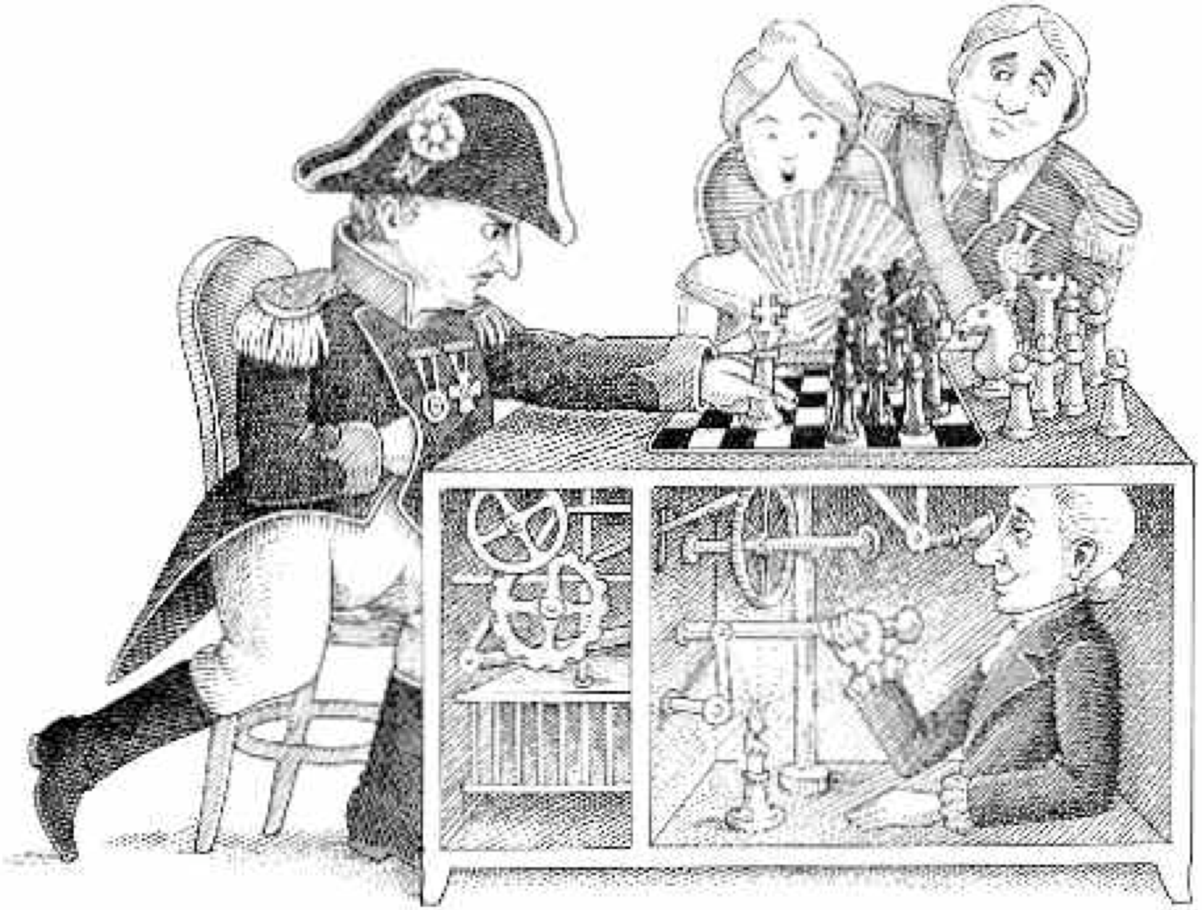


Von Kempelen's
"The Turk" automaton

A Brief History of Artificial Intelligence Part I & II

Ramon López de Mántaras Badia

IIIA-CSIC

mantaras@iiia.csic.es

http://www.iiia.csic.es/~mantaras

What is AI?

Artificial Intelligence is the science of making machines capable of performing tasks that, in order to do them, we admit that we must have intelligence

Two aspects: cognitive and technological

The two aspects

- **Cognitive:**

the goal is to get machines with a <u>general</u> intelligence equal to or greater than human intelligence as well as to better understand human intelligence (Cognitive Science)

What is intelligence?

How do you know if a machine is smart? (Turing test)

- **Technological:**

have machines with an increasingly wide and easy-to-use range of complex applications without worrying about whether the methods are cognitively plausible or not. It is <u>narrow</u> AI

The imitation game: The Turing test

- **"Suppose we have a person, a machine, and an interrogator. The interrogator is in a room separated from the other person and the machine. The object of the game is for the interrogator to determine which of the other two is the person, and which is the machine. The interrogator refers to the other person and the machine by the labels 'X' and 'Y' - but, at least at the beginning of the game, does not know which of the other person and the machine is 'X' - and at the end of the game says either 'X is the person and Y is the machine' or 'X is the machine and Y is the person'. The interrogator is allowed to put questions to the person and the machine of the following kind: "Will X please tell me whether X plays chess?" Whichever of the machine and the other person is, X must answer questions that are addressed to X. The object of the machine is to try to cause the interrogator to mistakenly conclude that the machine is the other person; the object of the other person is to try to help the interrogator to correctly identify the machine. " (Turing, 1950)**

The imitation game: The Turing test (cont.)

If an average interrogator is not able to know, with a certainty of at least 70%, if X is the person or the machine after asking for 5 minutes, then the machine is intelligent.

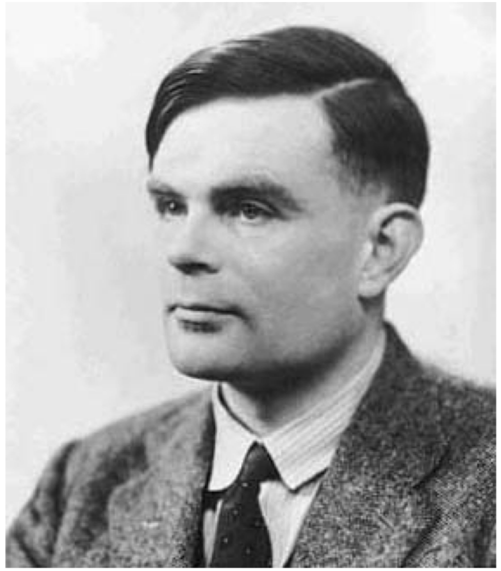
Requires your computer to have the following capabilities:

- **Language comprehension**
- **Knowledge representation**
- **Automatic reasoning**
- **Learning**

Better tests:

"Total" Turing test also requires:

- **Artificial vision**
- **Robotics**



Alan Turing (1912-1954)

- **Winograd's schemas (testing deeper language understanding**

History: the gestation of the AI (1943-1956)

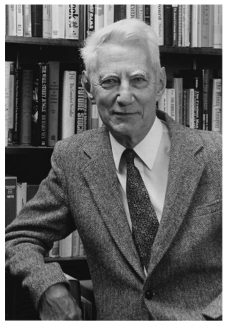
- **McCulloch & Pitts (1943)**
  - artificial neuron model
- **First ideas about learning in neural networks Hebb (1949)**
  - simple rule for updating the weights of connections between neurons ("cells that fire together, wire together")
- **Marvin Minsky (1951)**
  - first electronic neural network (SNARK: 40 neurons, 3000 valves, and … remnants of the autopilot system of a scrapped B-54 !!), simulates a mouse walking in a maze.
- **Shannon (1950) and Turing (1953)**
  - first programs that played chess

Warren McCulloch (1898-1969)

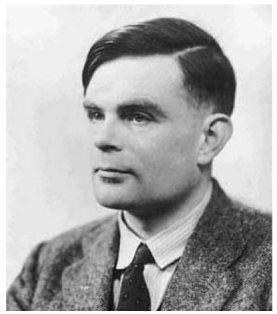
Walter Pitts (1923-1969)

D.O. Hebb (1904-1985)

Marvin Minsky (1927-2016)



