Round table discussion on

Whether Neural Networks can be intelligent like human?

A literature review on

Formal Definitions of Machine Intelligence

for a round table discussion on

Whether Neural Networks can be intelligent like human?

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Turk

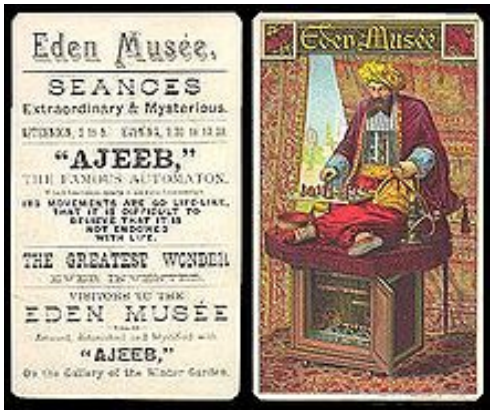
A legendary chess automaton in 18th century.
Wolfgang von Kempelen created it and claimed it plays chess like human to impress Maria Theresa (1770).

Napoleon vs. the Turk at Schönbrunn

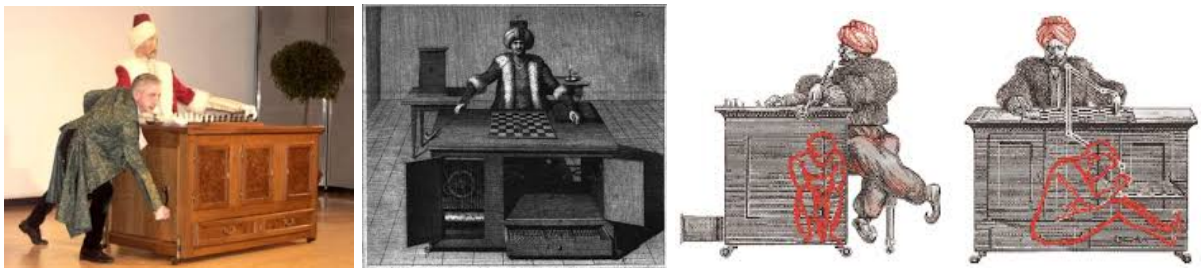
It debuted in Schönbrunn Palace, then toured in Europe after 1783

Märzel bought the Turk (1811)

In 1826, he opened an exhibition in New York



It was human not the machine who played.



The secret had been perfectly kept for more than 100 years.

It was not until Dr. Silas Mitchell fully revealed the secret in the book "The Last of a Veteran Chess Player" (1857).

$\Rightarrow$ No one had claimed it was human!

Turing's Chess Machine

The game was with three chess players A, B and C.
A is in a separate room with B who operates the paper machine.
C plays chess from outside with either A or B and should guess

whether he is playing, with human or the paper machine.

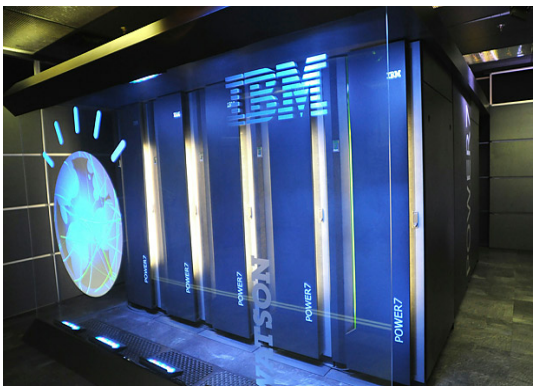
Does Turing Test still work after more than 50 years since his proposal?

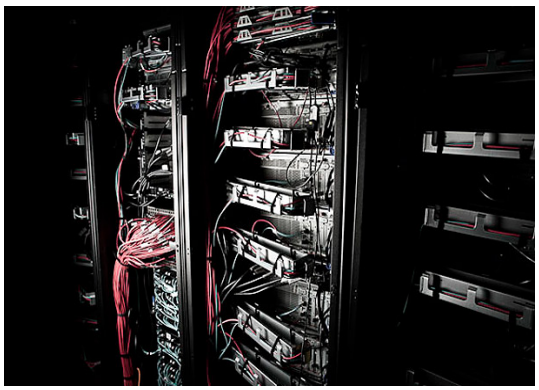
IBM's Deep Blue

Garry Kasparov vs. Deep Blue in 6 game match (1996)

Watson

I.B.M's ground-breaking question-answering-machine





Watson challenged 'Jeopardy!' (2011)

America's Favorite Quiz Show on TV

⇓ e.g.

"Who is the 19th-century painter whose name means police officer?"

"What is the city in U.S.
whose largest airport is named for a World War II hero;

and its second largest for a World War II battle."

