine learning...

But, the knowledge acquisition bottleneck !

History of AI : (1980-1990)

The machine learning period

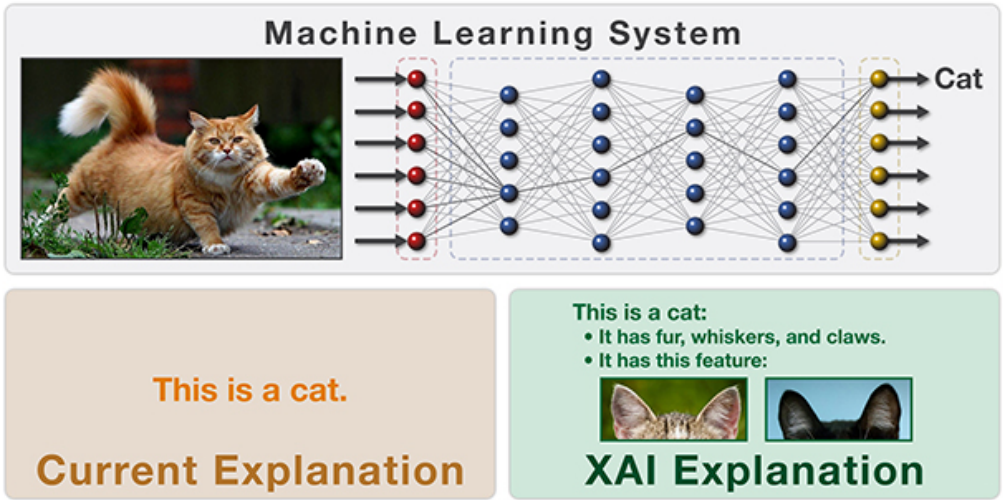
- Symbolic and statistical approaches
  - Decision trees
  - Neural networks
  - Multi-layer perception
  - Distributed AI : multi-agents

History of AI : since 1990

- Efficient approaches and algorithms for problem solving (SAT and CSP).
- Deep blue wined Kasparov at the chess game in 1997.
- Natural Language Interfaces.
- Expert systems in real time.
- Re-birth of the neural networks, Kohonen maps
- Hidden Markov models, probabilistic reasoning, data mining, bayesian network (uncertainty)
- Knowledge-based approaches are declining.
- Increase of the available data (Web) : indexation, information retrieval, information extraction, ontologies

History of AI : Today

- **Deep learning, deep learning and again deep learning...**
  N. Paragios : My deep depression
  https://www.linkedin.com/pulse/computer-vision-research-my-deep-depression-nikos-paragios
- School of though on **Explainable AI**
  http://home.earthlink.net/~dwaha/research/meetings/ijcai17-xai/



A turning point ?

AI in the new age : a turning point ?

Maybe but :

- It was always an expectation in the 60s
- Then, first *AI Winter* in the 70s.
- Rebirth of AI with expert systems and new *AI Winter* in the 80s.
- History is repeating... Not so long ago, AI was considered as an old science and neural networks as inefficient...

Predictions and realities

An evidence

Progress has been made in all the domains, but we remain still so far of our initial aims

Predictions and realities

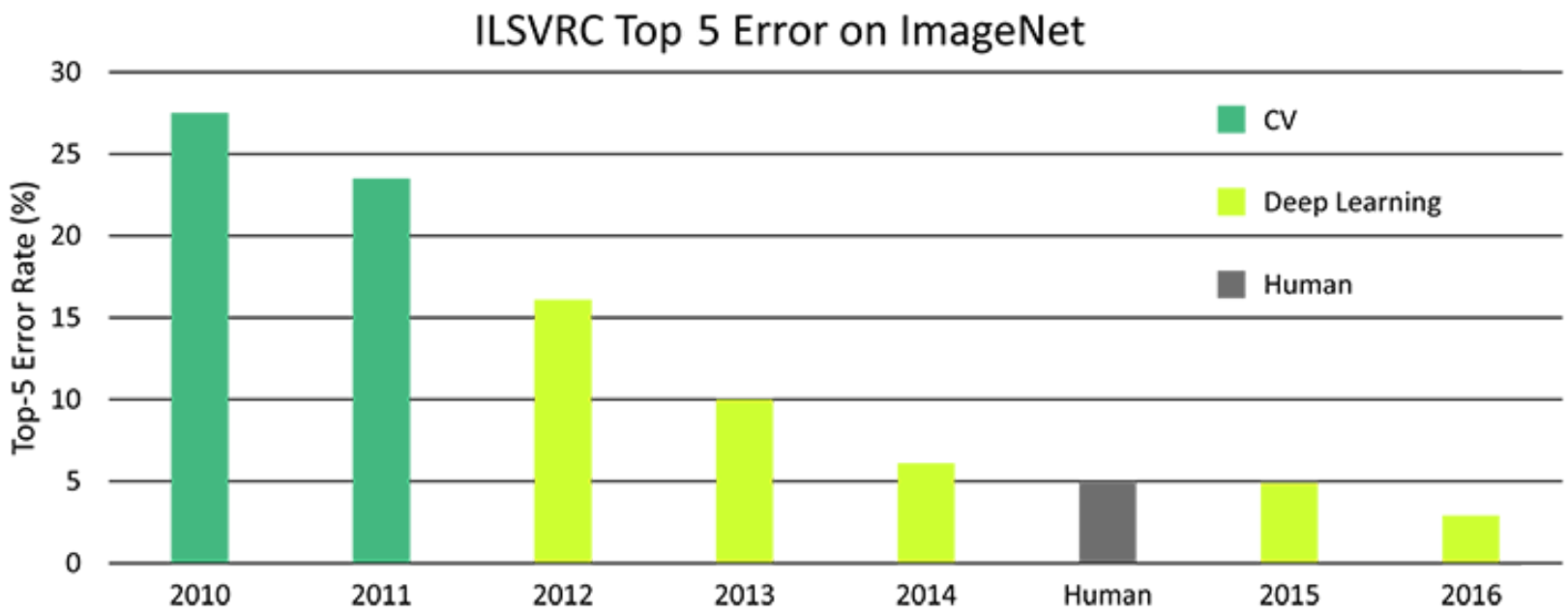
- Today, there is no artificial vision system that is able to recognize objets as efficiently than humans [ECVision]
- But, intelligent systems for :
  - video-surveillance
  - biometry
  - medical image analysis
  - ...

Predictions and realities

Image classification

ILSVRC challenge [a] : 1000 categories. A turning point in 2012

a. http://www.image-net.org/challenges/LSVRC/

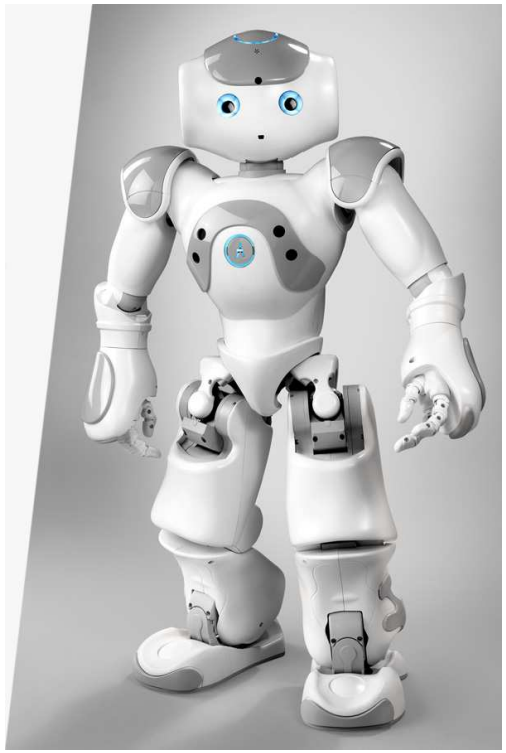


Predictions and realities

- In 1958, Simon predicted that a computer will win in chess in 10 years.
- Deep blue in 1998
- Winner in chess, checkers, reversi
- Until 2016, the Go game was a challenge but since 2016, expert level...

Predictions and realities

- In 1970, we predicted that robots will be everywhere.
- It's not the case, domestic robots are still in fictions
- But, industry is full of robotics, robotics in surgery...



