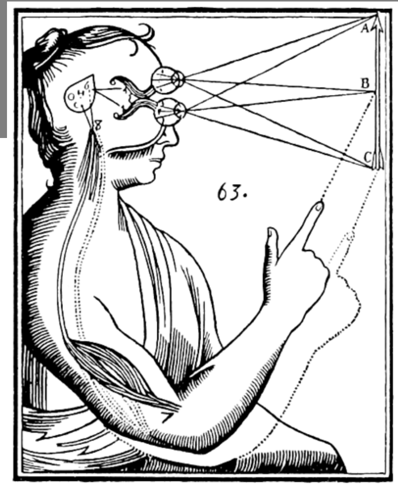
Artificial Intelligence

An Introduction

Marco Piastra



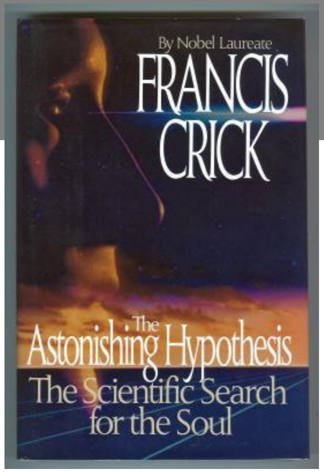
(from Wikipedia)

- [Descartes, R., *Discours de la Methode,* 1637]

  "I had after this described the **reasonable soul**, and shown that *it could by no means be educed from the power of matter*, as the other things of which I had spoken, but that it must be expressly created;

  and that it is not sufficient that it be lodged in the human body exactly like a pilot in a ship, unless perhaps to move its members,

  but that it is necessary for it to be joined and united more closely to the body, in order to have sensations and appetites similar to ours, and thus constitute a real man" [English version from Project Gutenberg]



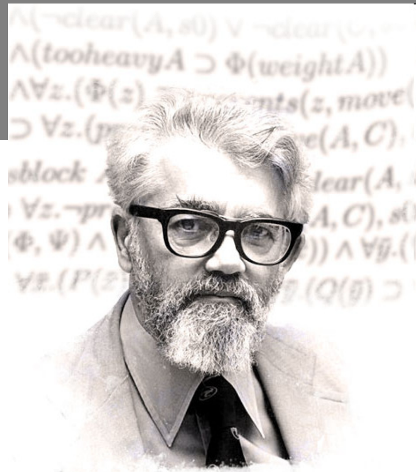
(from Wikipedia)

- [Crick, F., *The Astonishing Hypothesis,* 1994]

  "You, your joys and your sorrows, your memories and your ambitions,
  your sense of personal identity and free will,

  are in fact no more than the behavior of a vast assembly
  of nerve cell and their associated molecules."

"Artificial Intelligence" (first appearance of the term)



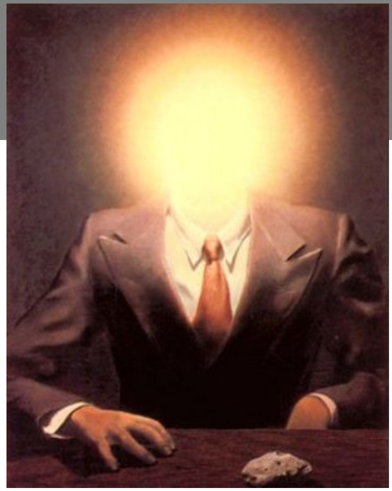
(from Wikipedia)

- [John McCarthy et al., 1955]

  "We propose that a two-month, ten man study of **artificial intelligence** carried out during the summer of 1956 [...]

  The study is to proceed on the basis of the conjecture that 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 may be speculated that a large part of human thought consists of manipulating **words** according to **rules** of **reasoning** and **rules** of **conjecture**."



(from Wikipedia)

- [Searle, J. R., *Minds, Brain and Science,* 1986]

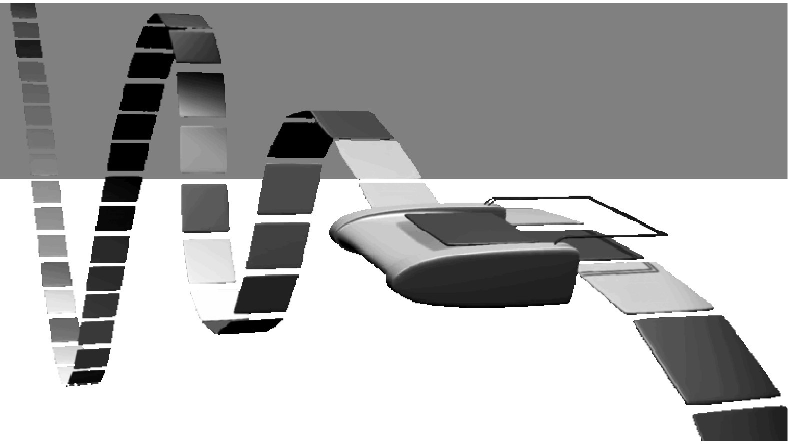
  "Because we do not understand the brain very well we are constantly tempted to use the latest technology as a model for trying to understand it.

  In my childhood we were always assured that the brain was a telephone switchboard ('*What else could it be?*').

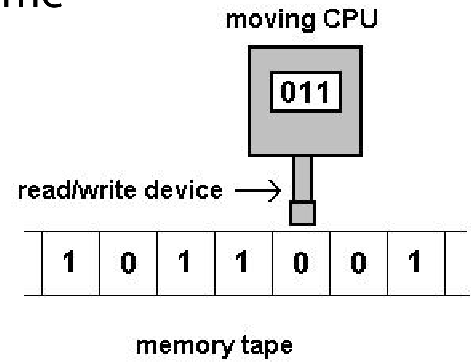
  I was amused to see that Sherrington, the great British neuroscientist, thought that the brain worked like a telegraph system. Freud often compared the brain to hydraulic and electro-magnetic systems. Leibniz compared it to a mill, and I am told some of the ancient Greeks thought the brain functions like a catapult.

  At present, obviously, the metaphor is the digital computer."