Watson vs. two human ex-champions

⋆ The holder of the longest unbroken winning streak.

⋆ An undefeated champion and the game's biggest money winner.

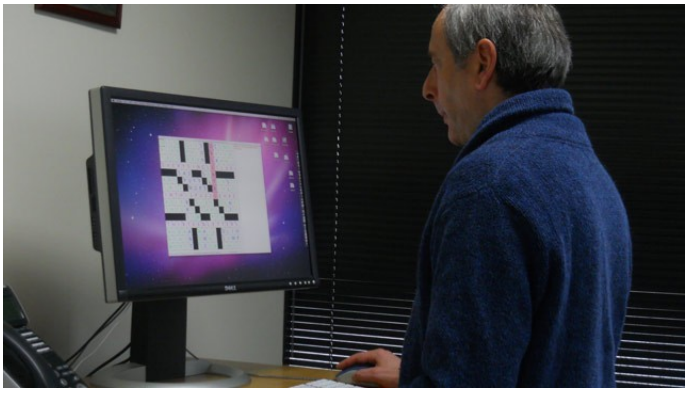
The final tally

The two humans won $24,000 and $21,600
while

Watson $77,147

Crosswords solving algorithm

Dr. Fill designed by Matthew Ginsberg



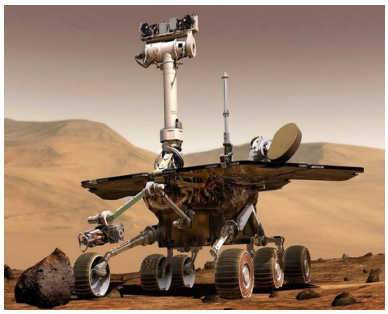
American Crossword Puzzle Tournament

in Brooklyn (2012)

600 humans of the world's best crossword players participated.
The trophy went to a human and Dr. Fill finished 141st.

Still impressive, isn't it?

Are Roomba or Mars Rover intelligent?

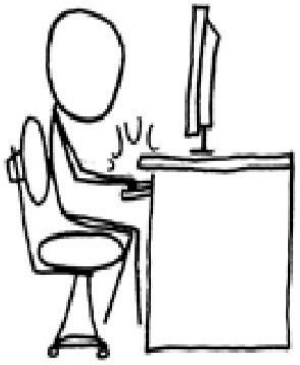
Or, what about Siri in iPhone?

They might pass the Turing Test!

Turing Test

tests the ability to fool ordinary people, not foolish people, about whether

the dialogue via teletype is with a human or with a computer.



The dicision is binary

i.e.

intelligent or not-intelligent

Then how intelligent?
or
Which agent is more intelligent?

How those proposed machine intelligences are actually intelligent?
How we define intelligence?
How can we measure it?

How those measurements really represent an intelligence?

Or, not intelligent at all?

We'd better ask monkey to throw darts.

Malkiel
A Random Walk Down Wall Street

"A monkey throwing darts at the WSJ to select a portfolio might be better than the one carefully selected by experts.

A degree to how a machine is intelligent

Gregory Chaitin (1987), Warren Smith (2006)
tried to answer it using complexity theory.

⇓

Now we have a fair amount of such definitions.

Legg & Hutter's definition

From informal

"An agent's ability to achieve goals in a wide range of environments."

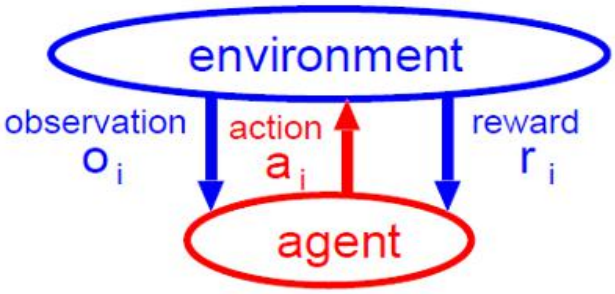
$$\Downarrow$$

to formal

$$\gamma(\pi) = \sum_{\mu \in E} 2^{-K(\mu)} \cdot V_{\mu}^{\pi}$$

Agent interacts with environment

Observation $o_i \Rightarrow$ Action $a_i \Rightarrow$ Reward r_i



Yields a history :

$$o_1 \rightarrow a_1 \rightarrow r_1 \rightarrow o_2 \rightarrow a_2 \rightarrow r_2 \rightarrow o_3 \rightarrow a_3 \rightarrow r_3 \rightarrow o_4 \rightarrow \cdots$$

E.g.
Agent who forecasts stock market

Observes market

$\Downarrow$

Action: buy or sell stocks

$\Downarrow$

Rewards: profit or loss

Definition of agent

Function that takes the current history as input
and
produces an action as output

$$\pi(a_k|o_1 r_1 a_1 o_2 r_2 a_2 \cdots o_{k-1} r_{k-1})$$

or probability function for non-deterministic.

