

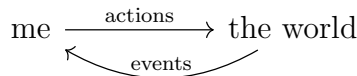
Handout for honours seminar talk on AIXI*

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Game of Life

Life is a game:



There are two players: The world acts without desires. I act with desires.

See - Think - Act

See

- a is **action**.
- $e = (o, r)$ is **event** from **environment**, containing **observation** and **reward**.
- $\mathfrak{a} = ae$ is one **round** of the game of life.
- $\mathfrak{a}_{<t} = \mathfrak{a}_{1:t-1} = a_1e_1 \cdots a_{t-1}e_{t-1}$ is all **history** from round 1 to $t-1$.
- N is **horizon**, or length of the game.
- $R(\mathfrak{a}_{1:N}) = r_1 + \cdots + r_N$ is **total reward** in life.

Beat the highscore, maximize $R(\mathfrak{a}_{1:N})$.

Think

Metaphysics before physics.

Epicurus (300s BC): “Keep all hypotheses that are consistent with the facts.”

Ptolemy (100s): “We consider it a good principle to explain the phenomena by the simplest hypothesis possible.” (Occam’s Razor)

Thomas Bayes (1760s):

$$P(H|E) = \frac{P(E, H)}{P(E)} = \frac{P(E|H)P(H)}{\sum_i P(E|H_i)P(H_i)}$$

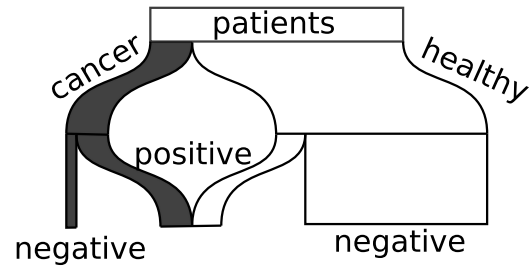


Figure 1: Bayes rule in cancer testing.

I like to interpret it as “weighting the **multi-verses**”.

Alan Turing (1930s): Everything calculable by a machine is calculable by a Turing machine.

Ray Solomonoff (1964): Predict using all consistent Turing machines, weighted by description length.

- p is the **program** run by the environment.
- $p(a_{1:t}) = e_{1:t}$ says that the program, given the action history $a_{1:t}$, replies with the environmental history $e_{1:t}$

- $\ell(p)$ is **length** of program.

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$$M(\mathfrak{a}_{1:t}) = \sum_{p:p(a_{1:t})=e_{1:t}} 2^{-\ell(p)}$$

is the probabilistic **mass** of all the multi-verses where, given that I played $a_{1:t}$, the world replied with $e_{1:t}$.

*pdf at <http://tiny.cc/eqat5y>

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Act

John von Neumann, Oskar Morgenstern (1947): Maximize the expectation of reward.
Marcus Hutter (2000s): Intelligence measures an agent's general ability to achieve goals in a wide range of environments.

AIXI

Proposed by Marcus Hutter (professor at ANU, researcher at DeepMind), around 2000.

At final round: maximize expected $R(\mathfrak{a}_{1:N})$:

$$\begin{aligned} a_N^* &= \operatorname{argmax}_{a_N} \mathbb{E}[R(\mathfrak{a}_{1:N}) | \mathfrak{a}_{1:N-1} a_N] \\ &= \operatorname{argmax}_{a_N} \sum_{e_N} R(\mathfrak{a}_{1:N}) \frac{M(\mathfrak{a}_{1:N})}{M(\mathfrak{a}_{1:N-1})} \\ &= \operatorname{argmax}_{a_N} \sum_{e_N} R(\mathfrak{a}_{1:N}) M(\mathfrak{a}_{1:N}) \end{aligned}$$

In general, at round t ,

$$a_t^* = \operatorname{arg} \left(\max_{a_i} \sum_{e_i} \right)_{i=t}^N R(\mathfrak{a}_{1:N}) M(\mathfrak{a}_{1:N})$$

Why AIXI?

Artificial General Intelligence (AGI): The game of life is hard. Make someone who's better at the game.

AIXI is self-optimizing, Pareto-optimal, and has maximal intelligence. A mathematically precise **gold standard** for AGI.

It's not Turing computable, but it is approximately so.

Inspirational hyperboles(?)

John von Neumann (1950s): Accelerating progress of technology appears to approach an essential singularity in history, beyond which we cannot predict.

Irving Good (1964): The first ultraintelligent machine is the last invention that human need ever make.

Hugo de Garis (1990s): It would be a cosmic tragedy if humanity freezes evolution at the puny human level.

Nick Bostrom (2014): We are probably the stupidest possible biological species capable of starting a technological civilization.

Further reading

- [Bos14] Standard reference on super AI. *New York Times bestseller*.
 - [Hut17] Online AI course by Marcus Hutter, archived at the Internet Archive.
 - [Hut05] Standard reference on AIXI.
Has online page <http://www.hutter1.net/ai/uaibook.htm>.
 - [LH07] General definition of intelligence.
 - [Leg08] PhD thesis on super AI, by Shane Legg, student of Marcus Hutter, cofounder of DeepMind.
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References

- [Bos14] Nick Bostrom. *Superintelligence: Paths, Dangers, Strategies*. Oxford University Press, 2014.
- [Hut05] Marcus Hutter. *Universal Artificial Intelligence: Sequential Decisions based on Algorithmic Probability*. Springer, Berlin, 2005.
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- [Leg08] Shane Legg. *Machine super intelligence*. PhD thesis, Università della Svizzera italiana, 2008.
- [LH07] Shane Legg and Marcus Hutter. Universal intelligence: A definition of machine intelligence. *Minds and machines*, 17(4):391–444, 2007.