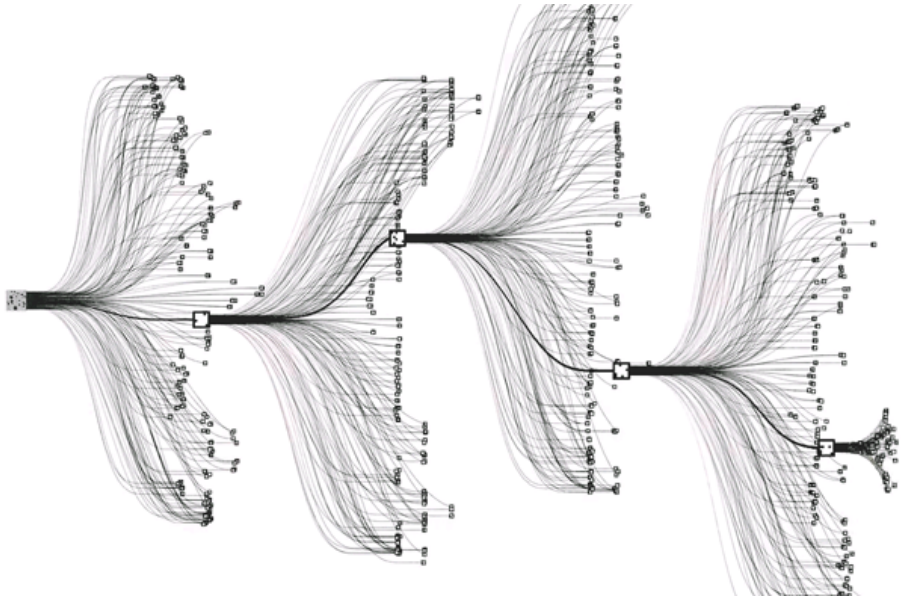
Main characteristics of AI problems

- High societal and economic impact (affect billions of persons)
- Diverse.
- Complex.

Why AI problems are complex ?

Computational complexity

- Several problems are NP-complete.



https://en.wikipedia.org/wiki/Go_and_mathematics

Why AI problems are complex ?

Data - Information - Knowledge

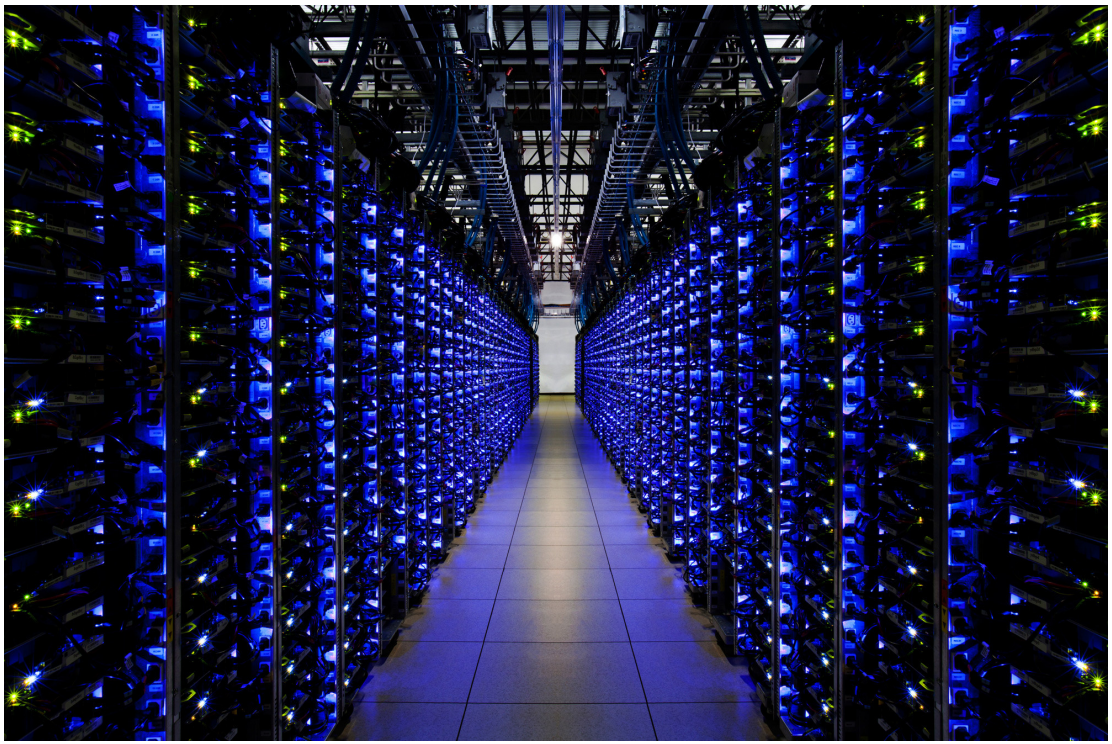
More than data, knowledge is mandatory (implicit or explicit) to learn, reason and explain and justify a decision.

What represents this image ?

From AI to Explainable AI

AI : available resources

Computation and storage resources



AI : available resources

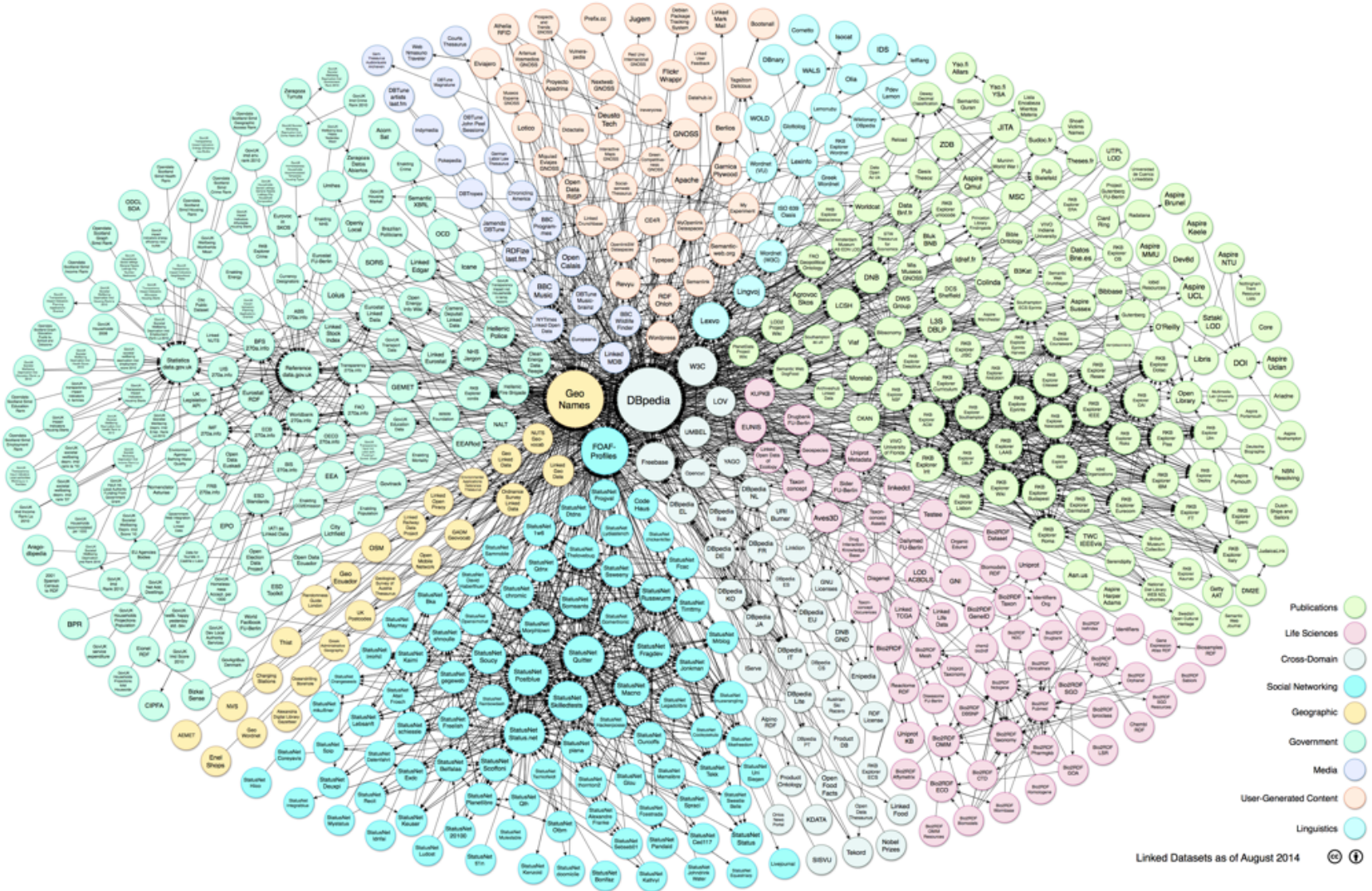
Data deluge (for some tasks)