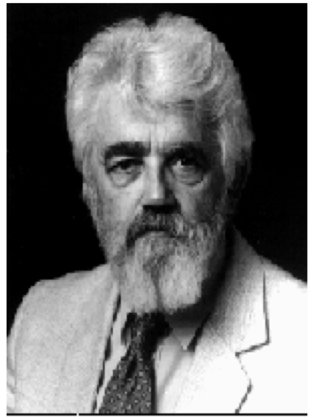
Claude Shannon (1916-2001)



Alan Turing (1912-1954)

The birth of AI (1956)

Marvin Minsky
(1927-2016)



John McCarthy
(1927-2011)

Darthmouth Summer Workshop (1956)

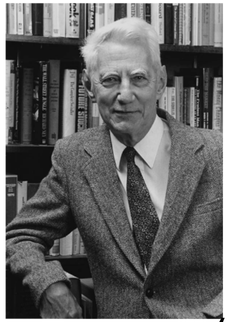
Nathaniel
Rochester
(1919-2001)

"Every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it"

(It became clear that computers could manipulate esymbols representing concepts)

⇓

PHYSICAL SIMBOL HYPOTHESIS

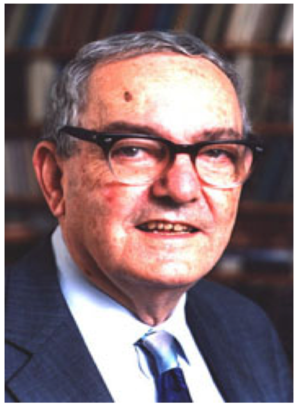


Claude
Shannon
(1916-2001)

Adoption of the term: Artificial Intelligence

the "<u>Logic Theorist</u>" (Newell & Simon) proved most of the theorems in chapter 2 of "Principia Mathematica" (Bertrand Russell), using heurístic search, goal-oriented behavior and inference rules

Allen Newell
(1927-1992)



Herbert Simon
(1916-2001)

Logic Theorist

- **The Logic Theorist used the same set of axioms, definitions and rules used in the "Principia Mathematica". The axioms are:**
- **$(p \vee p) \rightarrow p$ (1)**
- **$p \rightarrow (q \vee p)$ (2)**
- **$(p \vee q) \rightarrow (q \vee p)$ (3)**
- **$[p \vee (q \vee r)] \rightarrow [q \vee (p \vee r)]$ (4)**
- **$(p \rightarrow q) \rightarrow [(r \vee p) \rightarrow (r \vee q)]$ (5)**

Using 3 inference rules: substitution, replacement, and modus ponens, LT proved new theorems.

Examples:

Substituting "p" by "p V q" in the second axiom, we get the new theorem:

$$\text{“}(p \vee q) \rightarrow [q \vee (p \vee q)]\text{”}$$

Replacing "$p \rightarrow q$" by its equivalent "$\neg p \vee q$" in the second axiom we get the new theorem:

$$\text{“}\neg p \vee (q \vee p)\text{”}$$

Applying the modus ponens (If "A" and "$A \rightarrow B$" are theorems, then "B" is a theorem),

from: axiom 1: $(p \vee p) \rightarrow p$

and from the previously proved theorem: $[(p \vee p) \rightarrow p] \rightarrow (p \rightarrow p)$

We get the new theorem: "$p \rightarrow p$"

How does it work?

- **Given an expression to prove, LT begins with the set of axioms above + theorems already proved, and applies the rules of inference successively until it reaches the expression sought. A proof is a sequence of expressions, each derived from the previous ones, that leads from known axioms and theorems to the desired expression.**
- **Example: Proving "$(A \rightarrow \neg A) \rightarrow \neg A$"**
  - **1. $(A \vee A) \rightarrow A$ (by axiom 1)**
  - **2. $(\neg A \vee \neg A) \rightarrow \neg A$ (substitution of A by $\neg A$)**
  - **3. $(A \rightarrow \neg A) \rightarrow \neg A$ (replacement of $(\neg p \vee q)$ by $(p \rightarrow q)$)**
  - **Q.E.D.**
- **LT took 10 seconds on the JOHNNIAC computer (RAND coorporation) programmed in IPL (compiled manually into machine language) in 1956**

1952-1969: A period of enthusiasm and great expectations ("look, Ma, no hands!")

- GPS (Newell and Simon, 1959)
  - Solved simple problems (puzzle type) using means-ends analysis. The order in which the GPS considered the goals, sub-goals, and actions to be performed was similar to how people did it (as opposed to the LT).
- Geometry Theorem Prover (Gelernter, 1959)
  - like LT, he proved theorems through the explicit representation of axioms (problem of the multiple paths of reasoning to be followed potentially, ie first attempts to focus the search using informed heuristics)
- Checkers player (Arthur Samuel, 1952)
  - who "self-learned" to play "checkers" at a very high level (demonstration on TV in 1956 causing great social impact)
- → improvement of search methods and first successes in machine learning

General Problem Solver

- The basic idea is to "reduce the differences" between the initial state and the final state (or solution state) of a problem ("means-ends analysis").

- The solution is given by the sequence of operators (actions, transitions) that lead from the initial state to the final state

(You need to be able to represent problems by means of states)

Example

- **Prove that from $S \wedge (\neg P \rightarrow Q)$ we can deduce $(Q \vee P) \wedge S$**

GPS compares these two expressions and the first difference it observes is that S appears on different sides of the connective $\wedge$.

GPS looks at a "table of differences-methods" and under the difference labelled "change of position" finds the theorem:

$$\text{“}(A \wedge B) \equiv (B \wedge A)\text{”}$$

in the list of methods. GPS applies it and obtains: $(\neg P \rightarrow Q) \wedge S$.

Next detects that there is a difference between the connectives ("$\rightarrow$" and "$\vee$"), looks again at the table of diferències and finds that under the label "change of connective" there is the theorem:

$$(\neg A \rightarrow B) \equiv (A \vee B)$$

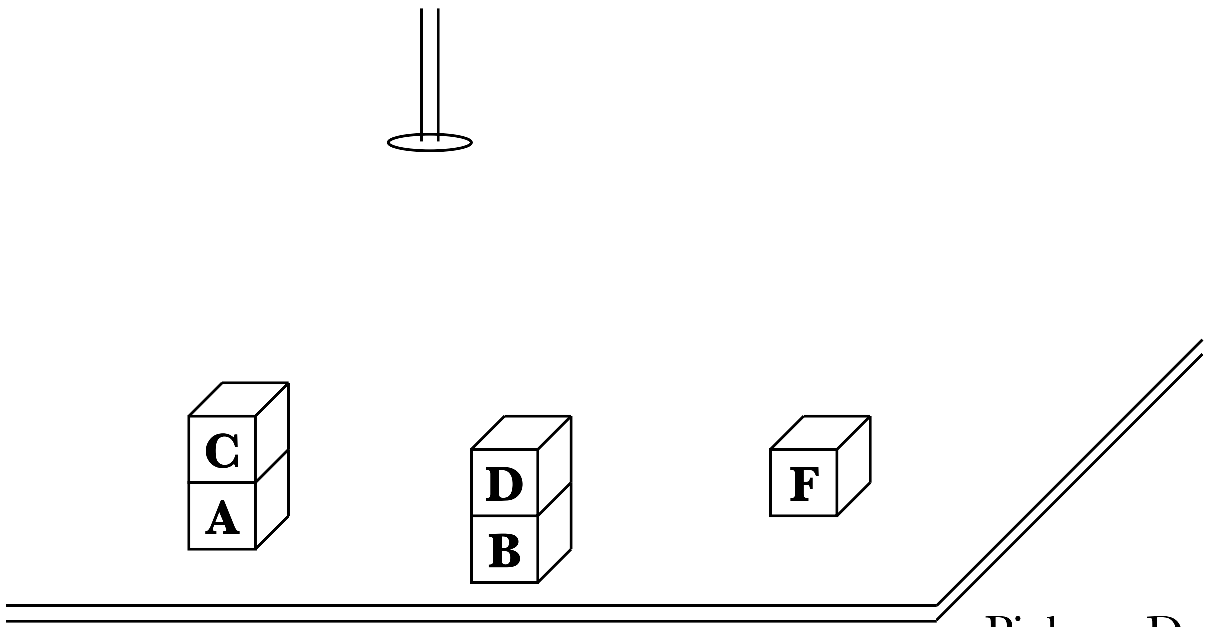
applies it $(\neg P \rightarrow Q) \wedge S$ and obtains: $(P \vee Q) \wedge S$.

