# Intelligent navigation? Then how intelligent?

Akira Imada

Brest State Technical University (Belarus)

# Let's name a few

- Navigation for an Intelligent Mobile Robot
  - J. Crowley (1985) IEEE
- Intelligent Mobile Robot Navigation
  - F. Cuest et al. (2005) Springer
- Optimal Path Planning For Intelligent Mobile Robot Navigation
  - N. Shiltagh et al. (2013) IJEAT

# 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?

and so on.

# Or, not intelligent at all? We'd better ask monkey to throw darts.

Burton G. Malkiel "A Random Walk Down Wall Street"

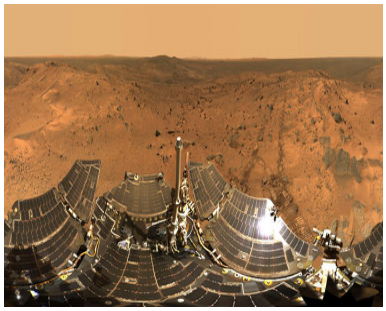
*"A monkey throwing darts at the WSJ to select a portfolio might be better than the one carefully selected by experts."*

$\Downarrow$

Are those machines less intelligent than a monkey?

(A key question of this talk.)

# Are Roomba or Mars Rover intelligent?

# Or more generally

IBM's Deep Brue ... beat Kasparov in 7 matches of chess
Watson ... beat human champions in U.S. TV quize show "Jeopardy"
Dr. Fill ... made a good job in world Crosswords tornament

Sinii ... i-phone

# A degree to how a machine is intelligent

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

$\Downarrow$

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 $r_i$


creating a series $o_1 a_1 r_1 o_2 a_2 r_2 o_3 a_3 r_3 \cdots$

# E.g. Agent to Invest in Stock Market

(1) observes financial environment of stock market

$\Downarrow$

(2) makes an action in the environment, i.e., to sell or to buy

$\Downarrow$

(3) gets rewards, i.e., 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 indeterministic.

# Definition of environment

Function which produces output $o_k r_k$ given the current 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 indeterministic.

# 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 infinitely 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 $U$

$\Downarrow$

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

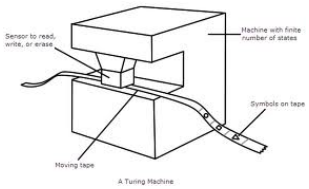
pragmatic intelligence

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

$$\Downarrow$$

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

# Problem is, translation of environment by Turing machine




$\Downarrow$

Are there easier alternatives to the Turing machine?

# Hernándes-Orallo

The other representations of environment

$\Downarrow$

(i) $\lambda$-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 easy 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.

$\Downarrow$

Create a hierarchy of increasingly difficult environments.

$\Downarrow$

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 inteligence of proposed machine in proposed environment!

$\Downarrow$

So far not very good!

# Let's try our definition!

To fulfill our purpose

- Let's be specific not universal!
- Let's be more unpredictable!
- Let's be simple!
- Let's be sophisticated more or less!
- Let's learn from previous experience!

## Let's be specific not universal!

Our goal is to measure intelligence of a proposed machine not 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 we know he is not good at Mathematics,

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!

# Let's be specific not universal!

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

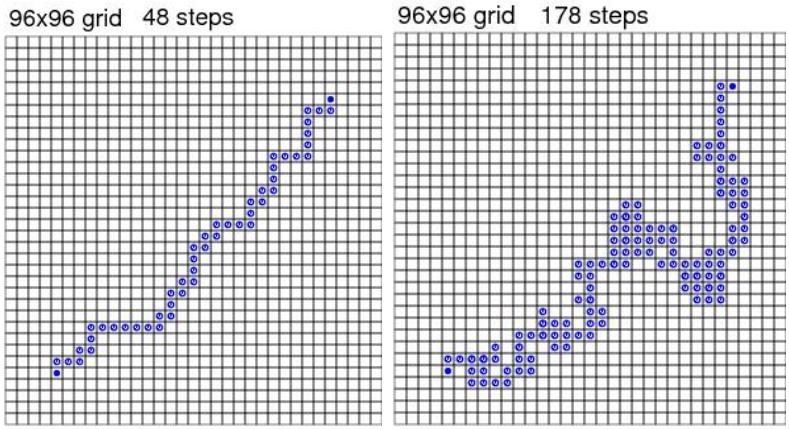
# Let's be more unpredictable!

Human-intelligence is 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 going for a walk in Manhattan)

# Let's be more unpredictable!

**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!

Excelent but always slightly diffiernt

(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.

# Let's be more unpredictable!

What we expect for the robot to be intelligent is,

"A different action even in a similar situation!"

# Let's be simple!

**"Occam's Razor Principle"**

The simpler the expression, the more beautiul it is!

$\Downarrow$

The simpler the actions, the higher the intelligence.

# Let's be sophisticated more ore less!

Once Kluger wrote in the TIME Magazine

*"intelligent individuals are more difficult to learn to know."*

$\Downarrow$

So does a Machine Intelligence?

# Let's be sophisticated more ore less!

"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."

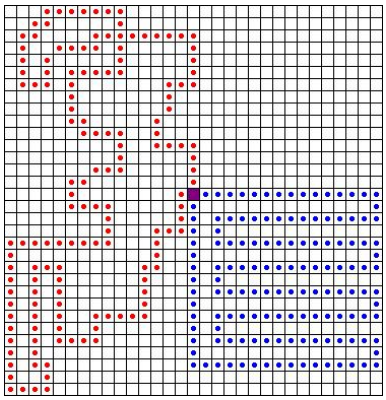
vs

"I describe — in Section 2, — in Section 3, — in Section 4, ...

and conclusion in Section 7."

# Let's be sophisticated more ore less!

Which looks more sophisticated?



# Let's learn from previous experiences!

# What we include in our definition are:

- Let's be specific not universal!
- Let's be more unpredictable!
- Let's be simple!
- Let's be sophisticated more ore less!
- Let's learn from previous experience!

# Our proposal

Repeat a run in a same condition to see similarity, simplicity, learning

$$\gamma(\pi) = \sum_i \frac{\{\text{REWARDS}\}_i \cdot \{\text{IMPROVEMENT}\}_i \cdot \{\text{EXPECTED REWARD}\}_i}{\{\text{COMPLEXITY}\}_i \cdot \{\text{SIMILARITY}\}_i}$$

# Not a Conclusion but ...

It's still too early to claim "Our machine is intelligent (as human)!"

Lots of things awaits for our further research.

# Thank you for your interest!