

A Short Introduction to (Symbolic) Artificial Intelligence

Methods, Success Stories, Limitations

Digital Humanism Summer School
September 2023

Stefan Woltran



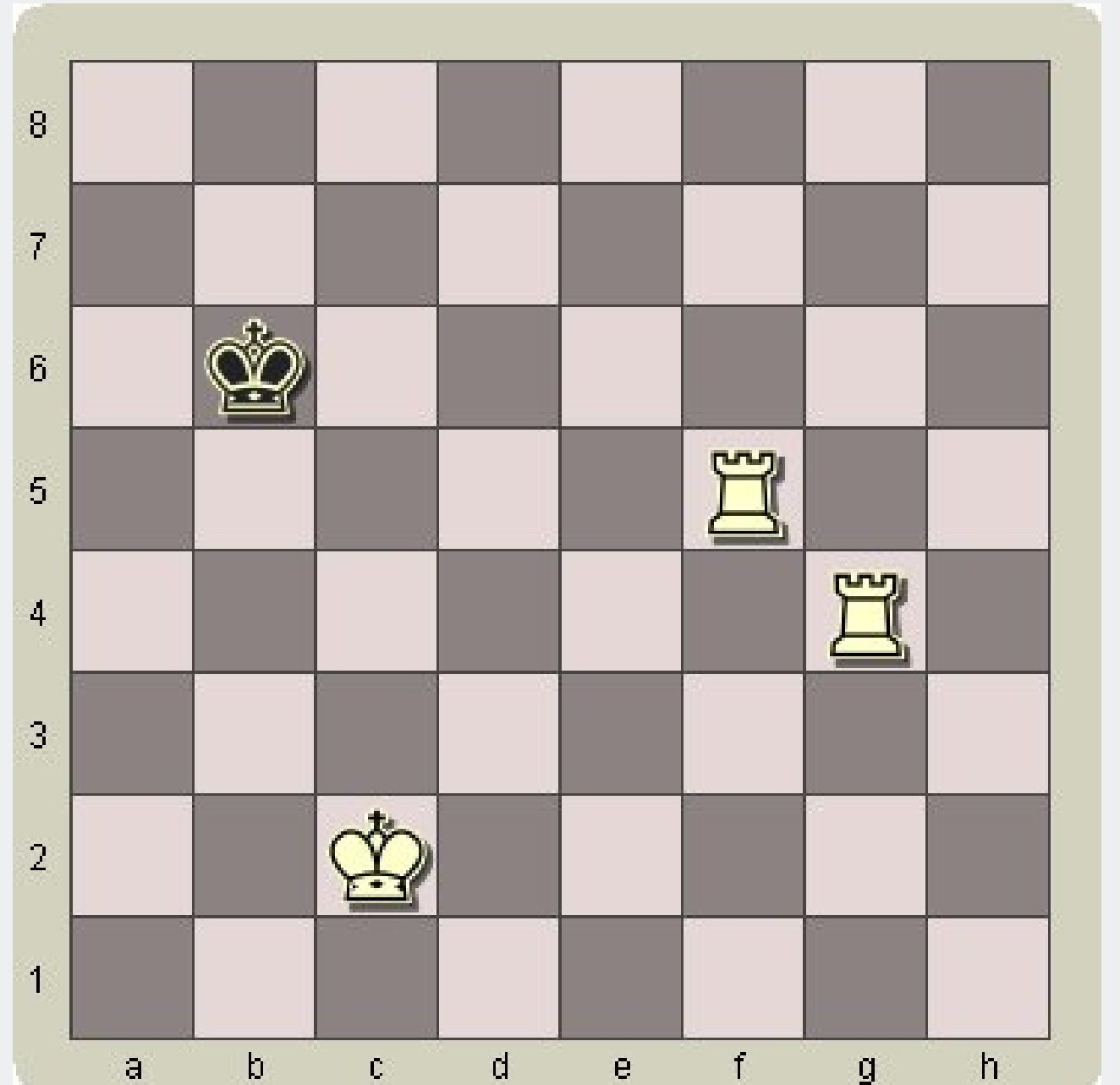
Informatics



Center for Artificial Intelligence
and Machine Learning

It's white's turn.