Finally, the difference between $(P \vee Q) \wedge S$ and the goal $(Q \vee P) \wedge S$ is again solved by the theorea: $(A \vee B) \equiv (B \vee A)$, obtaining:

$$(Q \vee P) \wedge S$$

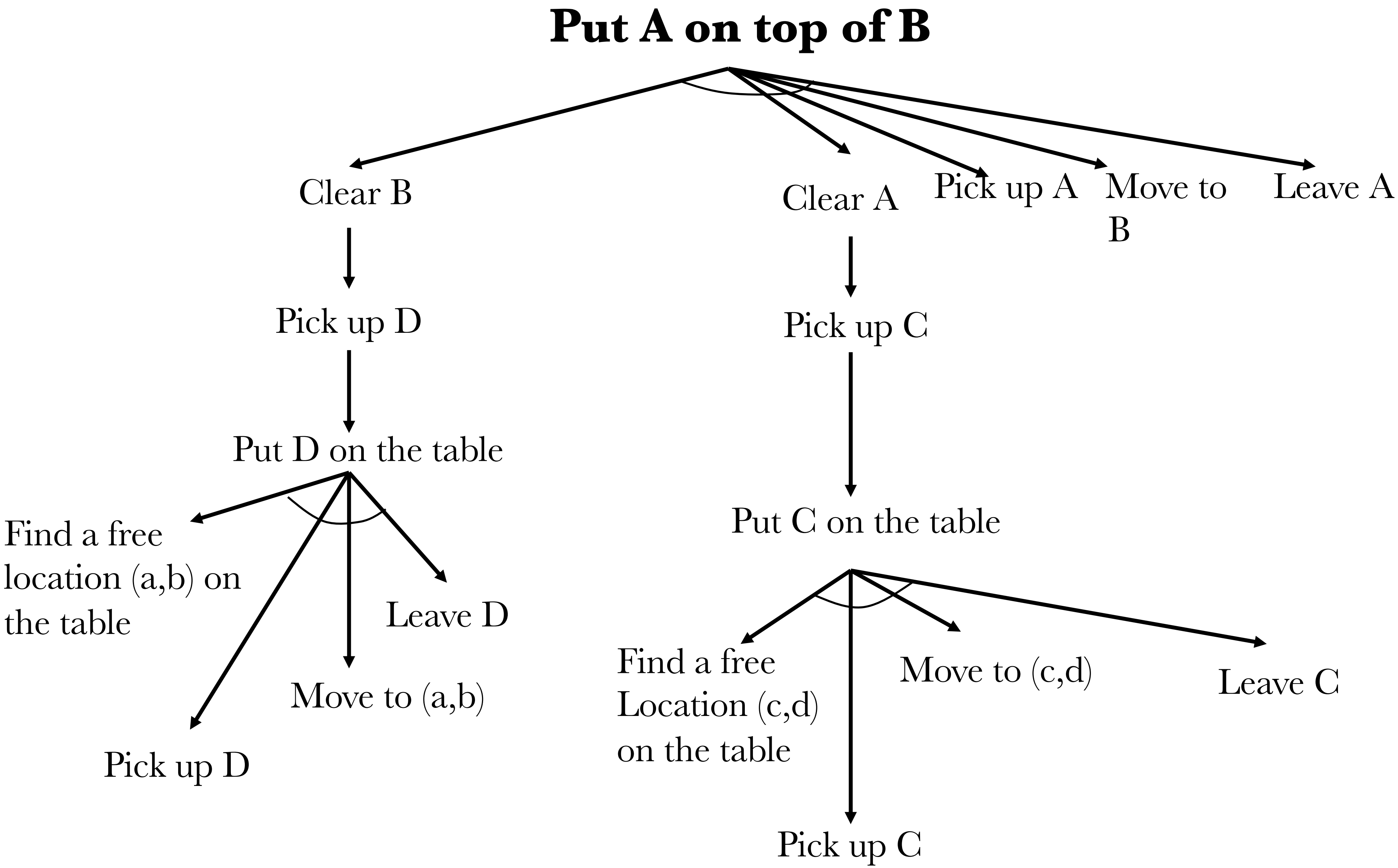
Example of reducing differences by decomposing the final goal into a combination of simpler sub-goals

- Put A on top of B



Pick up D,
move to a free position on the table,
leave D,
pick up C,
move to another free position,
leave C,
pick up A,
move to the position occupied by B,
leave A

Detailed action plan

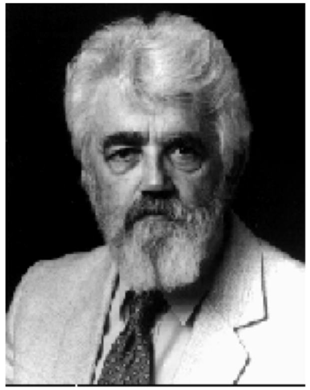


1952-1969 (cont.)

- **LISP (MIT AI Lab Memo No. 1) by John McCarthy in 1958**

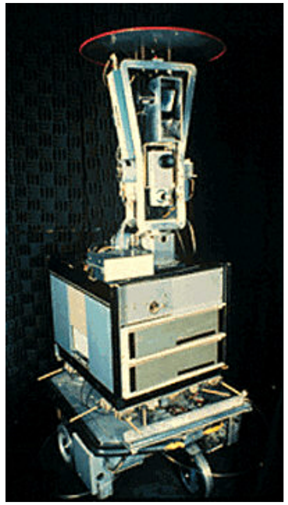
- **The article: “Programs with Common Sense” by J. McCarthy published in 1958 describing “Advice Taker” that used general world knowledge about the effects of actions performed in the world as a results of searching solutions to simple planning problems (for instance, generating a plan to go from home to the airport) → Advice Taker was the first AI system to represent knowledge by means of inference rules and using the <u>Resolution Principle.</u>**

- **Minsky at MIT (1958) and McCarthy at Stanford (1963) develop completely different approaches to AI:**
  - **→AI based on formal mathematical logic at Stanford and application of logic-based methods in Robotics (planning and search in SHAKEY)**
  - **→Development of non-formal methods at MIT (“micro worlds”)**
  - **→Most efforts focusing on how to represent knowledge**



John McCarthy
1927-2011

Marvin Minsky
1927-2016



Shakey, 1969

1952-1969 (cont.)

