Artificial Intelligence Reading Club

Chapter05: One Decade of Universal Artificial Intelligence

Hao ZHAN

haozhan1993@gmail.com

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1.Marcus Hutter

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I am Senior Researcher at Google DeepMind in London, and Honorary Professor in the Research School of Computer Science (RSCS) at the Australian National University (ANU) in Canberra. Before I was with IDSIA in Switzerland and NICTA. My research at RSCS/ANU/NICTA/IDSIA is/was centered around Universal Artificial Intelligence, which is a mathematical top-down approach to AI, based on Kolmogorov complexity, algorithmic probability, universal Solomonoff induction, Occam's razor, Levin search, sequential decision theory, dynamic programming, reinforcement learning, and rational agents. Generally I'm attracted by fundamental problems on the boundary between Science and Philosophy, which have a chance of being solved in my expected lifespan.

1.Marcus Hutter

Marcus Hutter

关注

Researcher@DeepMind & Professor at ANU
在 anu.edu.au 的电子邮件经过验证

science philosophy intelligence information physics

标题	引用次数	年份
Universal artificial intelligence: Sequential decisions based on algorithmic probability M Hutter Springer	1017 *	2005
Universal intelligence: A definition of machine intelligence S Legg, M Hutter Minds and machines 17 (4), 391-444	486	2007
A collection of definitions of intelligence S Legg, M Hutter Frontiers in Artificial Intelligence and applications 157, 17	430	2007
A new local distance-based outlier detection approach for scattered real-world data K Zhang, M Hutter, H Jin Pacific-Asia Conference on Knowledge Discovery and Data Mining, 813-822	332	2009
A monte-carlo aixi approximation J Veness, KS Ng, M Hutter, W Uther, D Silver Journal of Artificial Intelligence Research 40, 95-142	172	2011
Robust feature selection by mutual information distributions M Zaffalon, M Hutter arXiv preprint cs/0206006	120	2002

2.Introduction

1.AI Problem and solutions

AI has not progressed much in the last 50 years.

Some philosophical arguments that the grand goal of creating super-human AI may even be elusive in principle.

Both reasons have lead to a decreasedinterest in funding and research on the foundations of Artificial General Intelligence (AGI).

AI has focused on the wrong paradigm, namely deductive logical.

UAI(Universal Artificial Intelligence)

2.Introduction

1.AI Problem and solutions

Universal Artificial Intelligence (UAI) is such a modern information-theoretic inductive approach to AGI, in which logical reasoning plays no direct role.

UAI is a new paradigm to AGI via a path from universal induction to predictionto decision to action.

It has been investigated in great technical depth and has already spawned promising formal definitions of rational intelligence, the optimal rational agent **AIXI** and practical approximations thereof, and put AI on solid mathematical foundations.

2.Introduction

2.UAI and other approaches

cognitive psychology
behaviorism
philosophy of mind
neuroscience
linguistics
anthropology
machine learning
logic
computer science
biological evolution
economics

2.UAI and other approaches

Bottom-up vs Top-down

A top-down approach would start from a general principle and derive effective approximations (like heuristic approximations to minimax tree search).

Most AI research isbottom-up; extending and improving exist-ing or developing newalgorithmsand increasing their range of applicability

Deduction vs Induction

Traditional AI concentrates mostlyon the logical deductive reasoning aspect,while machine learning focusses on the inductive inference aspect.

3.Ingredients of UAI

AIXI is a Bayesian optimality notion for general reinforcement learning agents.

Planning and **Prediction**

4-5.Applications

How the complex phenomenon of intelligence with all its 70 Theoretical Foundations of Artificial General Intelligencefacets can emerge from the simple AIXI equation.

Embedded into our society

6-7.Outlook

Theoretical results for AIXI and universal Solomonoff induction.

Practical approximations, implementations, and applications of AIXI; UAI-based intelligence measures, tests, and definitions; and the human knowledge compression contest.

Outlook how UAI helps in formalizing and answering deep philosophical questions.

UAI and AIXI

The theory of UAI has interconnections with (draws from and contributes to) many research fields, encompassing computer science (artificial intelligence, machine learning, computation), engineering (information theory, adaptive control),economics (rational agents, game theory), mathematics (statistics, probability), psychology (behaviorism, motivation, incentives), and philosophy (inductive inference, theory of knowledge).

AIXI: Intelligent actions are based on informed decisions.
Attaining good decisions requirespredictionswhich are typicallybased on models of the environments.

Why AIXI?