Turing Machine (A. Turing, 1937)

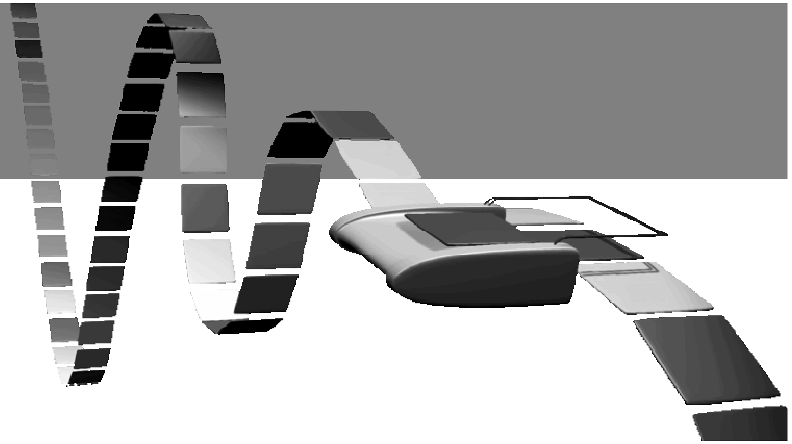


- An abstract model of effective computation
  - A **tape**, made up of individual **cells**
  - Each cell contains a **symbol**, from a finite **alphabet**
  - A **read/write head**, which can move in each direction - one cell at time
  - A **state register** that keeps the current **state**, from a finite set
  - A **transition table**, i.e. a set of *entries* like this:
    - { <*current state*, *symbol read*> → <*next state*, *symbol written*, *move*> }



- The **transition table** describes a *finite state machine*
  - Each *transition* is governed by the input symbol, the current state and the corresponding entry in the transition table
  - The next state is written into the state register
  - The output is written to the cell
  - Then the head moves (i.e. *left*, *right*, *none*)

Turing Machine (A. Turing, 1937)



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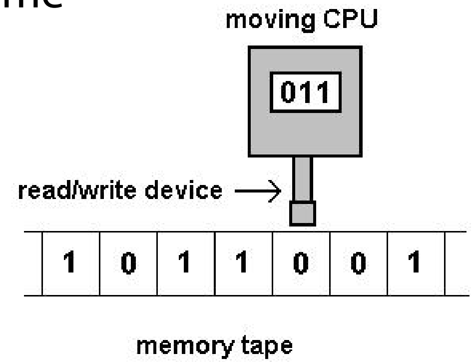
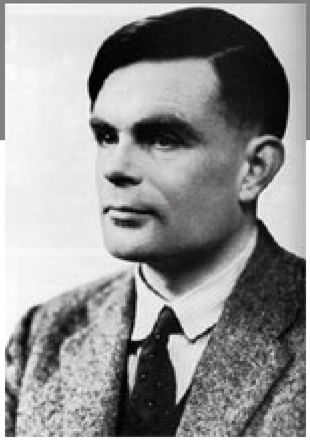


- What is the meaning of this?
  - The Turing Machine is a mathematical model of a physical computing device
  - (*It is very simple*)
  - Any given problem for which there is a Turing Machine that computes the solution is clearly computable by a physical machine

  - ***Is the vice-versa also true?***
  - (*If a problem is computable by a physical machine, does it exist a Turing Machine for it?*)

Church-Turing Thesis



Caution: there is no such a thesis in the original writings of either author. Its formulation can be extrapolated from both. Hence the attribution (made by others)

- A possible formulation (from Wikipedia):

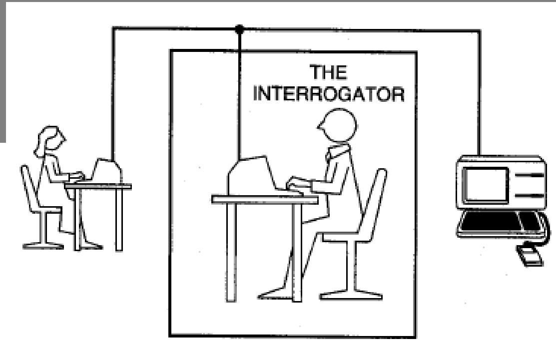
> *"Every 'function which would naturally be regarded as computable' can be computed by a Turing machine."*

The vagueness in the above sentence gives raise to different interpretations. One of these (though not entirely equivalent) is (from Wikipedia)*:*

> *"Every 'function that could be physically computed' can be computed by a Turing machine."*

Searle: "... At present, obviously, the metaphor is the digital computer."

Can machines think? (the Turing Test)



(from Wikipedia)

- Turing, A., *Computing Machinery and Intelligence*, 1950

  “[The ‘imitation game’] is played with three people,
  a man (A), a woman (B), and an interrogator (C) who may be of either sex.

  The interrogator stays in a room apart from the other two.

  The object of the game for the interrogator is to determine which of the other two is the man and which is the woman.

  He knows them by labels X and Y, and at the end of the game he says either ‘X is A and Y is B’ or ‘X is B and Y is A’

  The interrogator is allowed to put **questions** to A and B. […]

  We now ask the question,
  'What will happen when a machine takes the part of A in this game?‘

  Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman?

  These questions replace our original, 'Can machines think?' ”

Deep Blue

(from Wikipedia)

In 1945 A. Turing mentions playing chess as an example of intelligent human activity that some days machines could perform

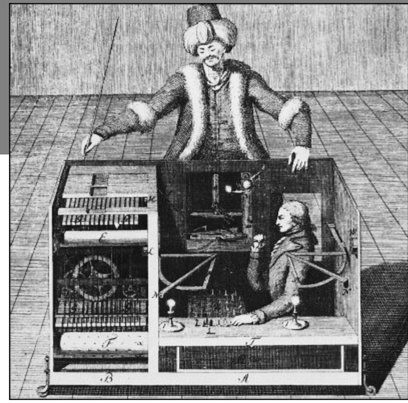
In 1946 A. Turing defines the first *algorithm* for playing chess

In1997 the *Deep Blue* system, made by IBM,
beats the world chess champion Gary Kasparov

- Deep Blue, 1997 (Campbell, M., Hoane, A. J., Hsu, F., 2001)
  - 30 standard CPUs (120Mhz) + 480 special-purpose CPUs
  ('chess search engines', each evaluating 2.5M moves per second)
  - Three-layered hardware architecture, 30 GB of RAM
  - *S*oftware written in C
  - Wide usage of a large database of recorded games played by grand masters

- Questions:
  - Is Deep Blue *intelligent*?
  - Does Deep Blue *perform* an intelligent human activity?