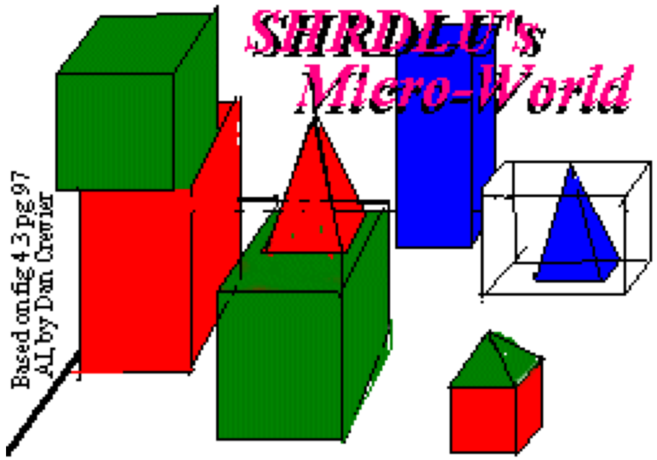
- **The "microworlds" at MIT**
  - SAINT (J. Slagle 1963): Integral calculus
  - STUDENT (D. Bobrow, 1967): Solving problems stated linguistically. Example: "if the number of customers of a shop doubles the square of the 20% of the number of announcements and the number of announcements is 45, how many clients has the shop?
  - ANALOGY (T. Evans, 1968): "A is to B as C is to?"
  - SIR de B. Raphael (1968): answered questions formulated by means of a very restricted subset of the english language)
  - THE BLOCKS' MICROWORLD (1970-1975)

    for <u>computer visión</u> (D. Huffman, 1971; D. Waltz, 1975)

    for <u>machine learning</u> (P. Winston, 1970)

    for <u>natural language processing</u> (T. Winograd, 1972)

    for <u>planning</u> (S. Fahlman, 1974)

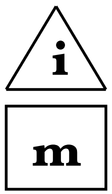


- **Progress on artificial neural networks**
  - S. Winograd & Cowan proved that a large number of elements can collectively represent a concept
  - The perceptron neural network (F. Rosenblatt, 1962) mathematically proved the convergence of the learning process

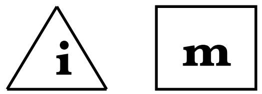
ANALOGY (Evans, 1968)

A is to B

A:

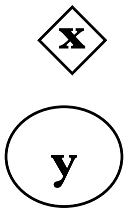


B:

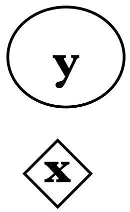


as C is to: 1, 2 o 3?

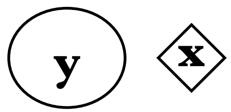
C:



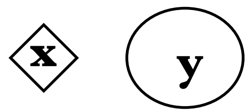
1:

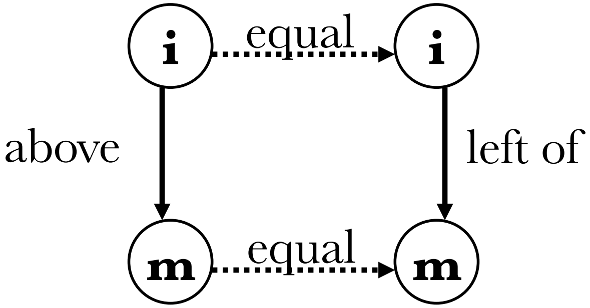


2:

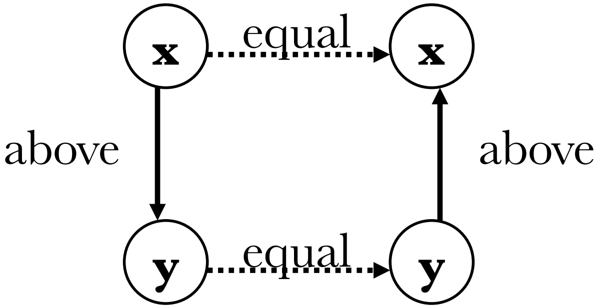


3:

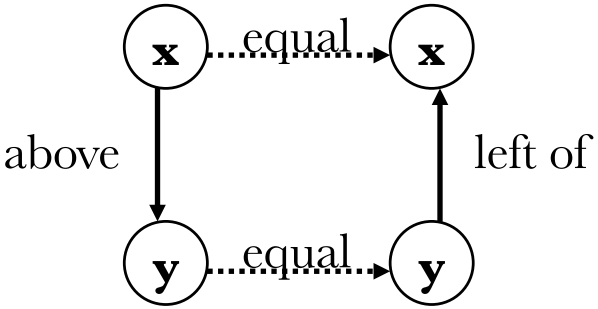




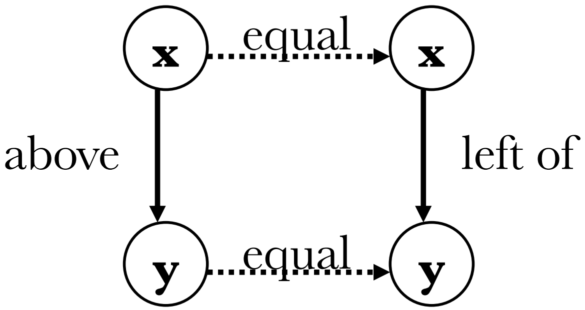
(corresponds to "A is to B")



(corresponds to "C is to 1")



(corresponds to "C is to 2")

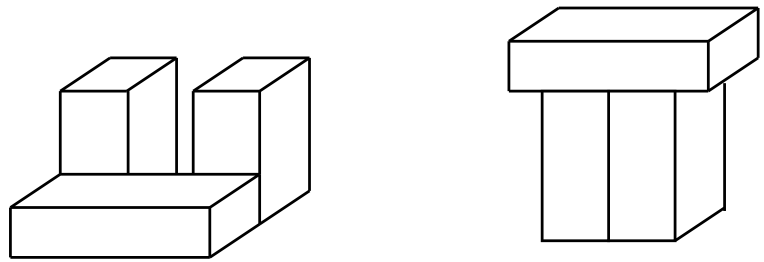


(corresponds to "C is to 3")

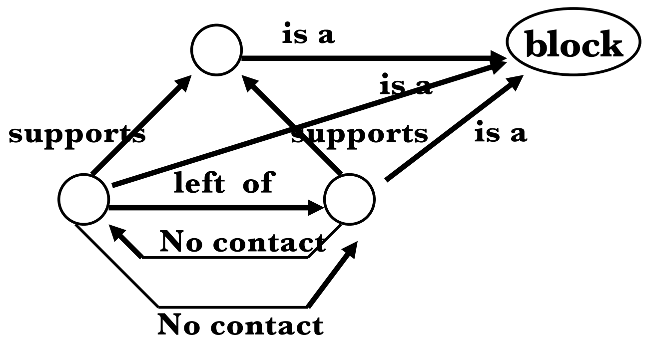
Learning based on examples and counter-examples that are near misses (Winston, 1970)

Examples of arch:

and counter-examples (near misses) of archs:



The system learns:



A dosis of realism (1966-1974): AI Winter

- **Failure of optimistic predictions by renowned researchers (e.g. H. Simon stated that in the late 1960s a computer would be the world chess champion and would prove an important mathematical theorem)**
- **Success of ELIZA (Weizenbaum, 1966) but… failure of machine translation between Russian and English:**

  "the spirit is willing but the flesh is weak"→ Russian → "the vodka is good but the meat is rotten"

  (In 1966, the U.S. government stopped all funding for machine translation based on a commission's opinion.)
- **Intractability of the problems that AI attacks: Before the theory of NP-completeness it was thought that it was possible to scale up from "microworlds" to real world problems but the reality was different (microworlds consist of few objects!)**
- **The "Lighthill" report in Britain (1973) based on the inability to attack the problem of the combinatorial explosion using the AI methods of the time (the "weak methods" and the simple syntactic manipulation of symbols)**
- **The book "Perceptrons" (Minsky and Papert, 1969) demonstrates the limitation of perceptrons: they can only recognize linearly separable classes the funding of research in Neural Networks was stopped. Ironically, in 1969 the method of "backpropagation" was discovered.**

⇓

domain knowledge is needed!