But, data are not labeled or with bias [1],

1. Unbiased Look at Dataset Bias : http://people.csail.mit.edu/torralba/research/bias/

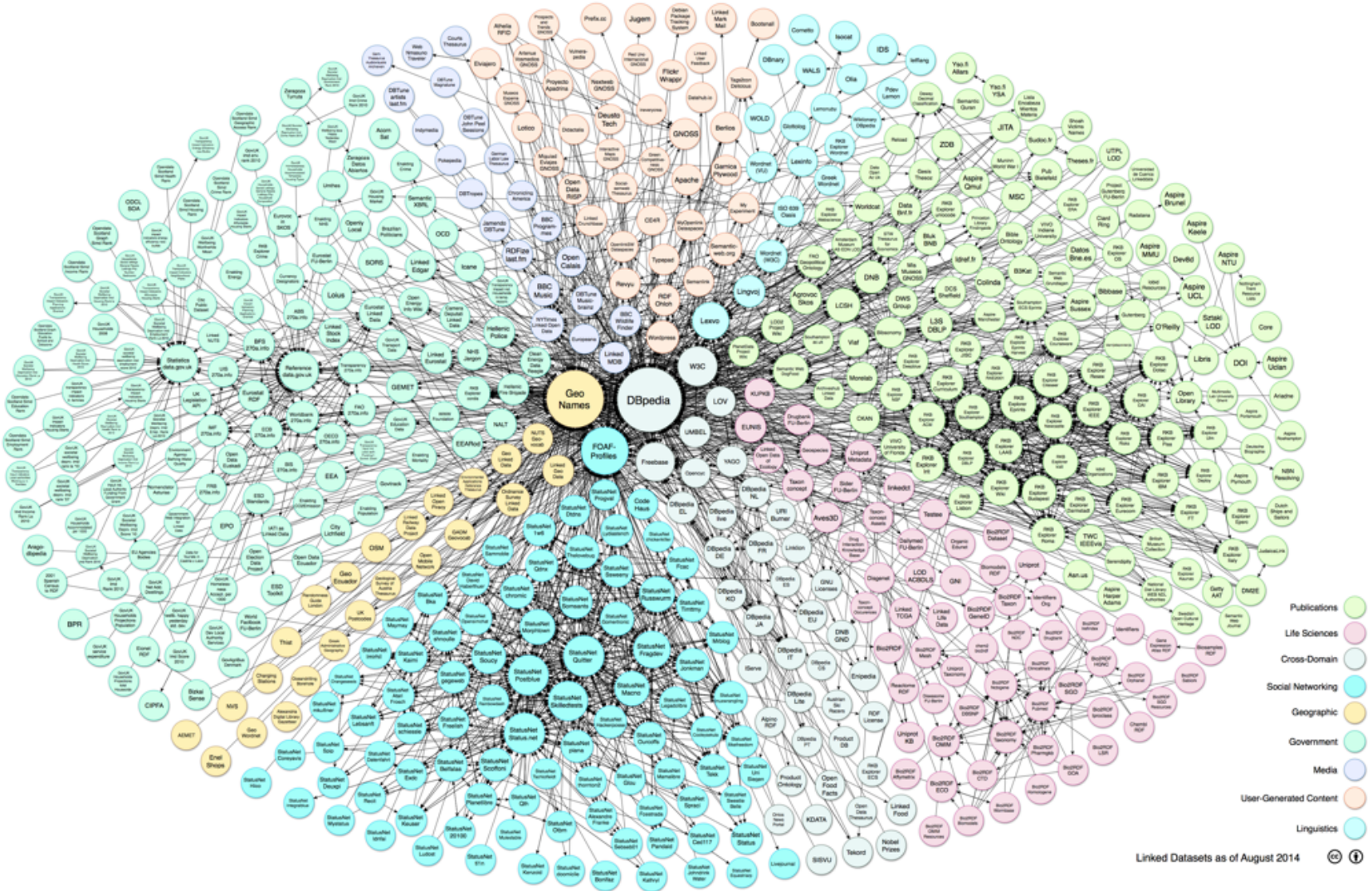
AI : available resources

Formal knowledge : ontologies in some domains, knowledge graphs (RDF triple store) (DB-Pedia, Yago, Knowledge Graph,...)



AI : available resources

Formal knowledge : ontologies in some domains, knowledge graphs (RDF triple store) (DB-Pedia, Yago, Knowledge Graph,...)



How to tackle an AI problem ?

Main paradigm

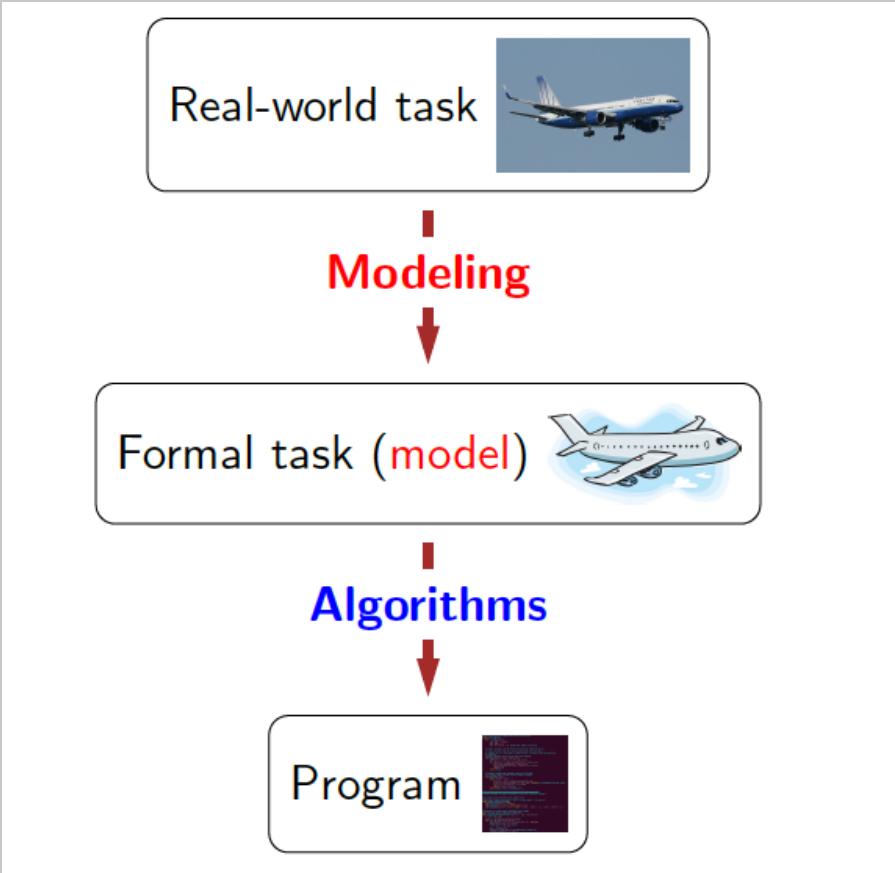


FIGURE – Source : cs221 course Stanford - Liang

How to tackle an AI problem ?

Example

- **Real task**
  - Input : list of 10000 web pages and a query
  - Output : 10 more relevant resukts for the query

Modeling

- $L = list(\text{web pages})$, q
- $f(x, q) = 10.match(x, q) + 3.pagerank(x)$

- **Formal Task**
  - Input : $L = [x_1, ...x_n], q$ and a function $f : X \times Q \rightarrow \mathbb{R}$
  - Output : k higher scores of f

Decoupling of what to solve (**modeling**) from how to solve **(algorithms)**

How to tackle an AI problem ?

Modeling-Inference-Learning paradigm

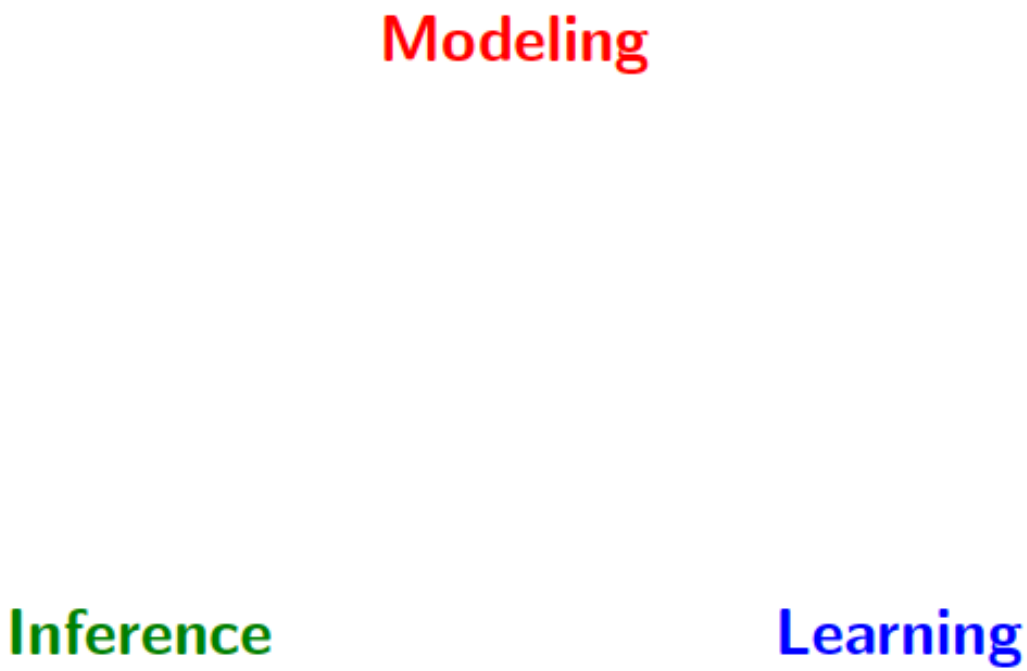


FIGURE – Source : cs221 course Stanford - Liang

How to tackle an AI problem ?