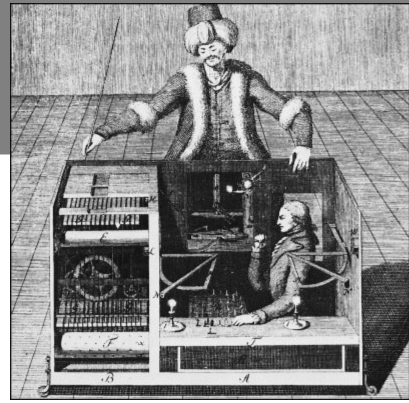
Can machines play chess?



(from Wikipedia)

- Programming a Computer for Playing Chess [Shannon, 1948]
  - Chess game statistics
    - More than 10^{43} different legitimate chessboard configurations
    - More than 10^{120} possible games
  - Strategy A
    - It is based on an *evaluation function* $f(\mathrm{P})$ defined for all possible, **final** positions:
      - +1 if the first player (i.e. the computer) wins, regardless;
      - 0 if it is a draw, regardless;
      - -1 if the second player wins, regardless;
    - The machine computes backwards the values of $f(\mathrm{P})$ of all possible, **non-final** positions starting from all possible **final** positions
    - The value assigned to each **non-final** position P is equal to the sum of f values of the **final** position which P may lead to
    - At each move, the computer chooses the move that leads to the position with the maximum value of f

Can machines play chess?



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    This strategy is unfeasible, even with modern computers (as it entails exploring all possible games)

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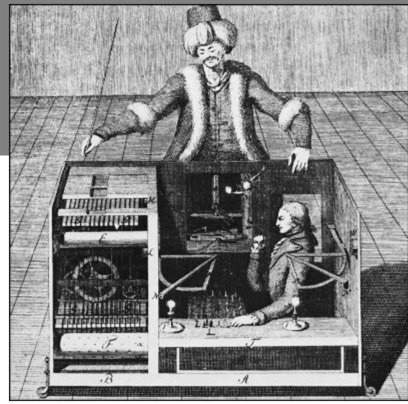

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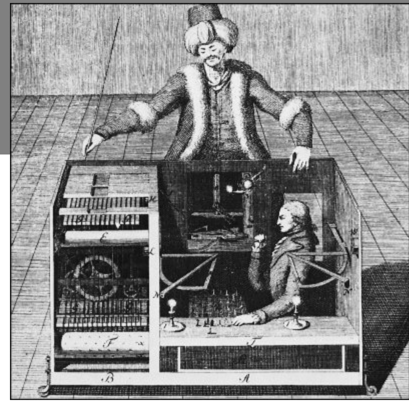
  - Strategy A (*revised*)
    - Use an *approximate evaluation function* $f^*(P)$ on all possible positions
    - Given the current position in the game, the machine *looks forward* by exploring all possible positions not farther away than k moves
    - The computer chooses the move with the MINIMAX method (see after)

Can machines play chess?



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  - Strategy B
    - "A good human player examines only **a few selected variations** and carries these out to a reasonable stopping point"
    - Use two functions that evaluate the stability of a position P and to what extent a move M in a position P *is worth being examined* at all
    - In short: find *higher level* patterns

Strategy A: *MINIMAX*

Two players: MAX △ (e.g. the computer) e MIN ▽ (i.e. the opponent)

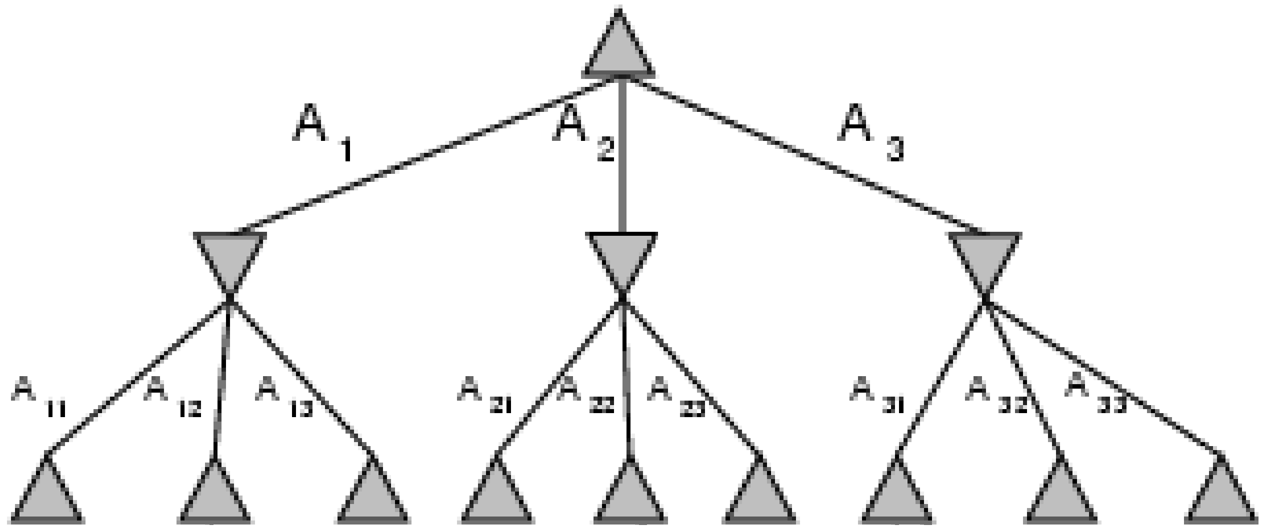
Game tree:

Each node represents a *position* P in the game

Each arc represent a possible *move*

Approximate evaluation function $f^*(P)$:

It yields an estimate of how good the position is for MAX



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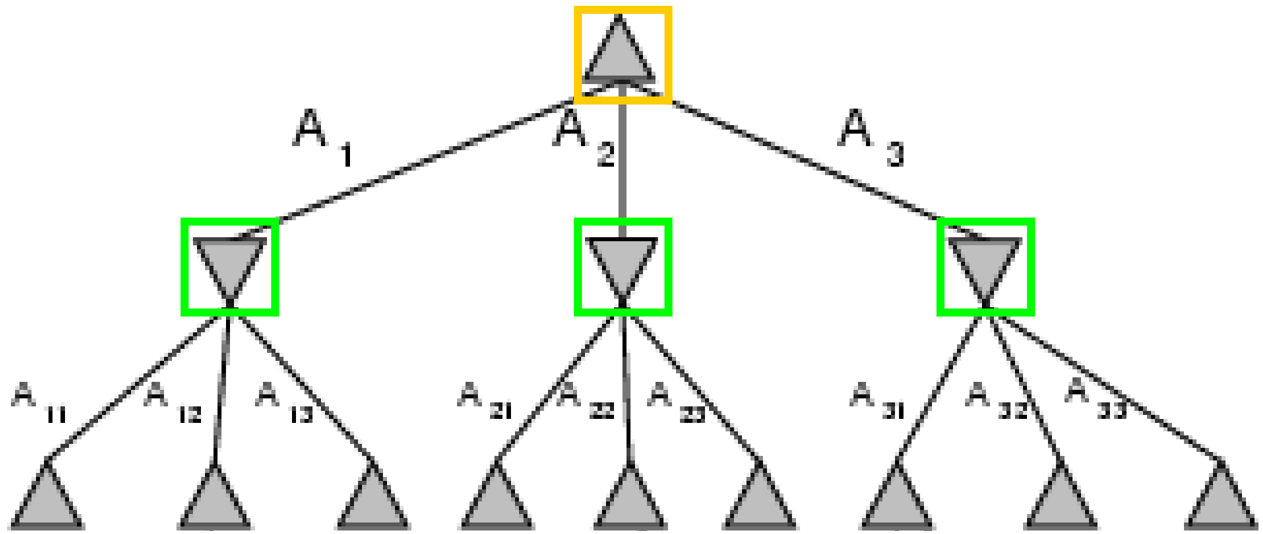
MAX moves:
there are three possible choices



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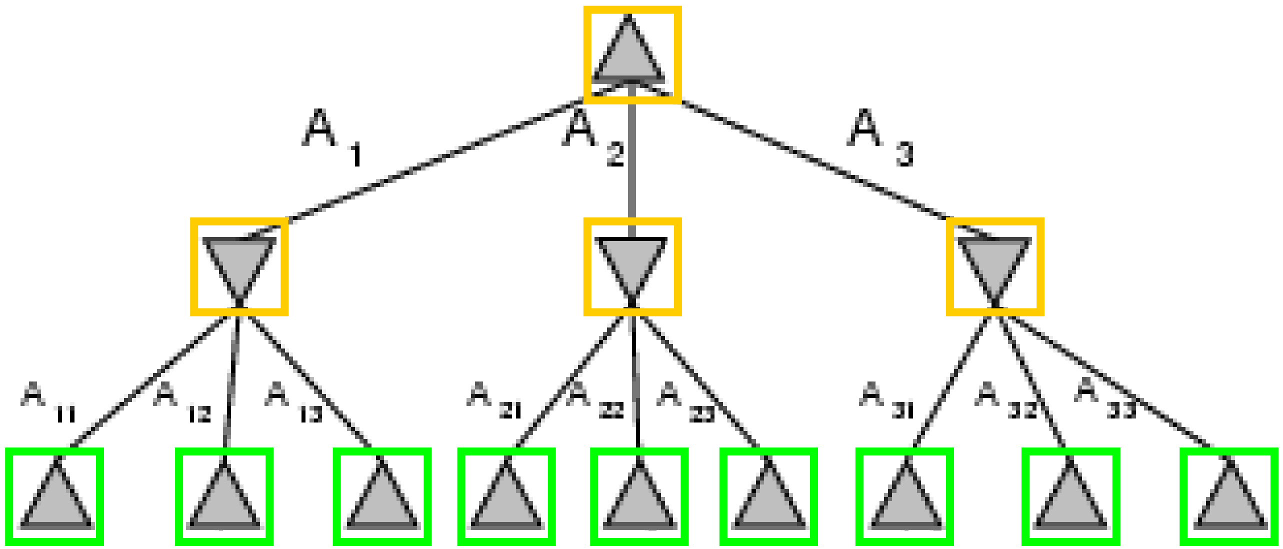
MIN moves:
three possible choices
at each position



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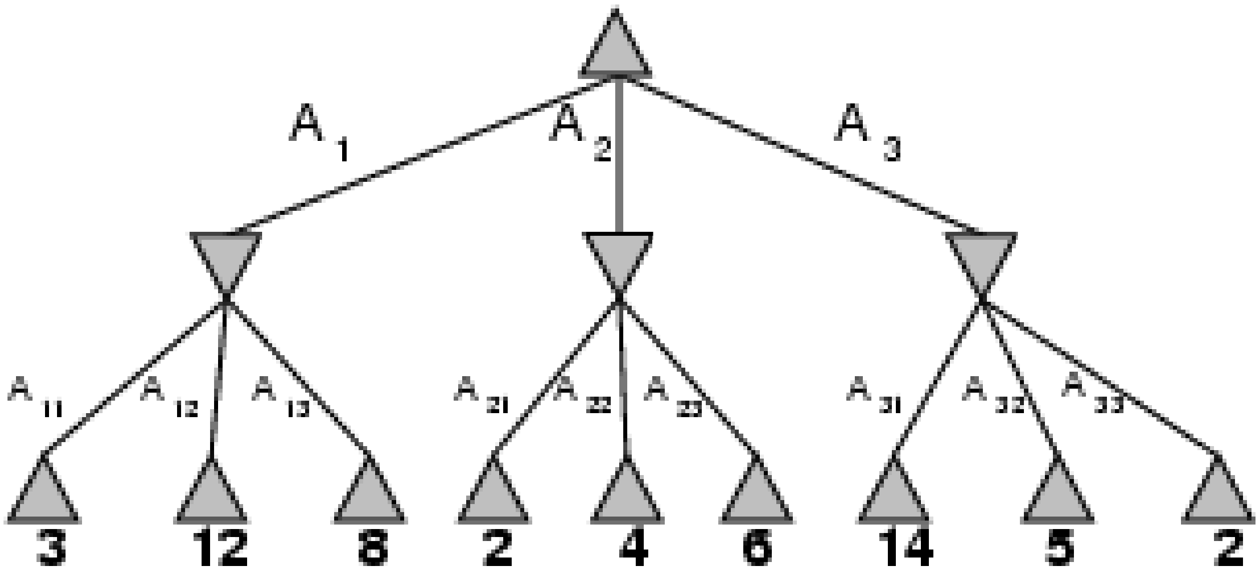