Definition of environment

Function which produces output the current $o_k r_k$ given the history

$$\mu(o_k r_k | o_1 r_1 a_1 o_2 r_2 a_2 \cdots o_{k-1} r_{k-1} a_{k-1})$$

or probability function for non-deterministic.

Expected value of sum of rewards

$$V_{\mu}^{\pi} = E(\sum_{i=1}^{\infty} r_i)$$

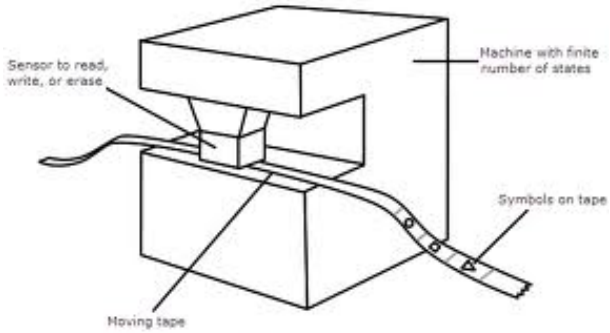
Definition of intelligence

Weighted sum of
expected value of sum of rewards over various environments

$$\gamma(\pi) = \sum_{\mu \in E} w_\mu \cdot V_\mu^\pi$$

How will those weights be specified?

Translate the environment into a binary string x by Turing Machine



A Turing Machine

Weights depend on complexity of task.

Calculate Kolmogorov complexity K of x
(length of the shortest program that computes x)
$K(x) = \min_p\{l(p)|U(p) = x\}$

$$\Downarrow$$

$$w_\mu = 2^{-K(\mu)}$$

The smaller the complexity the larger the weight.

Universal Machine Intelligence

by Legg and Hutter

$$\gamma(\pi) = \sum_{\mu \in E} 2^{-K(\mu)} \cdot V_{\mu}^{\pi}$$

"An agent's ability to achieve goals in a wide range of environments."

Too conceptual or too theoretical

Goertzel:

"Universal but not practical."

Goertzel

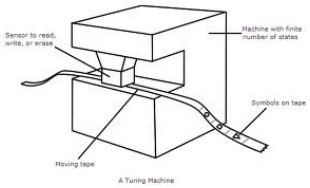
pragmatic intelligence

$$\Pi(\pi) = \sum_{\mu \in E, g \in G, T} \nu(\mu)\gamma(g,\mu)\tau_{g,\mu}(T)V^{\pi}_{\mu,g,T}$$

$$\Downarrow$$

It's not very practical yet, isn't it?

Problem is, translation of environment by Turing machine



⇓

Are there easier alternatives to the Turing machine?

Hernándes-Orallo

The other representations of environment

$\Downarrow$

(i) λ-calculus, (ii) combinatory logic, (iii) abstract state machines,
(iv) register machines, (v) Markov algorithms,
(vi) term-rewriting systems, ...

to generate environments and calculate complexity automatically.

"still Turing-complete, but
more natural and easier to work with than the Turing machine."

Hernandes's target was strings

He measured the ability of finding the shortest explanation for some strings of different difficulty in a fixed time

e.g.

$$x = aaaaaaabaaaaaaabaaaaaaabaaaaaaa$$

$$x = aabbbccdddeefffgghhhiiijjj$$

$$x = 1,2,3,5,7,11,13,17,19,23$$

$$\Downarrow$$

Still not so practical for our purpose.

Hibbird used finite state machine (FSM) to be a little more realistic

Environment and agent are both modeled as FSMs.

⇓

Create a hierarchy of increasingly difficult environments.

⇓

Agent intelligence is measured as the highest level of environment against which it can win the game.

Hibbird's game

Evader e produces the sequence by

$$x_{n+1} = e(y_1 y_2 y_3 \cdots y_n),$$

and predictor p produces the sequence by

$$y_{n+1} = p(x_1 x_2 x_3 \cdots x_n).$$

Then p wins round $n+1$ if $y_{n+1} = x_{n+1}$

and e wins if $y_{n+1} \neq x_{n+1}$.

Our purpose, however, is

to measure intelligence of proposed machine in proposed environment!

(1) Let's be specific not universal!

Our goal is not to measure a universal almighty robot!

Let's be specific not universal!

⋆ "She is an intelligent dancer,"

while we know she is not good at Mathematics.

Let's be specific not universal!

⋆ "He is an intelligent football player,"

while he has no sense of philosophy, which we don't care.

Let's be specific not universal!