Ockham: Ockham Razor

Kolmogorov: Kolmogorov Complexity

3.AIXI

The AIXI Model

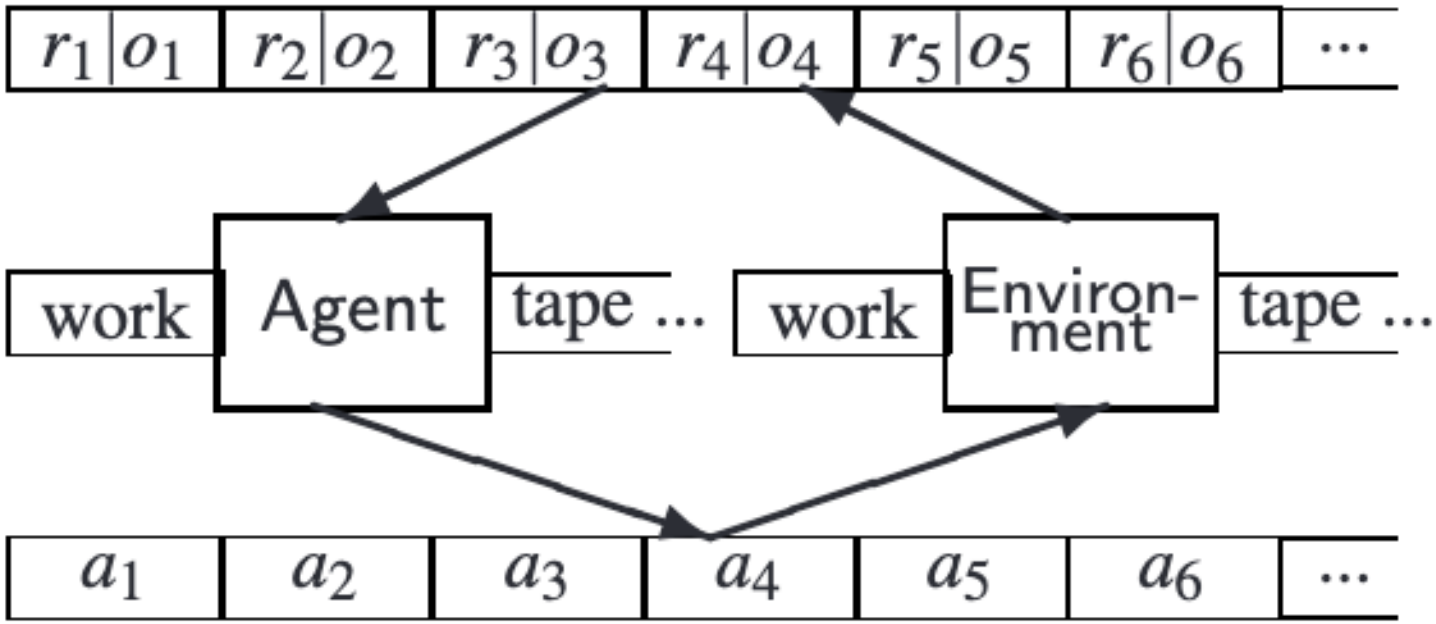
The AIXI agent is a formal, mathematical solution to the general reinforcement learning problem. It can be decomposed into two main components: planning and prediction. Planning amounts to performing an expectimax operation to determine each action. Prediction uses Bayesian model averaging, over the largest possible model class expressible on a Turing Machine, to predict future observations and rewards based on past experience. AIXI is shown in to be optimal in the sense that it will rapidly learn an accurate model of the unknown environment and exploit it to maximise its expected future reward.

Reinforcement Learning via AIXI Approximation (2010)

3.AIXI

$$\text{AIXI} \qquad a_k := \arg\max_{a_k} \sum_{o_k r_k} \ldots \max_{a_m} \sum_{o_m r_m} [r_k + \ldots + r_m] \sum_{q : U(q, a_1 .. a_m) = o_1 r_1 .. o_m r_m} 2^{-\ell(q)}$$

3.AIXI


$r_1|o_1$
$r_2|o_2$
$r_3|o_3$
$r_4|o_4$
$r_5|o_5$
$r_6|o_6$
...
work
Agent
tape ...
work
Environ-ment
tape ...
a_1
a_2
a_3
a_4
a_5
a_6
...

3.AIXI

$$V_\rho^m(h) = \max_{a_{t+1}} \sum_{x_{t+1}} \rho(x_{t+1} \mid h a_{t+1}) \cdots \max_{a_{t+m}} \sum_{x_{t+m}} \rho(x_{t+m} \mid h a x_{t+1:t+m-1} a_{t+m}) \left[\sum_{i=t+1}^{t+m} r_i \right]. \quad (5)$$

We will refer to Equation 5 as the *expectimax operation*. The m-horizon optimal action a_{t+1}^* at time $t+1$ is related to the expectimax operation by

$$a_{t+1}^* = \arg\max_{a_{t+1}} V_\rho^m(a x_{1:t} a_{t+1}) \quad (6)$$

Thank you for your time!