Compute f^* at bottom positions
(i.e. at *ply* 2)

Strategy A: *MINIMAX*

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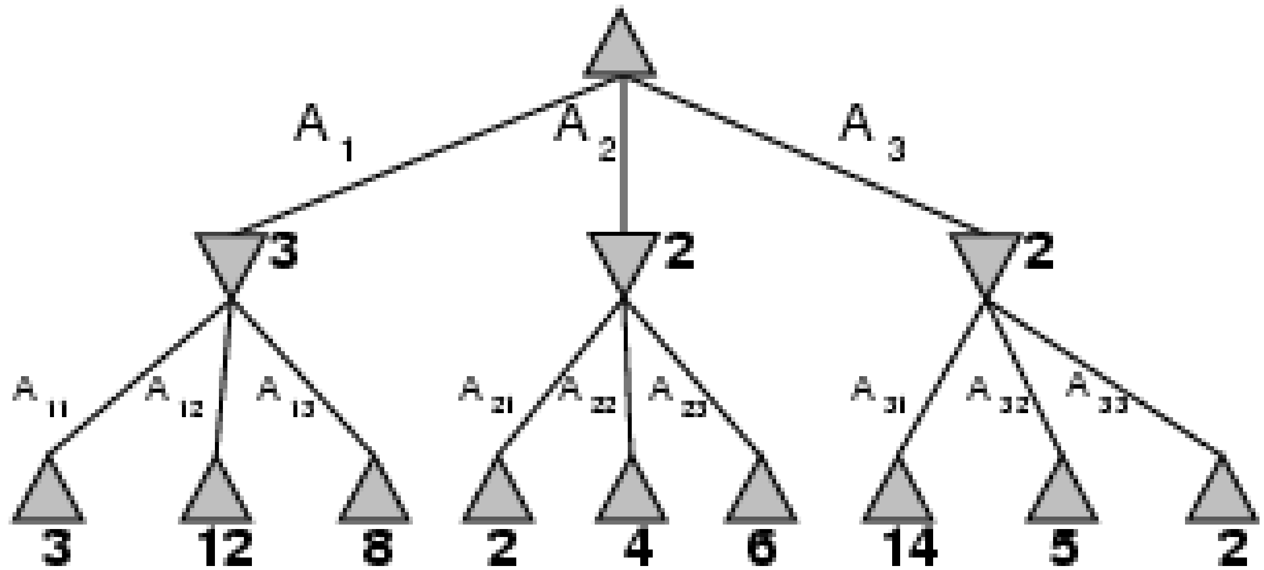
<u>Approximate</u> evaluation function $f^*(P)$:

It yields an estimate of how good the position is for MAX

Propagate backwards with MIN



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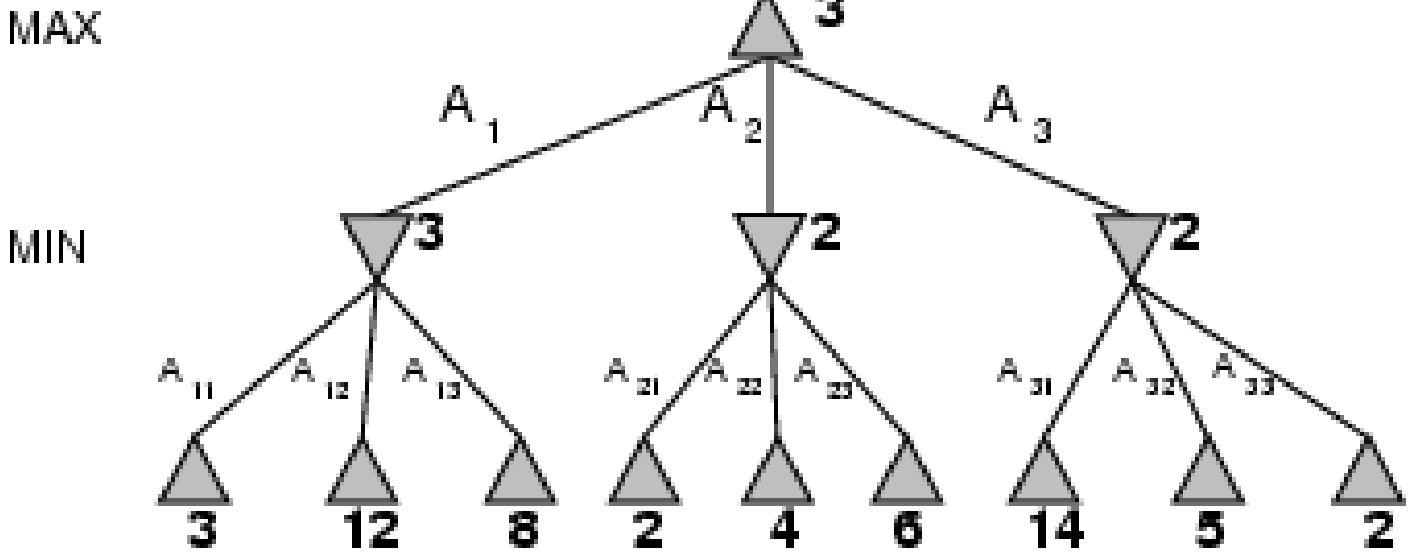
Propagate backwards with