New Spring: Knowledge-based Systems (1969-1985)

Abandonment of weak general methods → bad performance in complex domains

Solution: use very specific knowledge (Rules) that allow long reasoning steps in order to solve problems in very limited áreas of expertise (Expert Systems)

DENDRAL (Buchanan, Lederberg, Feigenbaum, 1969)

Stanford HPP: MYCIN and dealing with uncertainty (Feigenbaum, Buchanan, Shortliffe,1976): diagnosis of infectious deseases

Other expert systems:

PROSPECTOR (Duda, Gaschnig, Hart, 1979): Geology

R1 (McDermott, 1982): Configuration of computer systems around VAX 780

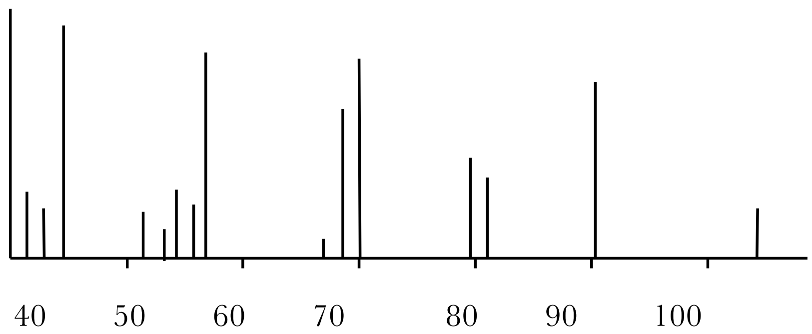
MILORD and the linguitic representation of uncertainty (IIIA, 1985): diagnosis of pneumonia

DENDRAL

Given the formula of an organic molecule:

$C_8H_{16}O$

And its mass spectrometry:



DENDRAL deduces the structure:

CH3 — CH2 — C — CH2 — CH2 — CH2 — CH2 — CH3

||

O

Example of rule in DENDRAL

<u>If</u> there are two spikes x_1 and x_2 such that

$x_1 + x_2 = M + 28$ (M is the mass of the molcule)

$x_1 - 28$ is a high spike

$x_2 - 28$ is a high spike

At least one of the two spikes x_1 or x_2 is high

<u>Then</u> there is a group $C = O$

Examples of rules of the MILORD Expert System

If the patient has dermatologic manifestations

and the manifestations are herpes

Then it is *higly possible* that the pneumonia is Bacterial

If the pneumonia is bacterial

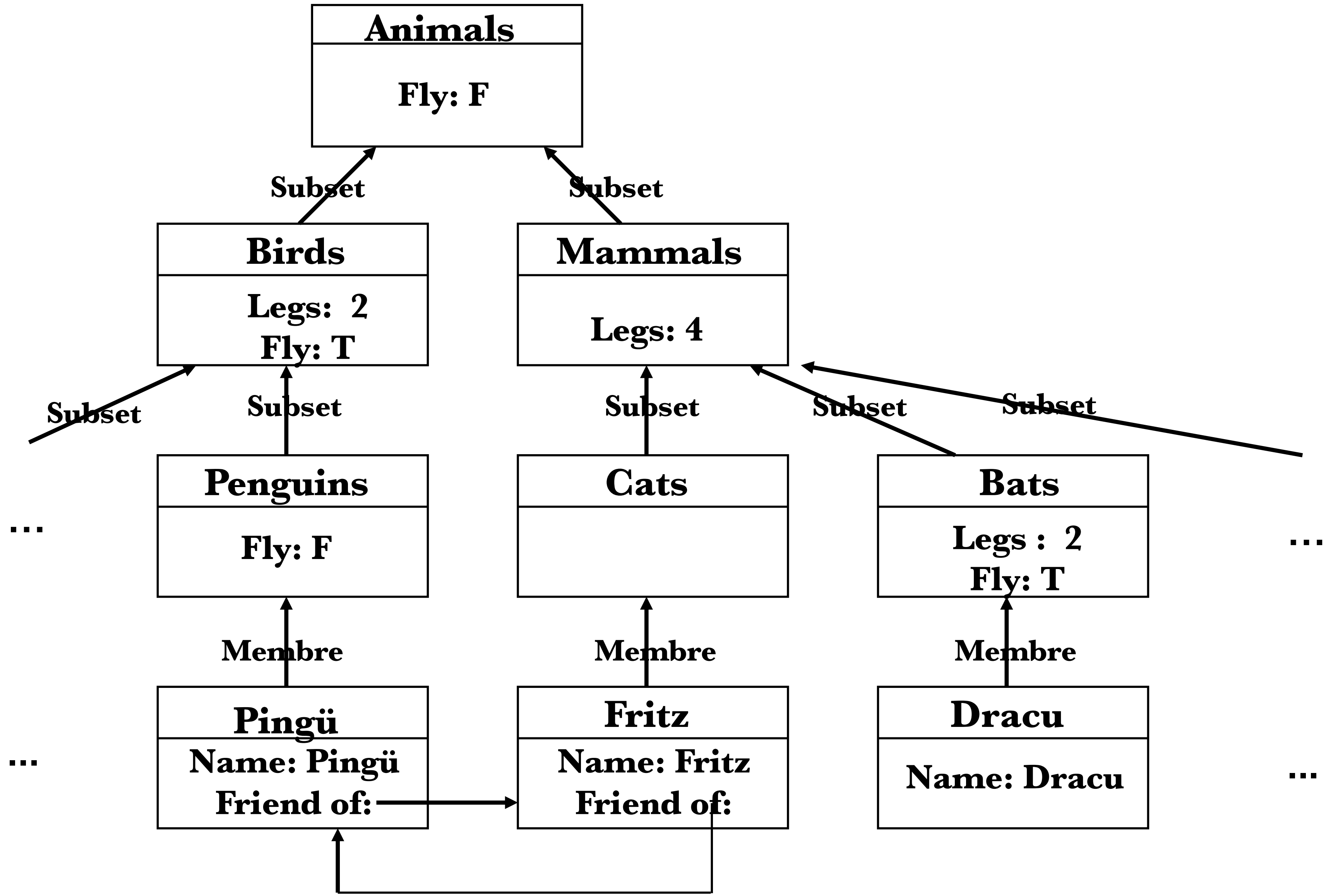
and there is breathing noise

Then it is *quite possible* thet the pneumonia is caused by a Enterobacteria

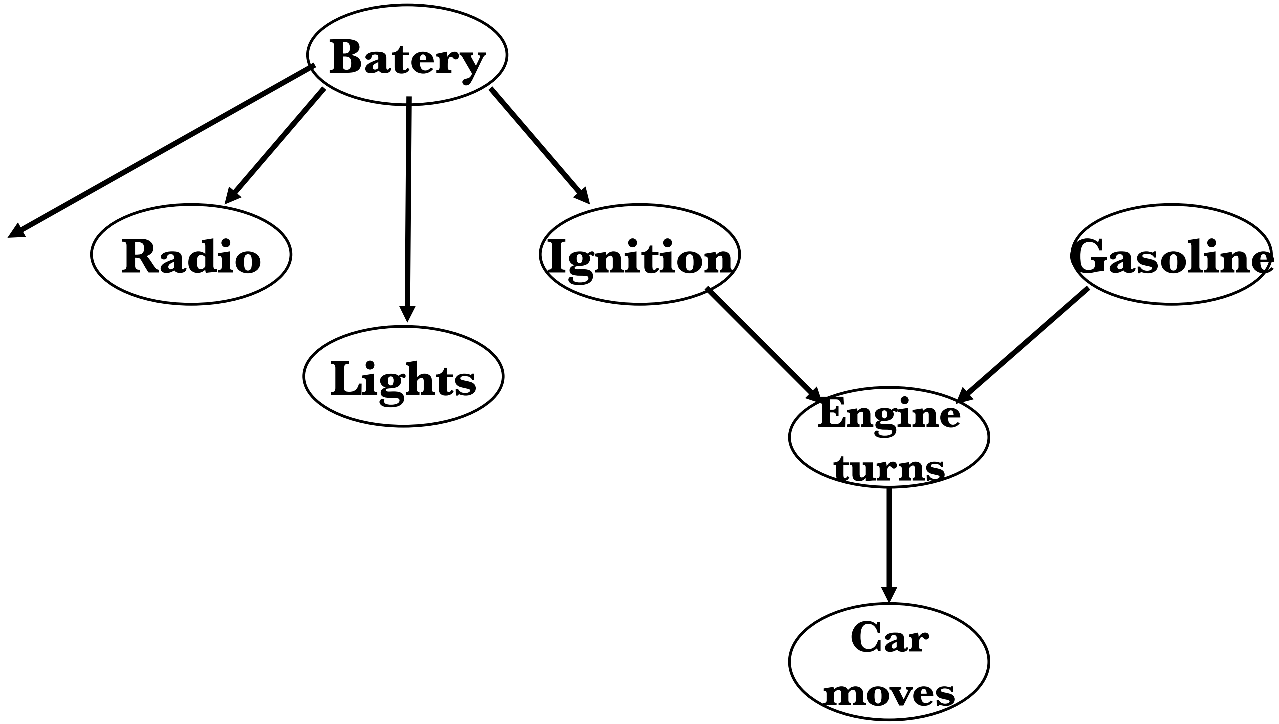
Knowledge Based Systems (cont.) (1969-1985)