Modeling

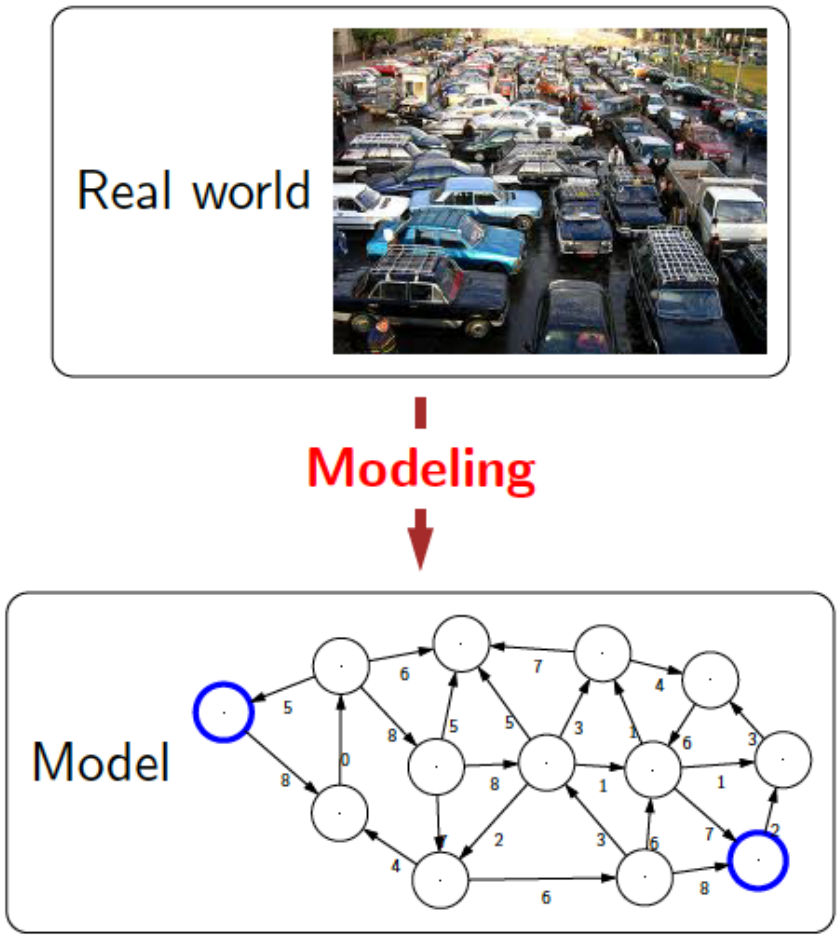


FIGURE – Source : cs221 course Stanford - Liang

How to tackle an AI problem ?

Inference

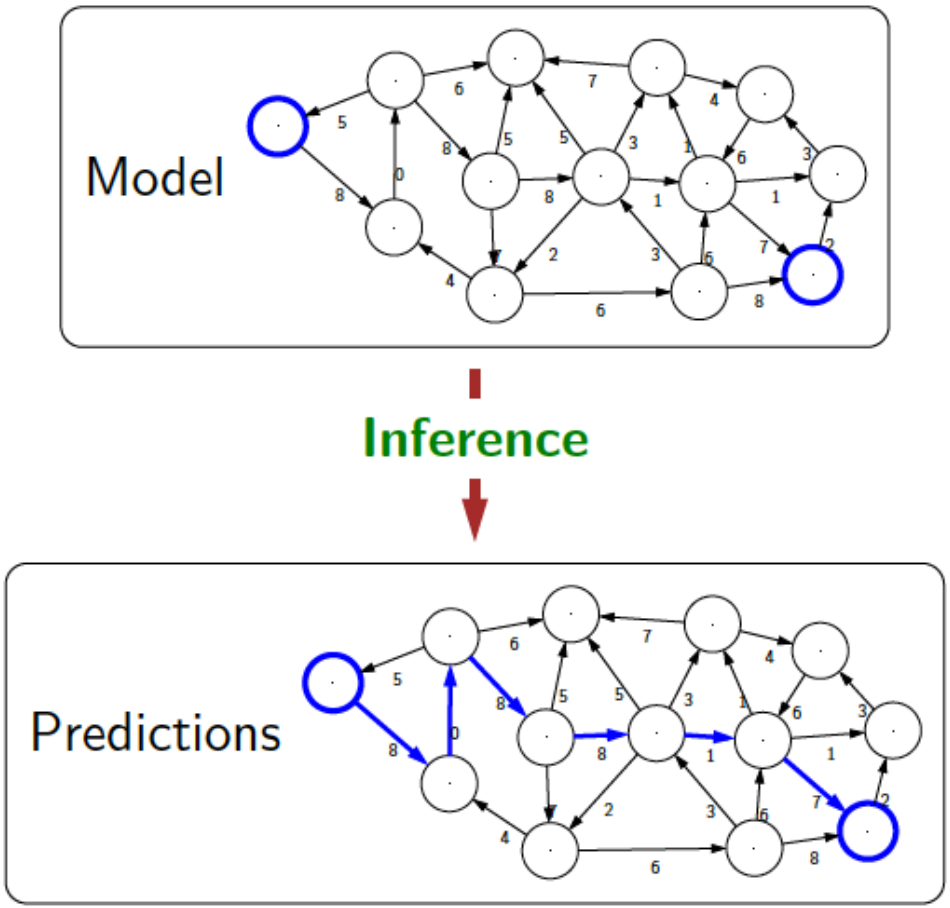


FIGURE – Source : cs221 course Stanford - Liang

How to tackle an AI problem ?