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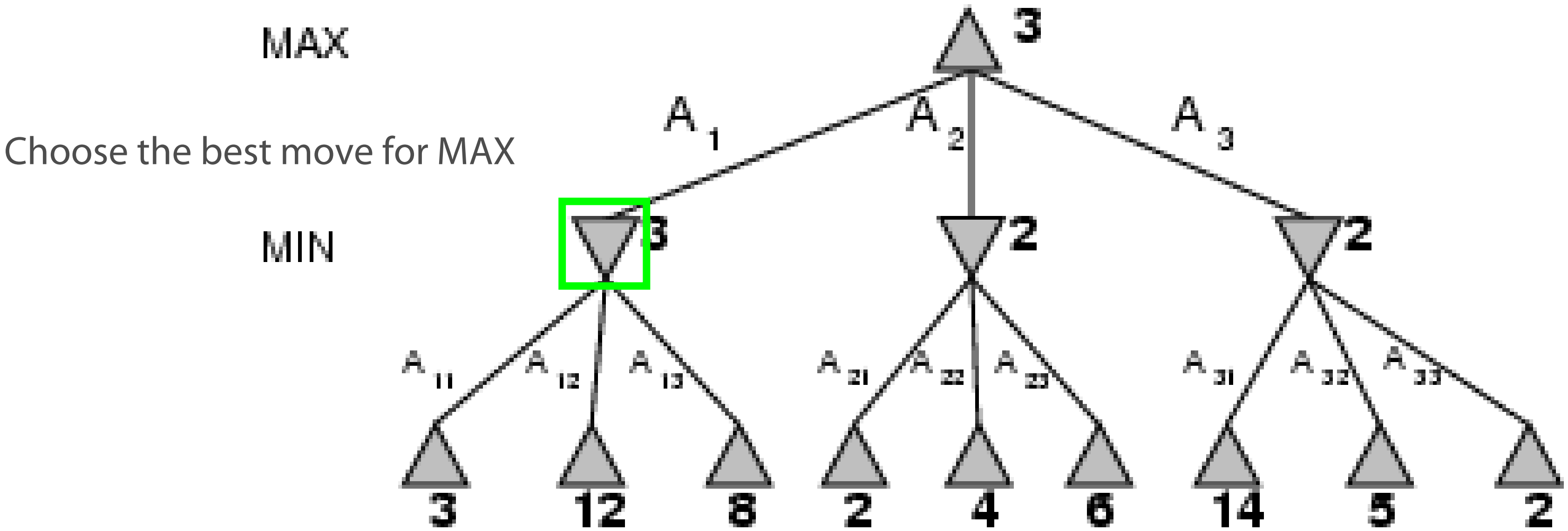


Strategy A: *MINIMAX*

(Obviously, the tree structure in the previous slides is definitely *simplified*)

In the game tree for chess, each node has an average *branching factor* of 30

The number of nodes in the game tree is $O(b^d)$

b is the average *branching factor*
d is the *depth* (i.e. how far the exploration goes)

Example:

The complete game tree for ply 2 contains 30^2 (i.e. around 10^3) nodes
The complete game tree for ply 6 around 10^9 nodes
A computer that can evaluate 10^6 positions per second would take more than 16 minutes

A typical chess game has ply 80-90

Human master players are believed to have an equivalent *lookahead* of ply 30-40 and more (but without explicit computation…)

Is therefore Strategy B superior to Strategy A?

Strategy A or Strategy B?

Note: the MINIMAX method can optimized (i.e. with *alpha-beta pruning*, see Wikipedia) so that it is possible to double the *depth* that can be explored in the same time

[Shannon, 1948]

Due to the high computational complexity of Strategy A, he foresees a progressive development of Strategy B

(i.e. something like "Computer can improve by emulating humans")

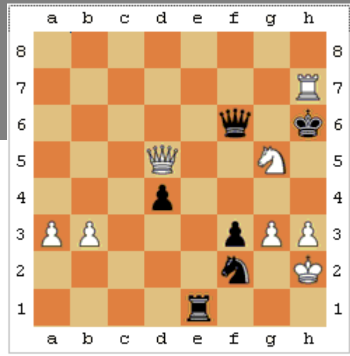
How did it go, in reality?

- At the early stages of computer chess technology, Strategy B was preferred
- During the period 1959-1962 a first 'credible' player was developed (Kotok-McCarthy) (at the *beginner* level)
- In 1973 the developers of the world champion of computer chess players abandoned Strategy B in favor of Strategy A
- Since then, Strategy A – with significant improvements – dominates the scene

  This includes *Deep Blue* and all current top-ranking computers

  Excellent computer chess players are now available for smartphones

Deep Blue



- Deep Blue, 1997 [Campbell, M., Hoane, A. J., Hsu, F., 2001]
  - Great *lookahead* power
    - On the average, it could search ply 12.2 ply in three minutes
  - Dedicated hardware
    - Special evaluation primitives implemented in silicon
  - Hybrid dedicated machine: hardware + software
    - Software algorithms in C for standard CPUs, easily modified
    - Specialized processors for exploring the game tree
  - Massive parallelism
    - More than 500 processors for parallel exploration
  - Huge database of games by grand masters (humans)

    (It was turned off at the end of the match)

- Same questions:
  - Is Deep Blue *intelligent*?
  - Does Deep Blue *perform* an intelligent human activity?