- **Project "Computers in Biomedicine" University of Rutgers**
- **Projects at MIT and the New England Medical Center**
- **Realization of the great importance of knowledge representation:**
  - **Natural Language: The LUNAR system (W. Woods, 1973)**
    - **First important NL system application (Question-Answering system about samples of lunar rocks, used by geologysts)**
  - **Work of Roger Schank and his students from 1977 to 1983 on the representation of stereotypical situations de situacions**
  - **New logic-based programming languages (PROLOG in Europa, PLANNER in US)**
  - **Structured representation of knowledge based on the concept of "<u>Frame</u>" (Minsky, 1975) and object-oriented languages**
- **Development of an extenssion of classical logic called Fuzzy Logic (Lotfi Zadeh, 1965)**
- **Works by Douglas Lenat on AM (re-discovery of mathematical concepts)**
- **Second Generation Expert Systems**
  - **model-based, <u>causal reasoning</u>, etc.**

Frames


Animals
Fly: F
Subset
Subset
Birds
Legs: 2
Fly: T
Mammals
Legs: 4
Subset
Subset
Subset
Subset
Subset
Penguins
Fly: F
Cats
Bats
Legs : 2
Fly: T
…
…
Membre
Membre
Membre
Pingü
Name: Pingü
Friend of:
Fritz
Name: Fritz
Friend of:
Dracu
Name: Dracu
…
…

Causal Reasoning



1985-2010

- **Fifth Generation Computing Project in Japan (and responses in the US with MCC and in Europe)**
- **Creation of many companies (Teknowledge, Intellicorp, Inference, etc.) both software (expert systems shells) and hardware (LISP machines). The first artificial vision and speech recognition systems are also beginning to be marketed. Many companies (GE, GM, Du Pont, etc.) are committed to AI.**
- **The needs of these companies to develop highly complex systems show the limitations of expert systems (second AI Winter):**
  - **They are brittle**
  - **They cannot "reconsider" what they have concluded**
  - **They cannot share knowledge with other expert systems**
  - **Difficulties maintaining the Knowledge Bases**
  - **“Knowledge acquisition bottleneck”**
  - **They cannot reuse previous conclusions from similar situations**
  - **They do not learn**

  →Case-Based Reasoning systems

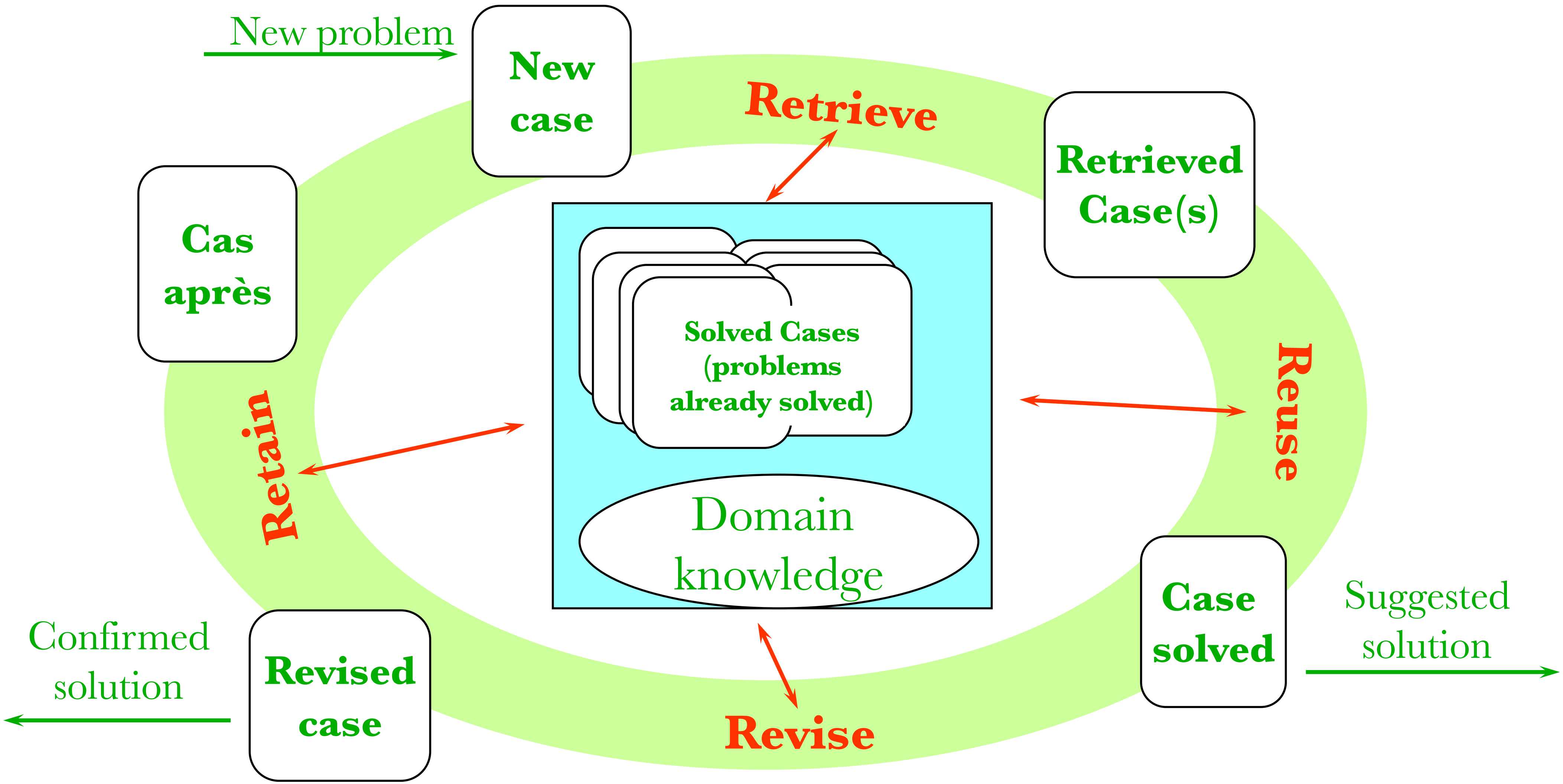
  →Multi-agent Systems

  → New opportunities around INTERNET

New problema solving approaches: Case-Based Reasoning (CBR)

In CBR, problems are solved by adapting previously solved solutions to similar problems

Case-Based Reasoning



(Aamodt &Plaza 94)

The great success of Deep Neuronal Networks(2010-present)

- **Affordable High Performance Computing and the availability of large quantities of data made possible the successes of deep neural networks (multi-level networks)**

- **Example of big successes: : speech recognition, Go playing (AlphaGo), autonomous vehicles, diagnosis based on medical images, automatic translation, personal assistants etc.**

- **The bet of large technological companies on AI**

- **Governments belief that AI is key for the future of the economy and to solve major problems: climatic change, personalized medicine, …**

Selection of things AI can do

- Autonomous robots and autonomous vehicles
- Expert decision making assistants (medicine, etc.)
- Speech recognition
- Planning systems
- Search engines
- Data Mining (bioinformatics, financial applications, etc.)
- Electronic commerce
- Fraud detection
- Management of mobile phone calls
- Advanced multimodal interfaces (visió, parla, gest)
- Proof of mathematical theorems
- Music composition and performance
- Games (chess, backgammon, Go, poker, computer games, etc.)
- Space robots
- …