Learning

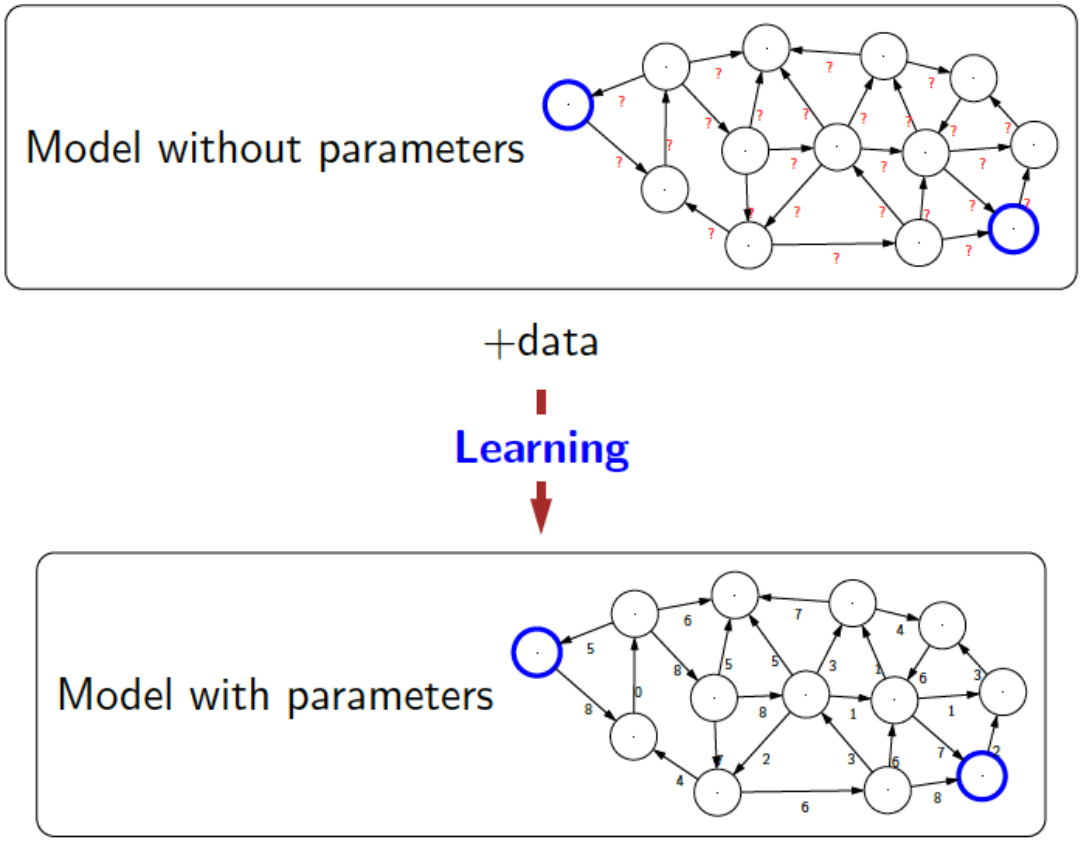


FIGURE – Source : cs221 course Stanford - Liang

The different approaches of AI in one slide

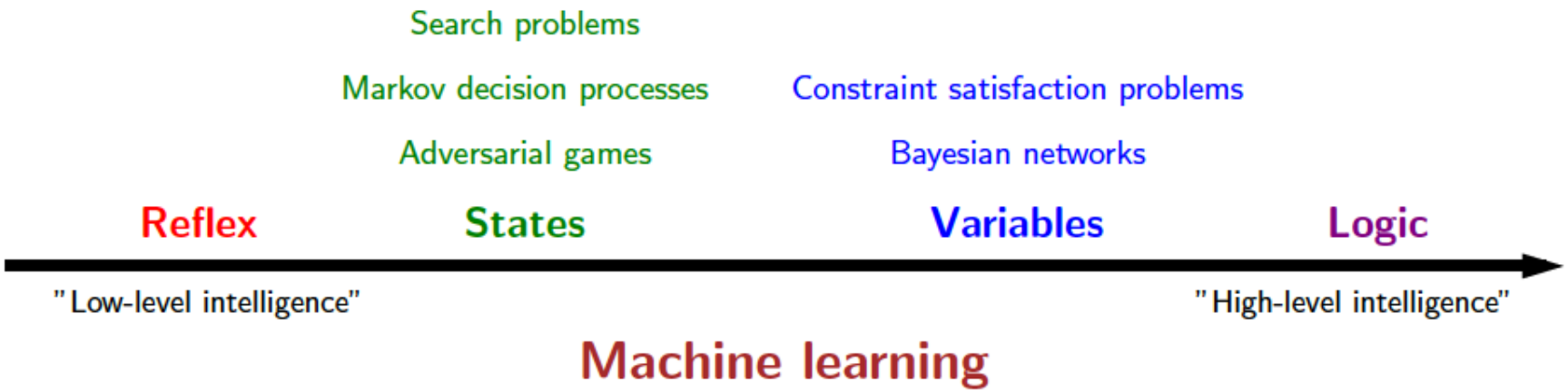


FIGURE – Source : cs221 course Stanford - Liang

This week

Machine learning

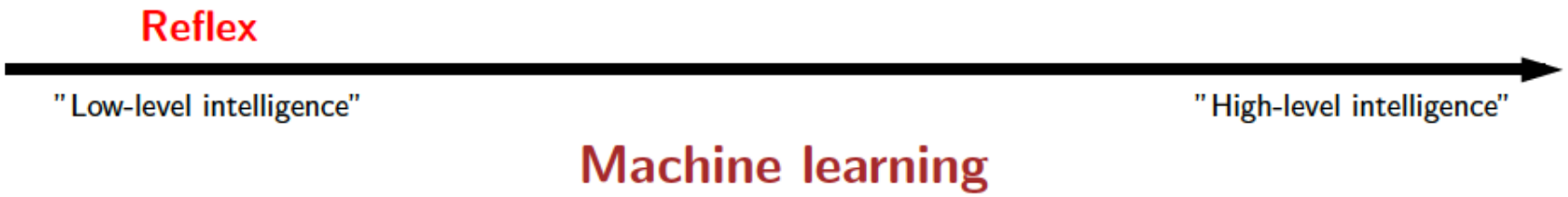


FIGURE – Source : cs221 course Stanford - Liang

Reflex agents

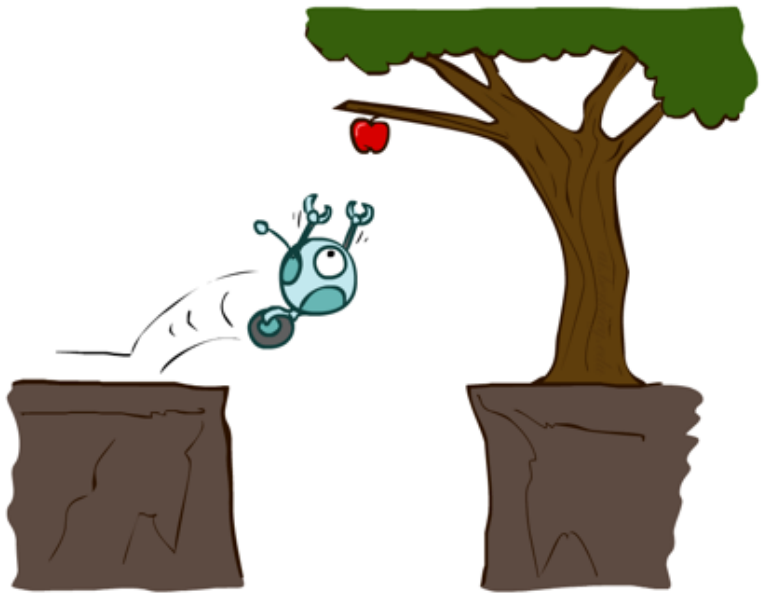


FIGURE – Source : CS188 Intro to AI - Berkeley

- The choice of the action (decision) is made from the current perception.
- Consider the world as it is without taking into account the consequences of its actions on its environment.

Reflex agents

Learning approaches

- Beginning : a set of examples that described the expected behavior of the system and a simple program with unknown parameters.
- The learning algorithm learns the parameters of the program from the available examples to reproduce the behavior of the system.
- The complexity is not in the program itself.
- Important point : generalisation.

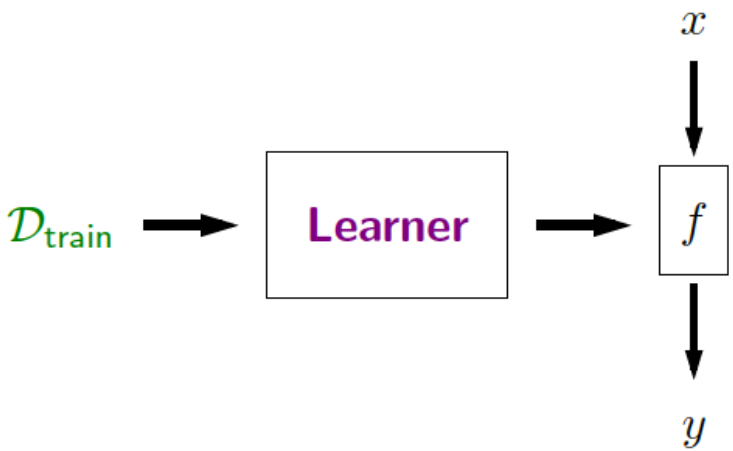
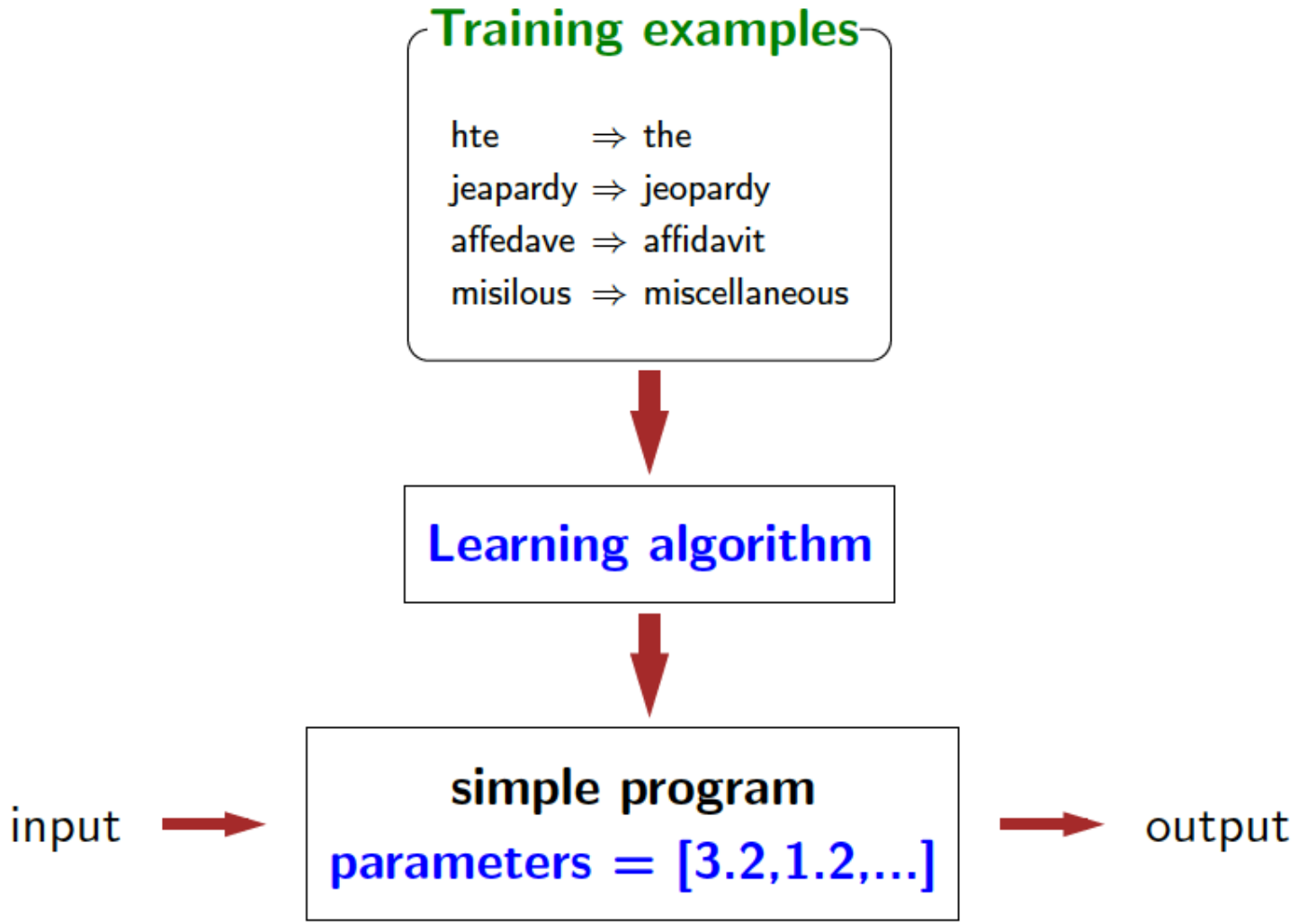