⋆ This conductor always makes an intelligent interpretation of symphony, but very bad at football.

⋆ Did Einstein play football intelligently?

⇓

Intelligence doesn't need to be universal!

E.g.,

A cooking robot could be said to be intelligent

Legg and Hutter's definition revisit

Their universal machine Intelligence

$$\gamma(\pi) = \sum_{\mu \in E} 2^{-K(\mu)} \cdot V_{\mu}^{\pi}$$

$$\Downarrow$$

Machine Intelligence for a specific one task

$$\gamma(\pi) = V^{\pi} = E(\sum_{i=1}^{\infty} r_i)$$

Not interesting any more!

Intelligence does not always mean highest rewords

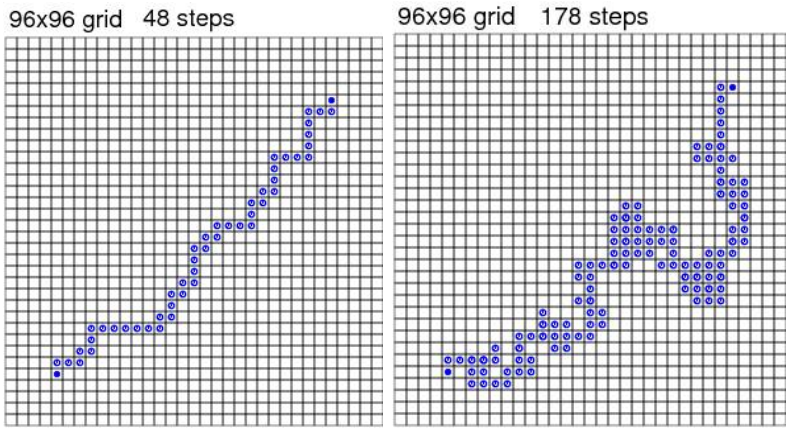
(2) Behavior should be unpredictable!

Human-intelligence is rather spontaneous, flexible, and/or unpredictable, more or less.

Or even erroneous sometimes.

Let's be more unpredictable!

Which route, do you think, is more intelligent?



(A business person & a philosopher's virtual walk in Manhattan)

Intelligence avoids a similar behavior

E.g. "I beg your pardon?"

Intelligent people try a different explanation for an easier understanding

while

others just repeat the same expression, maybe louder.

Let's be more unpredictable!

Excellent but always slightly different

(One of the reason I like this.)

(Professional should make always same performance?)

Let's be more unpredictable!

Why spontaneous?

We sometimes need spontaneous and unpredictable intelligence rather than efficiency or effectiveness like in case of Sony's AIBO.

It learns excellently and acts differently in different situation but repeats the same action in a same situation.

Then sooner or later, we will lose interest.

Let's be more unpredictable!

What we expect for the robot to be intelligent is,

"A different action even in a similar situation!"

(3) Let's require simple behaviors!

"Occam's Razor Principle"

E.g. Not-intelligent Q. & A. in a conference ⇒ spend lots of minutes for explanation for which just a couple of words would be enough

⇓

The simpler the actions, the higher the intelligence.

(4) Let's be sophisticated more ore less!

Once Kluger wrote in the TIME Magazine
"intelligent individuals are more difficult to learn to know."
due to its sophistication.

⇓

So does a Machine Intelligence?

Sophisticated vs. Simple

I describe — in Section 2, — in Section 3, — in Section 4, ... and conclusion in Section 7.

vs

The rest of the paper is organized as follows. Section 2 reviews —. — are presented in Section 3. Then, — is given in Sections 4. Section 5 presents —. Finally, Section 7 concludes the paper.

(5) Intelligent agents should be well capable to learn from previous experiences and keep learning!

"Topics of interest include, — but are not limited to" may not be an intelligent CFP!

What we include in our definition are:

- Let's be specific not universal!
- Behavior must be unpredictable!
  Different action even in a similar situation !
- Solution must be one of the simplest !
- Better to look sophisticated more or less!
- Excellent capability of keeping learning!

Our proposal

The intelligence of an agent π for a task μ is

$$V_{\mu}^{\pi} = \sum_{j=1}^{n} \sum_{i=1}^{m} F(a_{ij}) \cdot G(a_{ij}) \cdot H(a_{ij}) \cdot U(a_{ij})$$

repeating a run in a same condition to see
similarity, simplicity, learning and rewards
where a_{ij} is the i-th action in the j-th run,
m is a total number of actions in a run, and

n is a number of runs repeated in a same environment.

Concluding Remark

It's too early to claim "Our machine is intelligent"?
and

Same might hold for neural networks!

Thank you for your interest!

Now it's time to debate.

Can we create a machine intelligence by a neural network?