Examples of great achievements:
The best chess and Go players are (by far) machines

#	Name	Elo
1	SugaR XPrO 1.2 64-bit 4CPU	3446
2	Komodo 11.2 64-bit 4CPU	3433
3	Houdini 5.01 64-bit 4CPU	3402
4	Deep Shredder 13 64-bit 4CPU	3312
5	Fire 5 64-bit 4CPU	3300
6	Fizbo 1.9 64-bit 4CPU	3294
7	Andscacs 0.91 64-bit 4CPU	3265
8	Chiron 4 64-bit 4CPU	3240
9	Equinox 3.20 64-bit 4CPU	3222
10	NirvanaChess 2.4	

Live Chess Ratings - 2700chess.com
Update: 06 November 2017, 22:20 GMT

#	Name	Rating	Rapid	Blitz
1	Carlsen	2837.0	2909.0	2948.0
2	Aronian	2802.2	2819.0	2863.0
3	Mamedyarov	2799.0	2814.0	2770.0
4	Caruana	2799.0	2735.0	2728.0
5	Vachier-Lagra	2796.0	2839.0	2853.0
6	So	2788.0	2793.0	2747.0
7	Kramnik	2787.0	2795.0	2784.0
8	Anand	2782.0	2758.0	2736.0
9	Nakamura	2780.0	2829.0	2857.0
10	Ding Liren	2777.4	2733.0	2875

Monte Carlo Tree Search and Deep Learning to beat the world's #1 Go player (Alpha Go 3 - Ke Jie 0) 23-27 Maig 2017

Examples of great achievements: Medical diagnosis

- A group from the University of Queensland (Australia) has applied Deep Learning to combine medical images from mammograms, MRIs and ultrasounds to detect tumors in images that are not always detectable by doctors.
- Identification of 3 new indicators (from 8 to 11) to evaluate the probability that a breast cell biopsy can be positive based on analyzing large amounts of data from cancer cell samples (Stanford University)
- Prediction, analyzing 133,000 patients from 4 Chicago hospitals, up to 4 hours in advance (instead of about 30 minutes by cardiologists) of the probability of heart attack in patients admitted to ICUs (Carnegie Mellon University)
- The Hospital Clínic in Barcelona has developed an algorithm to predict the evolution of patients admitted for covid-19.

Example of what AI cannot do (yet?)

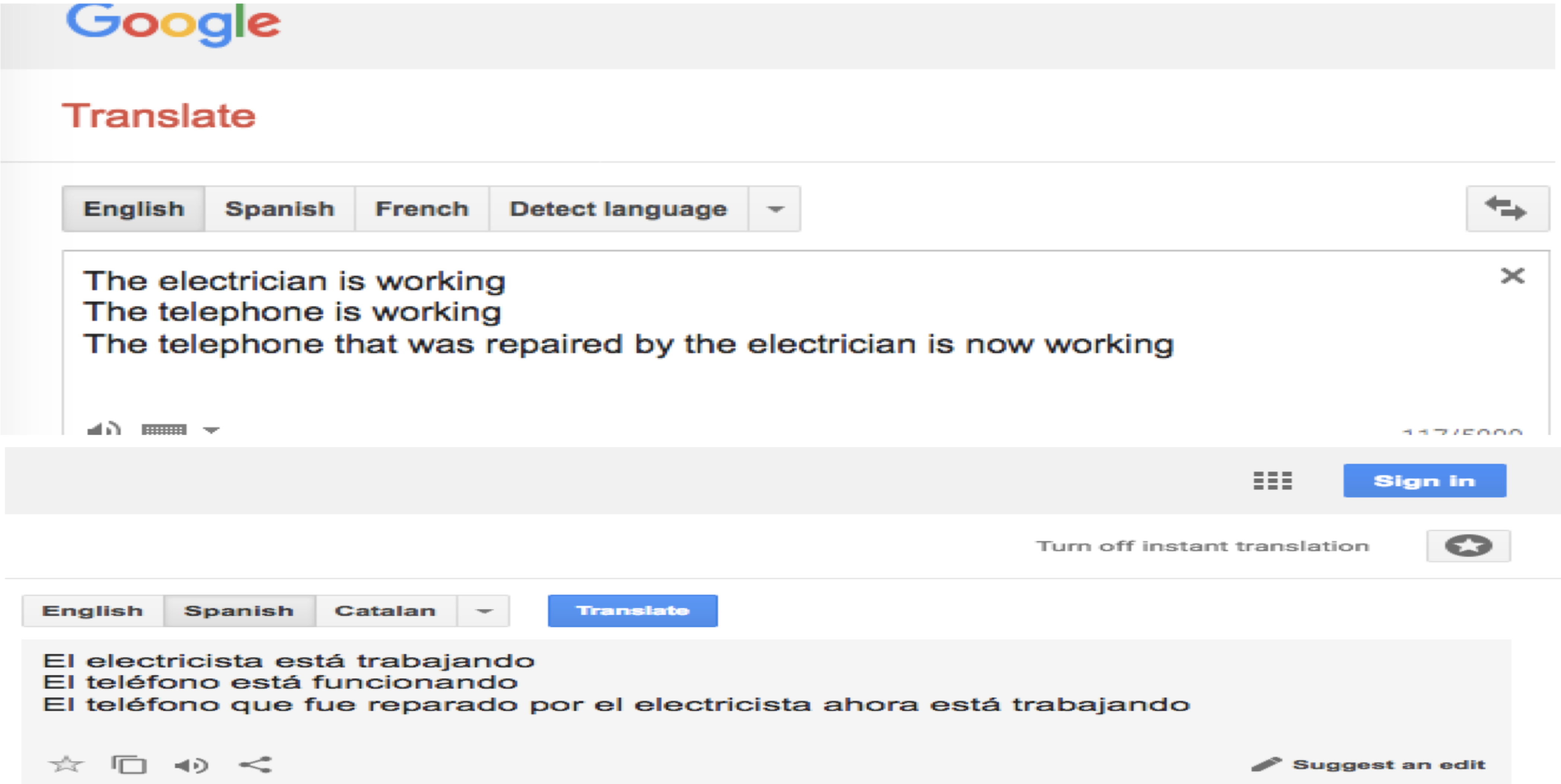
Robust understanding of (open-ended) language