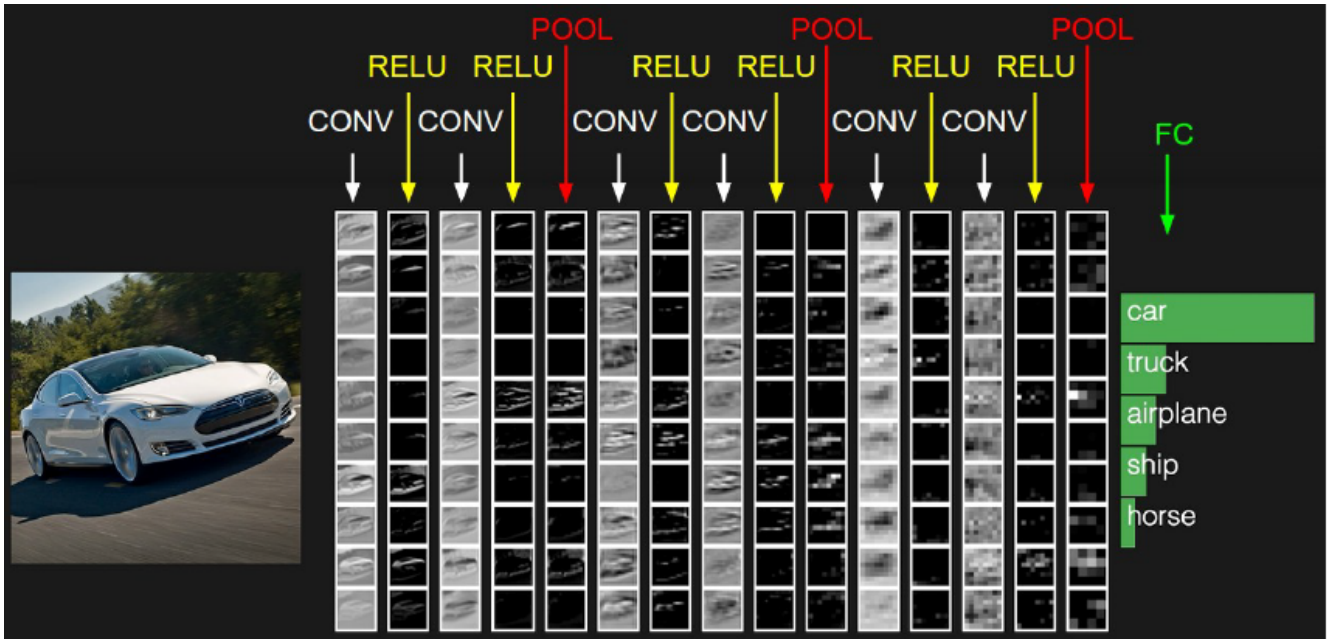
FIGURE – Source : cs221 course Stanford - Liang

Learning approaches

Example : orthographic correction



Reflex agents : example



Modeling-Inference-Learning paradigm

- Modeling = choice of the architecture of the network.
- Inference = Propagation of an observation in the network.
- Learning= parameters learning - Gradient descent- Backpropagation.

State-based models

State-based models- Adversarial search

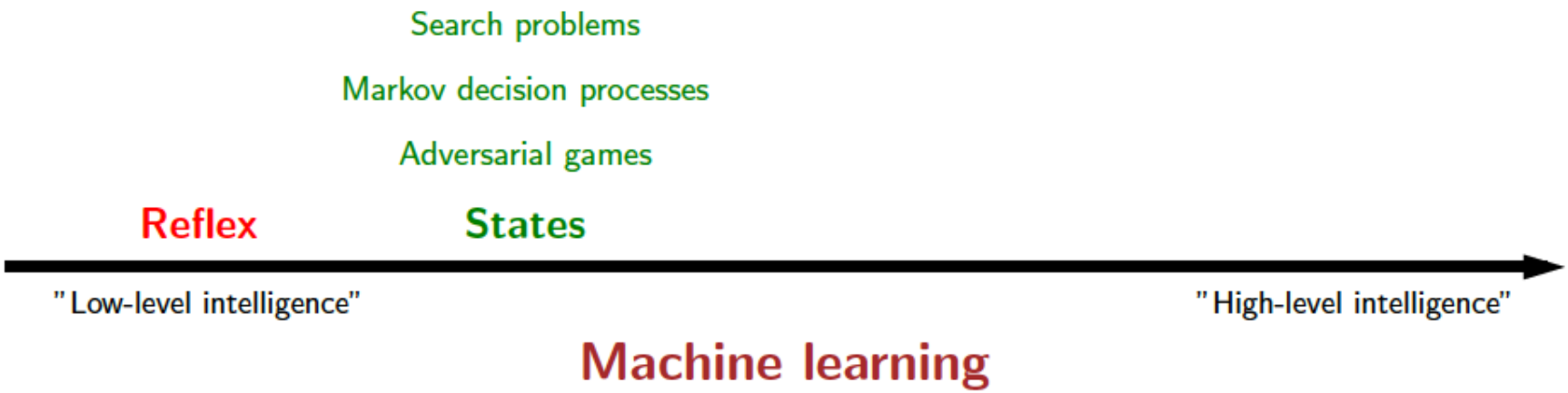
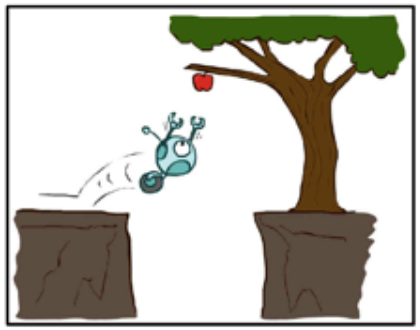