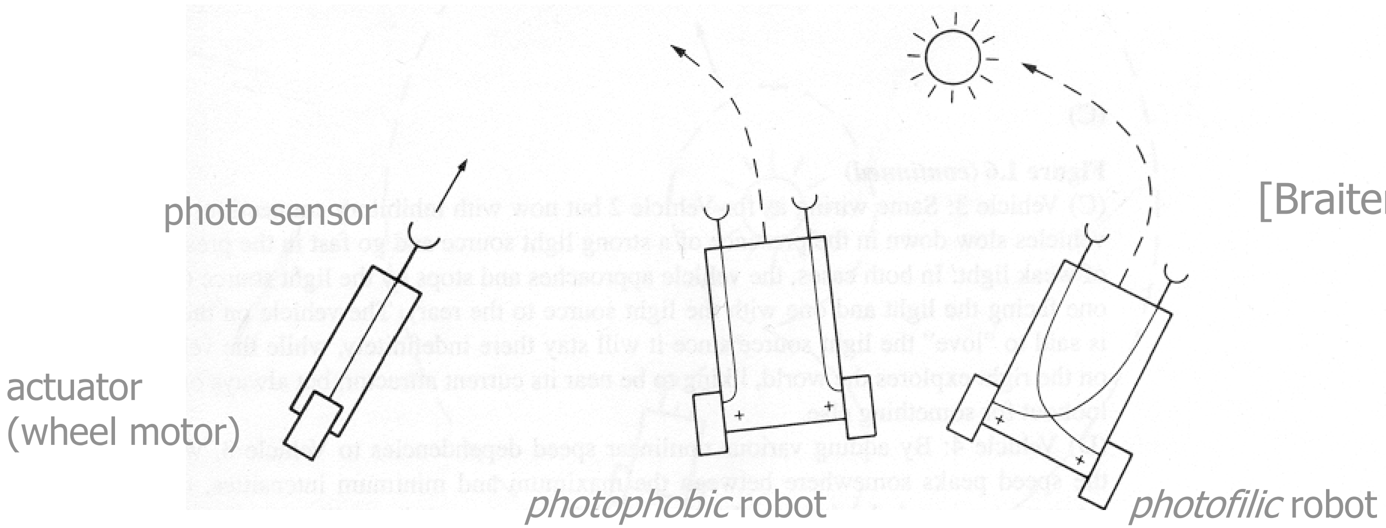
Do elephants play chess?

[Brooks, R., *Elephants Don't Play Chess*, 1990]

- Criticism of *intelligence* intended as the manipulation of *symbols*
  - A unique and synchronous control system
    - Studies on cerebral lesions suggest otherwise
  - A unique, *general purpose* and neutral computational device
    - Studies about human visual perception show clear preferences towards some interpretations over others
  - A unique language for the internal representation of reality
    - Human beings do it differently – e.g. *change blindness* [O'Reagan, J. K., Rensink, R. A., Clark, J. J., 1999]
  - Total separation between the thinker and its hardware (*disembodiment*)
    - Hence excluding all forms of non-symbolical intelligence

(Besides, how could it possibly *evolve* such a form of intelligence?)

Does this look intelligent?



[Braitenberg, V., 1986]

- Direct connection

  These robots by V. Braitenberg have just a *reactive* behavior, i.e. no ‘thought in between’: sensors are directly connected to actuators

  The resulting behavior is remarkable anyway ...

Three level of cognitive processing [D. Norman, 2004]

- **Visceral**

  The most immediate level of processing, in which we react to visual and other sensory aspects of a product that we can perceive before significant interaction occurs. Visceral processing helps us make rapid decisions about what is good, bad, safe, or dangerous.

- **Behavioral**

  The middle level of processing that lets us manage simple, everyday behaviors, which constitute the majority of human activity. Behavioral processing can enhance or inhibit both lower-level visceral reactions and higher-level reflective responses, and conversely, both visceral and reflective processing can enhance or inhibit behavioral processing.

- **Reflective**

  The least immediate level of processing, which involves conscious consideration and reflection on past experiences. Reflective processing can enhance or inhibit behavioral processing, but has no direct access to visceral reactions. This level of cognitive processing is accessible only via memory, not through direct interaction or perception. Through reflection, we are able to integrate our experiences with designed artifacts into our broader life experiences and, over time, associate meaning and value with the artifacts themselves.

DeepQA (a.k.a. "Watson")

- DeepQA, 2010 [Ferrucci, D., et al. 2010]

  The Event (14-18/02/2011)

  In a sequence of three "*Jeopardy!*" games, Watson beats in a very convincing way the all-times human champions

  - Brad Rutter, winner of the highest amount of money
  - Ken Jennings, winner of the longest string of games

(from Wikipedia)

  Jeopardy! : a quiz game

  In the real game, questions can also be about images, audio or video displays

  DeepQA can only accept spoken text as input

  Autonomous search, local memory

  The rules of the challenge forbid connecting to Internet during the game: DeepQA must use its local memory only

  It does use Internet during training

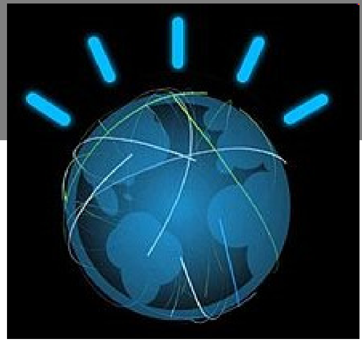
  Conventional hardware, massive parallelism

  High Performance system, with 2880 standard CPUs (no specialized hardware required)

  Linux SUSE ES 11, Software in Java and C++, with Apache Hapgood and Apache UIMA

  (IBM expects a commercial return from Watson)

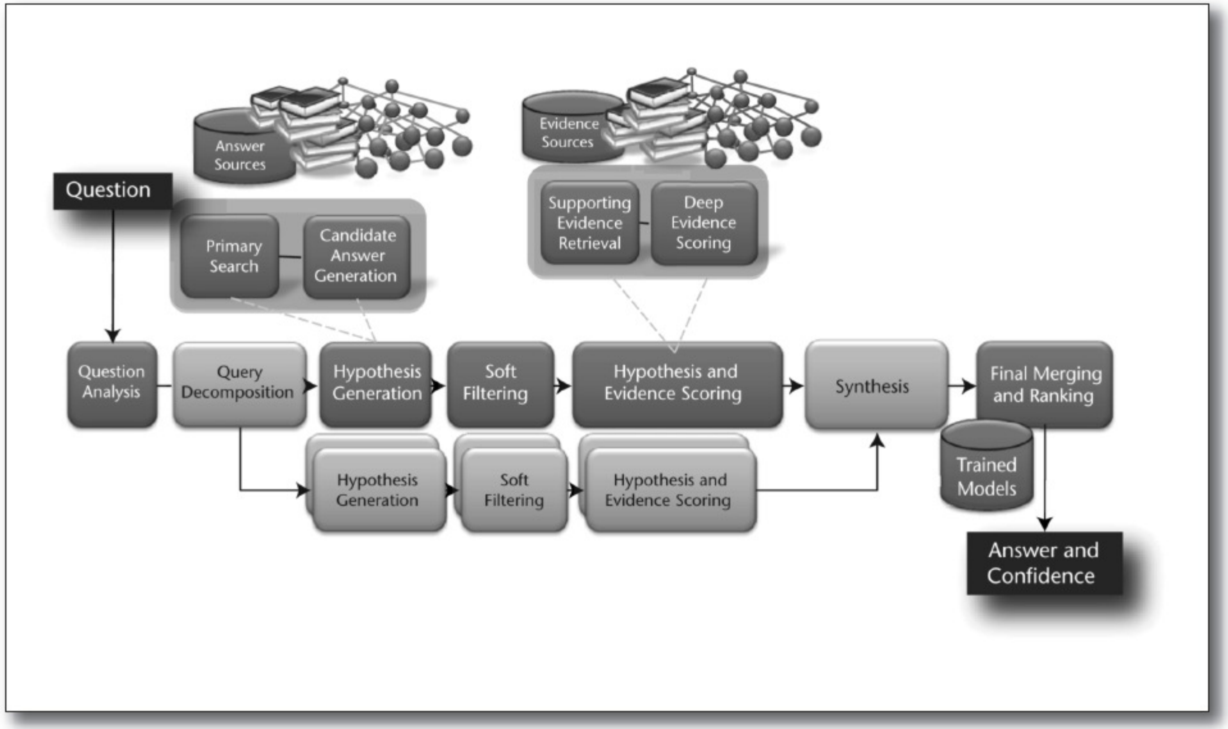
DeepQA (a.k.a. "Watson")