Interpret an arbitrary visual scene

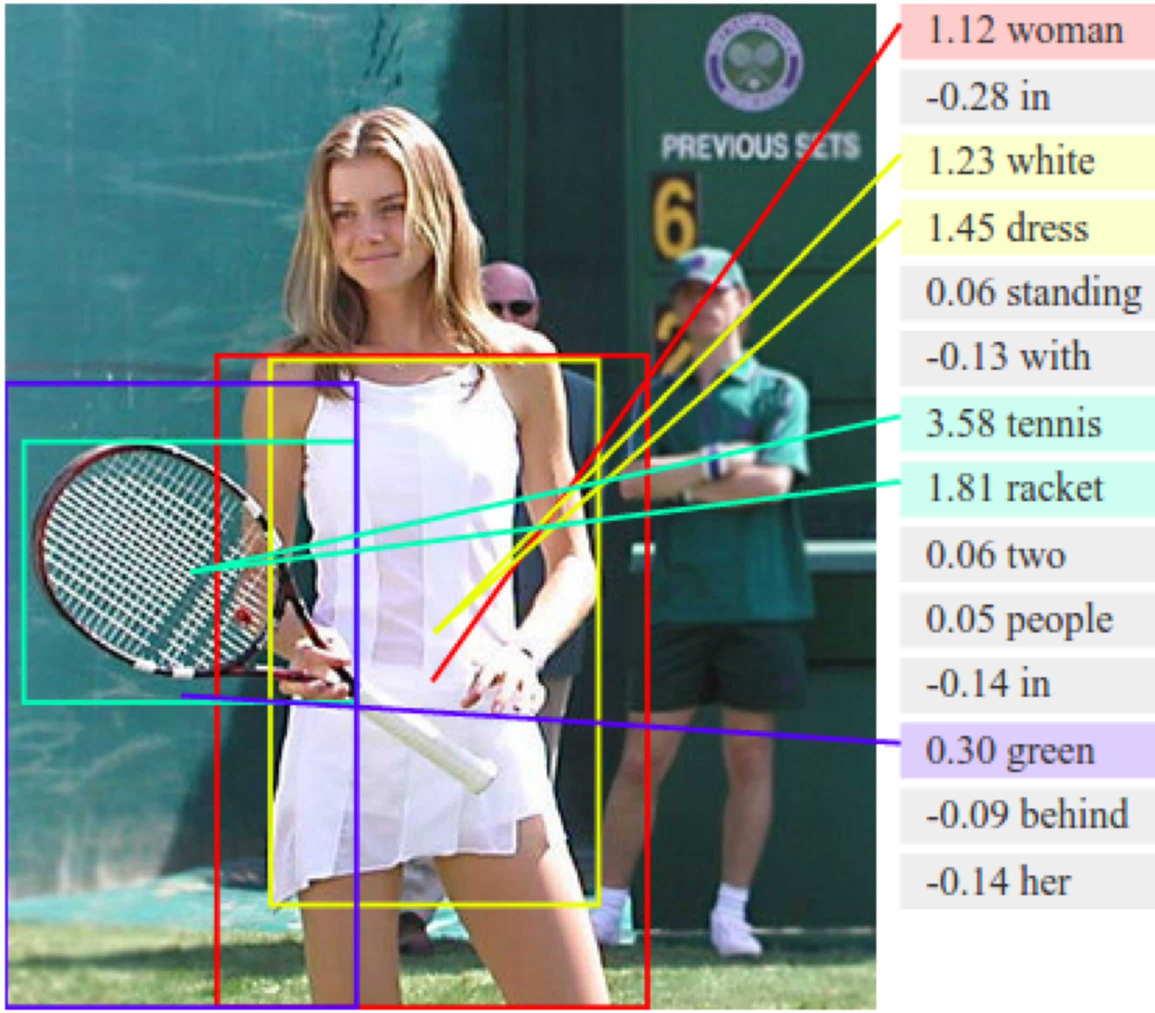
Learn incrementally and continuously

Exhibit autonomy and general intelligence!

Example of limitations: understanding language



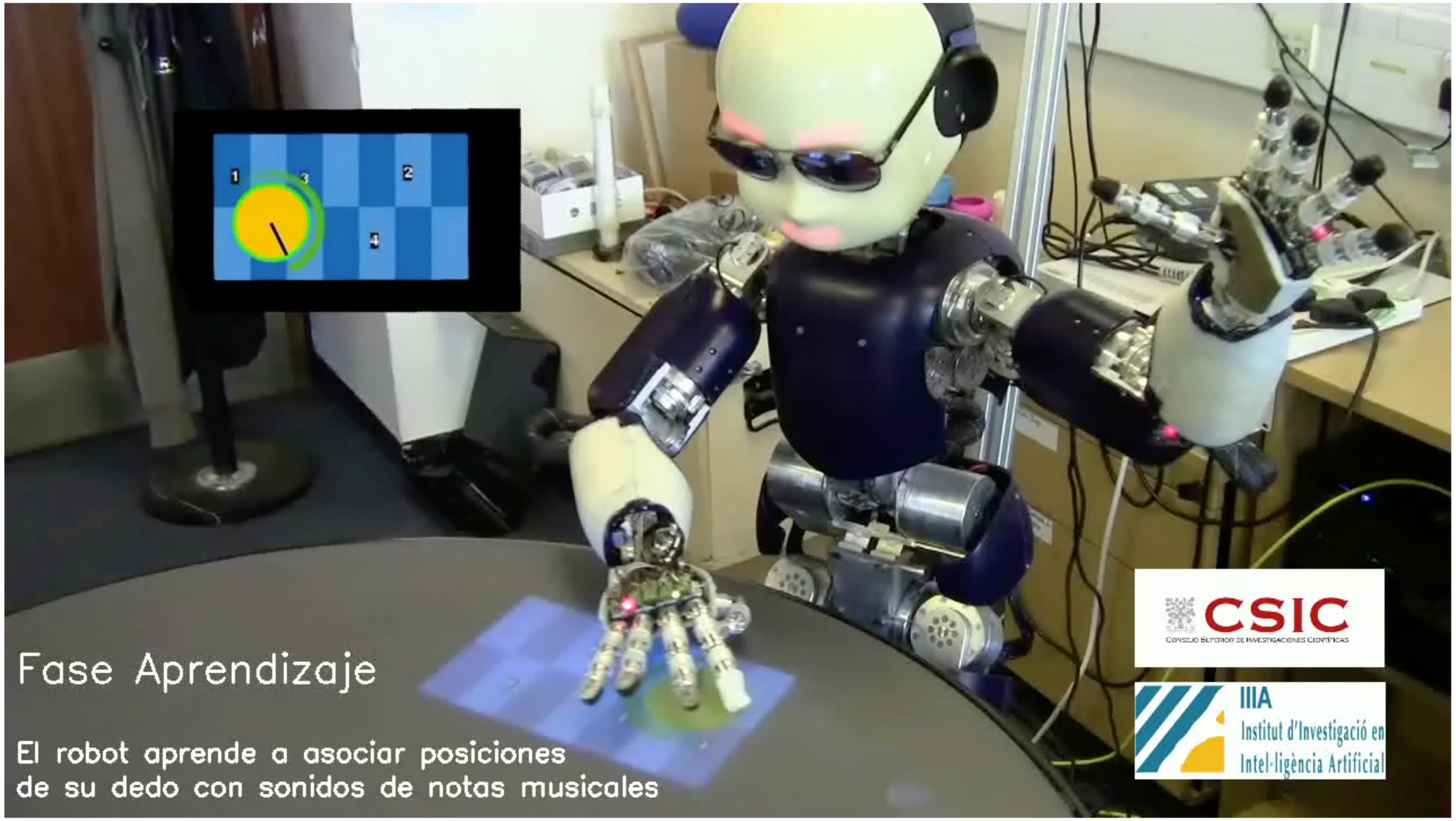
Example of limitations of scene analysis



Credit: Andrej Karpathy, Li Fei-Fei

Why we need common sense to understand scenes?

Learning cause-effect relations: Towards the acquisition of common sense knowledge



Autonomous Vehicles

Autonomous vehicles are a good example of a system that integrates virtually all components of an intelligent system:

Perception (very high resolution cameras + long range laser scanner, infrared and ultrasonic sensors)
Machine learning
Reasoning and Planning
Linguistic and gestural communication
Wireless communication with other vehicles and with road infrastructure

Ethical isssues of autonomous systems: Autonomous weapons

Samsung SGR A-1

Drones

Tanks

Impact on employment: Towards Human-Machine teams

Barcelona Declaration for the
proper development and usage of Artificial Intelligence

- –PRUDENCE
- –RELIABILITY
- –ACCOUNTABILITY
- –IDENTITY
- –MAINTAINING HUMAN KNOWLEDGE

http://www.iiia.csic.es/barcelonadeclaration

Conclusions

AI began as an attempt to answer the big question "What is intelligence?" and has become a scientific and technological field of great importance (hundreds of billions of dollars worldwide).

Today it is a technology that has made it possible to develop thousands of applications in a wide range of sectors and areas of knowledge

AI will continue to have important practical consequences in the form of start-ups, increased productivity, and improved quality of life.

But there are also important negative consequences: Privacy, mass control of citizens, autonomous weapons, bias and discrimination,...

The real issue in AI is not what machines are or are not capable of doing but what we should allow them to do **(Joseph Weizenbaum 1923 – 2008)**

In other words, the problem is not Dr. Frankenstein, the problema is his monster!

THE END !