FIGURE – Source : cs221 course Stanford - Liang

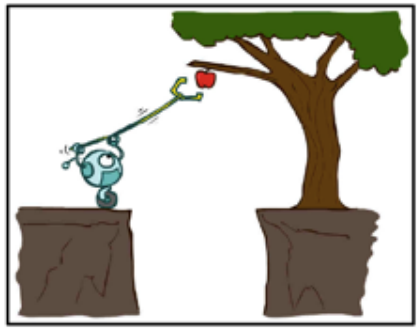
State-based models

Reflex agent



- Consider how the world IS

Planning agent



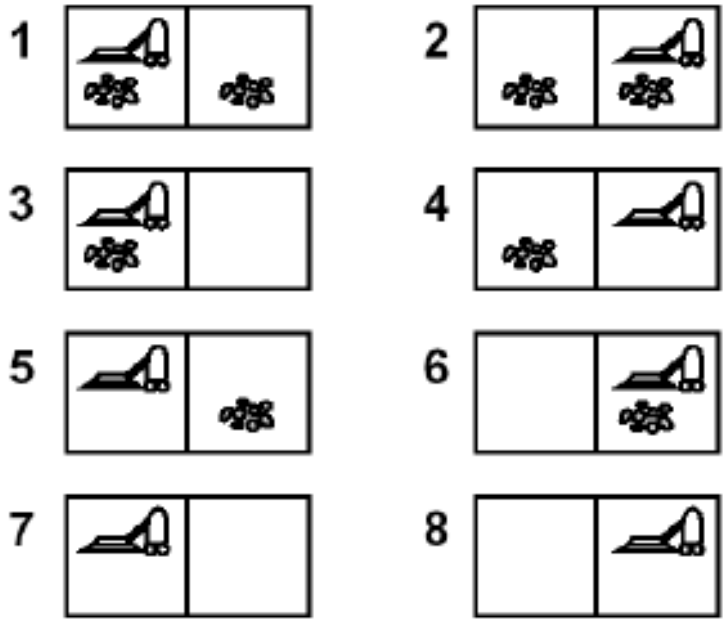
- Consider how the world WOULD BE

Goal-driven agent

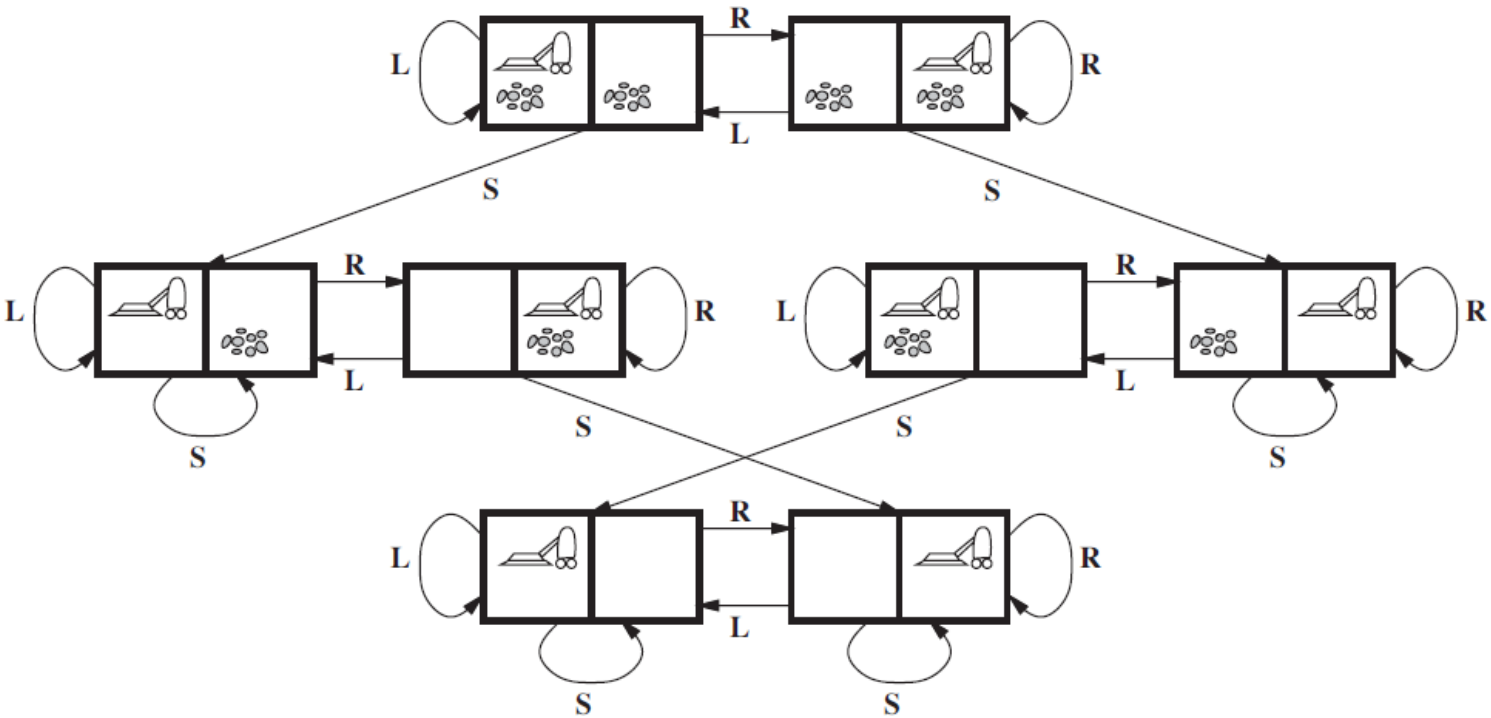
- Consider the world as it could be.
- Decisions are based in the hypothetical consequences of the actions.
- A model of how the world evolves is mandatory = State-based models and state graph.

Example : the vacuum agent

- States : 2 positions + dirty or not : 8 possible states.
- Initial state : anyone
- Function successor : possible actions *Move Left*, *Move right*, *Suck*.
- Goal : a clean room : state 7 or 8
- Cost : every link is 1 so number of steps.

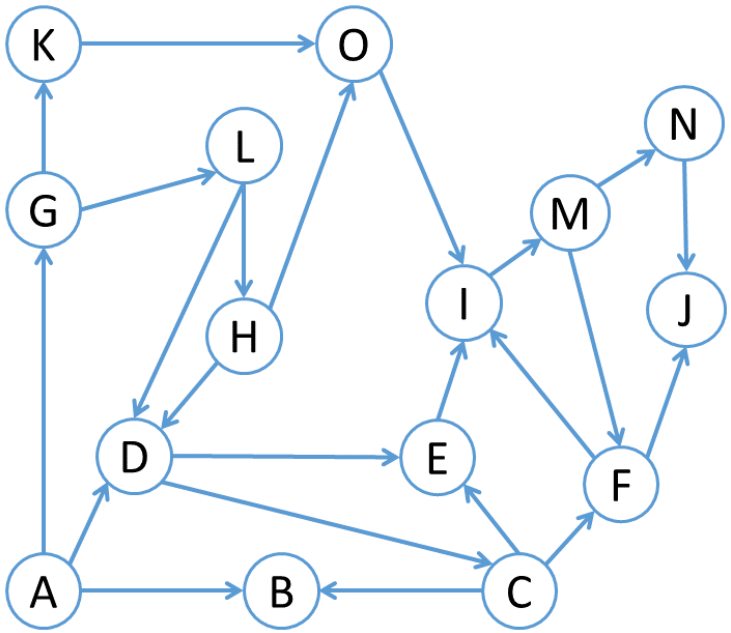


Example : the vacuum agent : the state space

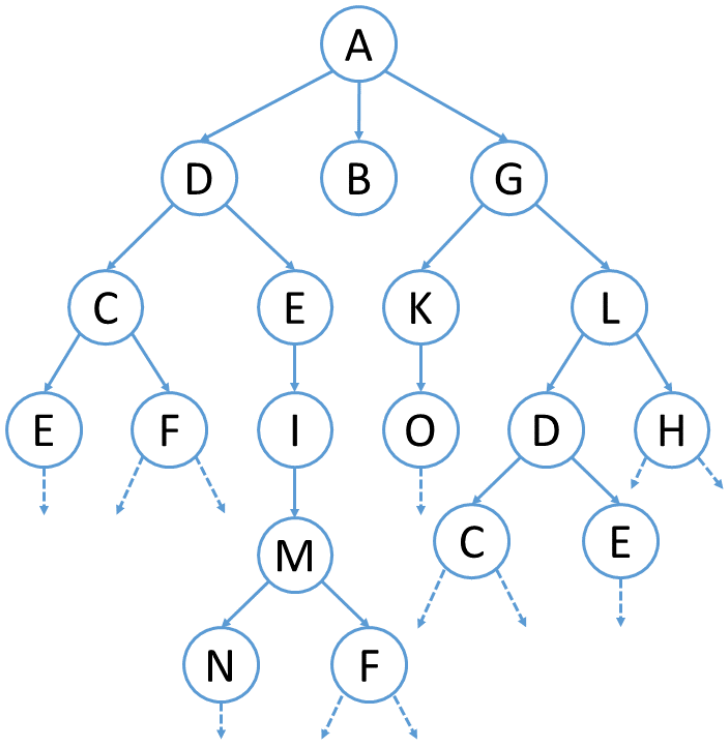


Representation by a tree

General problem



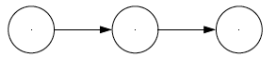
representation by a tree



State-based models : tree types

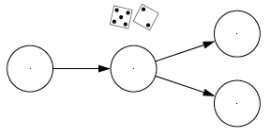
Search problems

Everything is under control



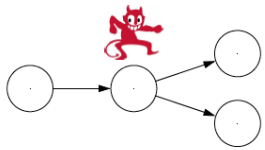
Markov decision process

Against nature



Adversarial search

Against opponent



State-based models

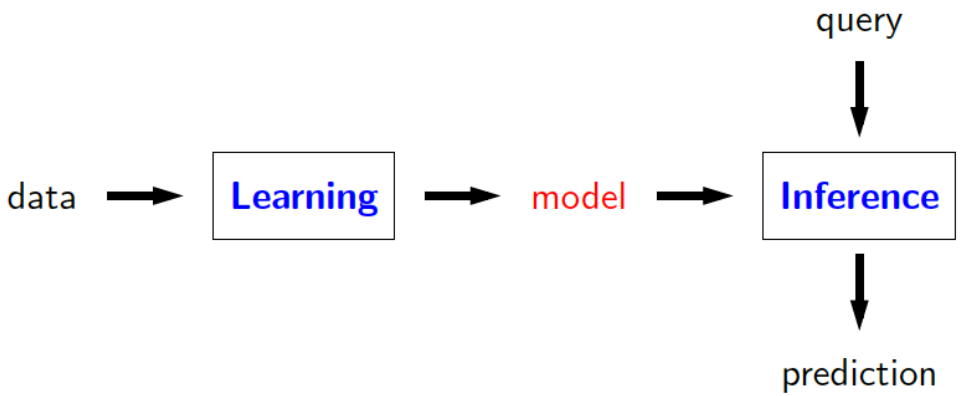


FIGURE – Source : cs221 course Stanford - Liang

Modeling-Inference-Learning paradigm

- Modeling = State-based models. Notions of actions, costs. Modeling of local interactions
- Inference = optimal path search (minimal cost), optimal strategy... Global optimum
- Learning =learning of the parameters of the model.