(from Wikipedia)

- How does it work?

  Very little is known…



(from [Ferrucci, D, et al. 2010])

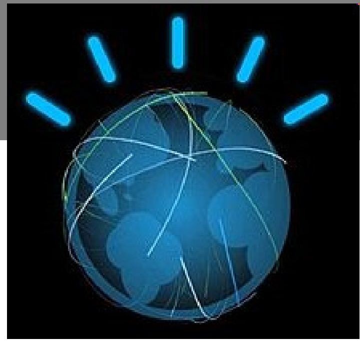
Processing stream

"They used nearly every trick in the book.." (from a video on YouTube)

Several competing streams in parallel

Each stream scores a 'degree of confidence': the best answer is chosen, at the end

DeepQA (a.k.a. "Watson")



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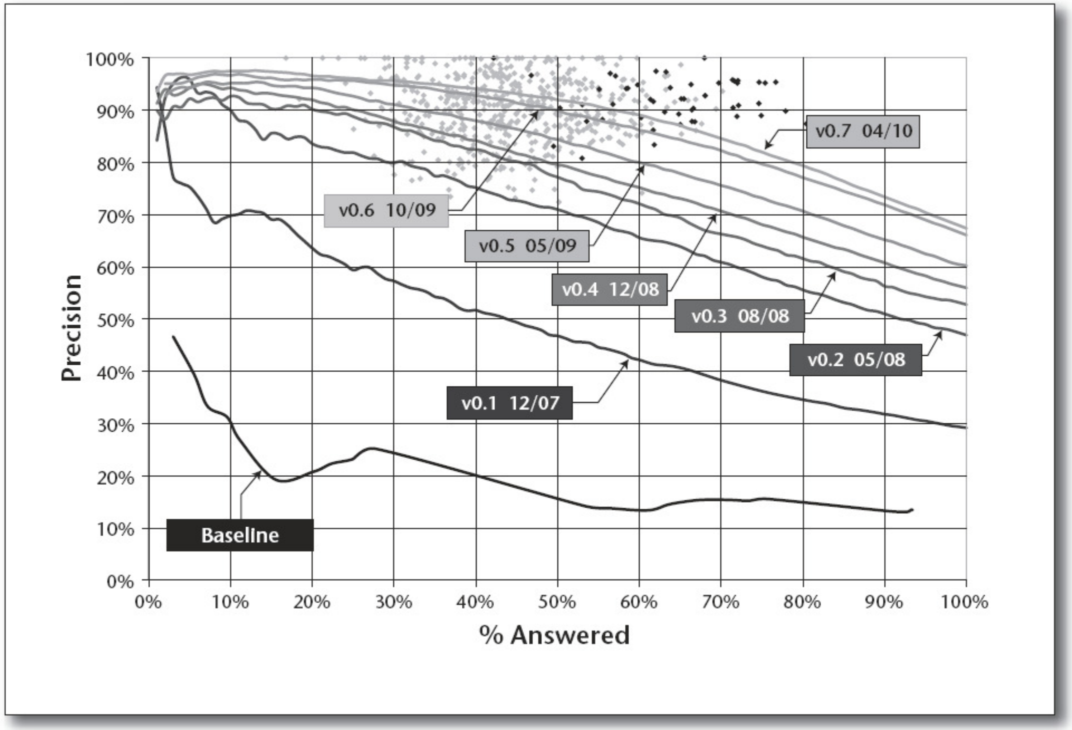

(from [Ferrucci, D, et al. 2010])

Progressive, incremental training

Vast usage of *machine learning* techniques

Is Watson intelligent?

- "Does Watson Think?"

  "Huh, hmm, what's my favorite response on that?
  (*Do submarines swim?*)
  […]
  I'd like to look at it as a sort of task-based view:
  when you think of Watson playing Jeopardy!
  it is acting like an intelligent Jeopardy! player,
  if you deconstruct its intelligence
  you're gonna find lots of different algorithms
  no one of them you would look at and say
  "Wow! That's really intelligent! It really understands the question!"
  […]
  You have this holistic effect,
  where it's solving a problem that you formally think
  that takes you *think,* to solve that problem, …
  Watson is doing it in a perhaps different way.
  […]
  And I think ultimately of it as a tool, that helps humans solving problems… "

D. Ferrucci, transcript from video http://www.ted.com/webcast/archive/event/ibmwatson

Artificial Intelligence

- A modern (*and cautious*) approach

  “The study of computer-based tools that help humans solving problems which *they* think require intelligence”

Artificial Intelligence

- A modern (*and cautious*) approach

  "The study of computer-based tools that help humans solving problems which *they* think require intelligence"

  "And which from time to time helps them understanding how their intelligence actually works."