Specify locally, optimize globally

Variable models - CSP

Variable models - CSP (Constraint Satisfaction Problem)

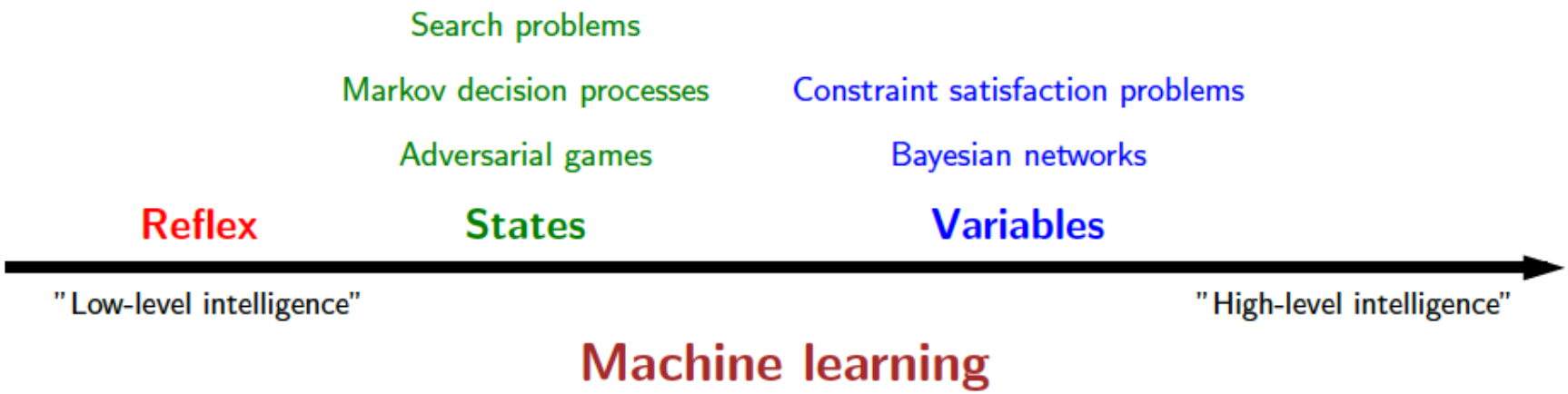


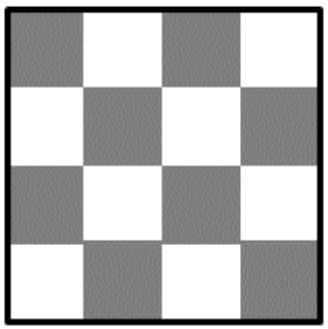
FIGURE – Source : cs221 course Stanford - Liang

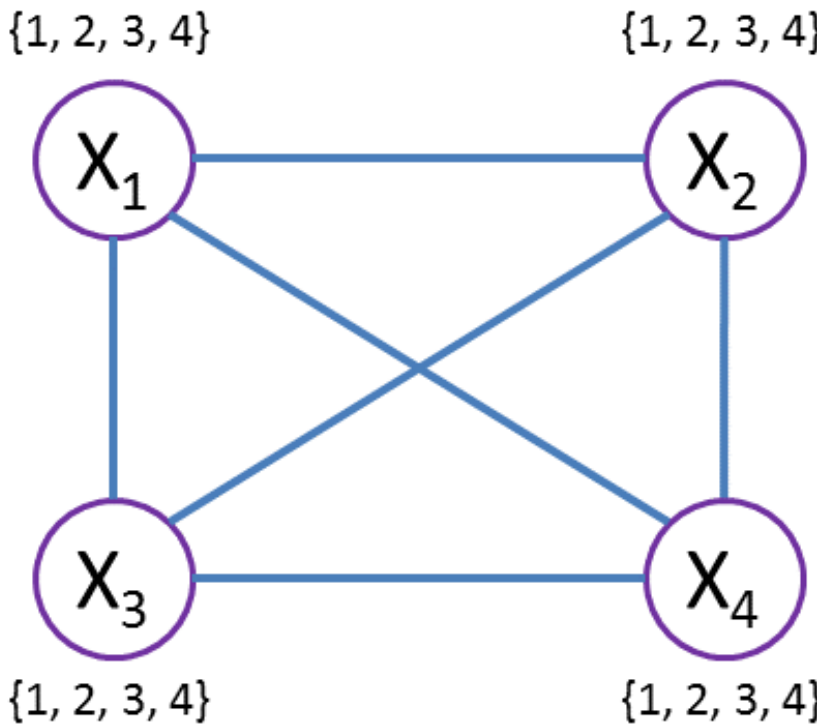
Variable models

Constraint Satisfaction Problem, Bayesian networks

Main idea : notion of variables

- Finding the good variable affections (Modeling)
- How to affect the values : algorithmic part.





Variable models

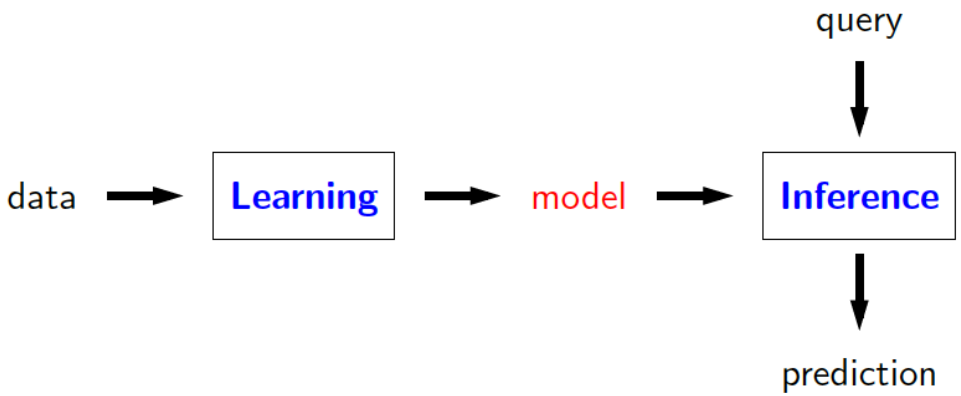


FIGURE – Source : cs221 course Stanford - Liang

Modeling-Inference-Learning paradigm

- Modeling = variable-based models. Notions of variables, of factors Modeling of local interactions
- Inference = search of the best affectation, conditional probabilities computing (diagnostic, planification)... Global optimum
- Learning =learning of the parameters of the model.

Specify locally, optimize globally

Logical models

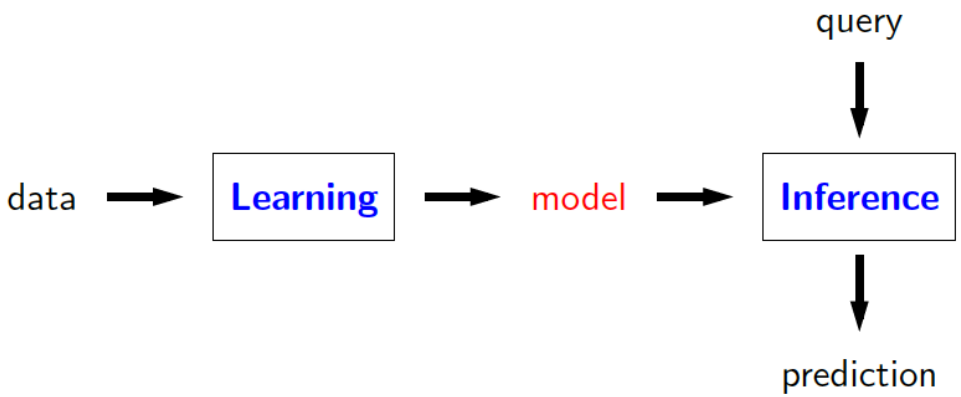


FIGURE – Source : cs221 course Stanford - Liang

Modeling-Inference-Learning paradigm

- Modeling =logics based models, inference rules. Highly expressive modeling
- Inference = application of the inference rules.
- Learning = **a few works**.

To conclude :

- AI : not a new science but a renewal ! !
- These two weeks : an appetizer