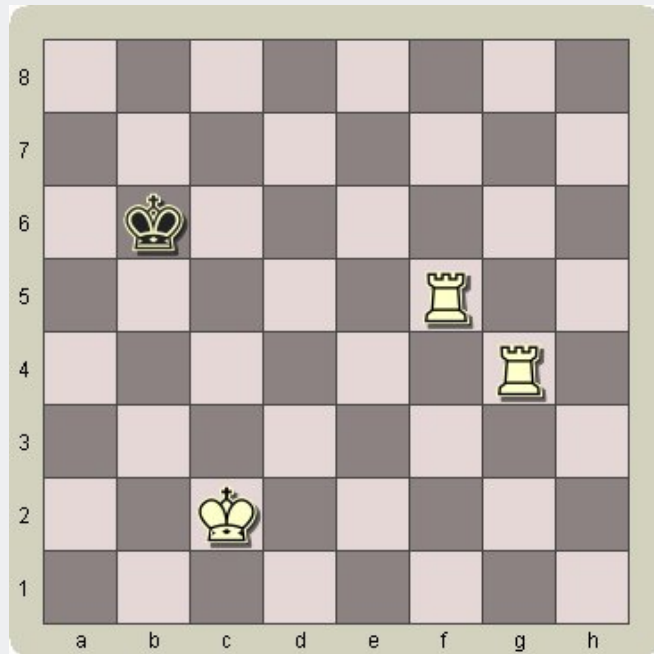
What is your move?



Which animal
do you
recognize?

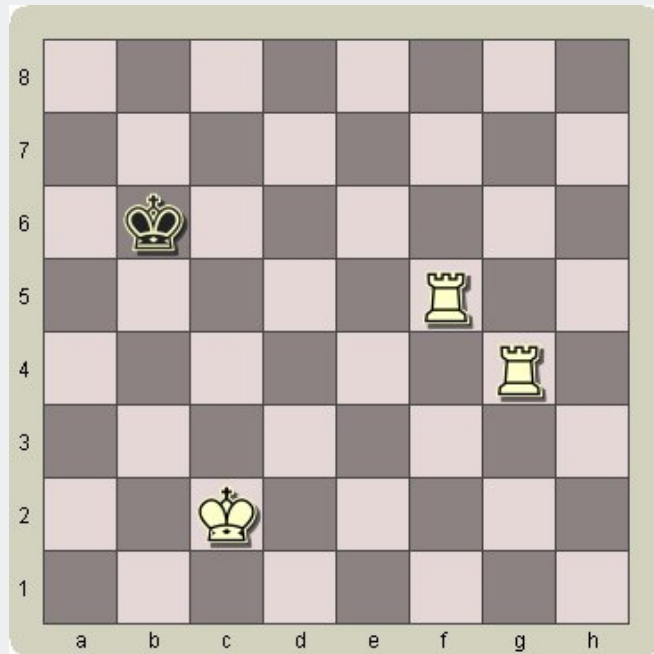


Did you approach the two exercises differently?



Artificial Intelligence (also) provides two different methodological paradigms

Symbolic AI



Subsymbolic AI



AI is born

Focus on specific intelligence

Focus on specific problems

- The Turing Test
- Dartmouth College conference
- Information theory-digital signals
- Symbolic reasoning

- Expert systems & knowledge
- Neural networks conceptualized
- Optical character recognition
- Speech recognition

- Deep learning: pattern analysis & classification
- Big data: large databases
- Fast processors to crunch data
- High-speed networks and connectivity

- Machine learning

Dartmouth conference led by John McCarthy coins the term "artificial intelligence"

1956

Edward Feigenbaum develops the first Expert System, giving rebirth to AI

1975 – 1982

IBM's Watson Q&A machine wins Jeopardy!
Apple integrates Siri, a personal voice assistant into the iPhone

2011

2014

YouTube recognizes cats from videos

2016

AlphaGo defeats Lee Sedol

1964
Eliza, the first chatbot is developed by Joseph Weizenbaum at MIT

1997

IBM's Deep Blue defeats Garry Kasparov, the world's reigning chess champion

Limited computer processing power
Limited database storage capacity
Limited network ability

- Real-world problems are complicated
- Facial recognition, translation
- Combinatorial explosion

- Disappointing results: failure to achieve scale
- Collapse of dedicated hardware vendors

AI Winter I

AI Winter II

Games Computers Play



1995:
Chinook wins world-championship in Checkers



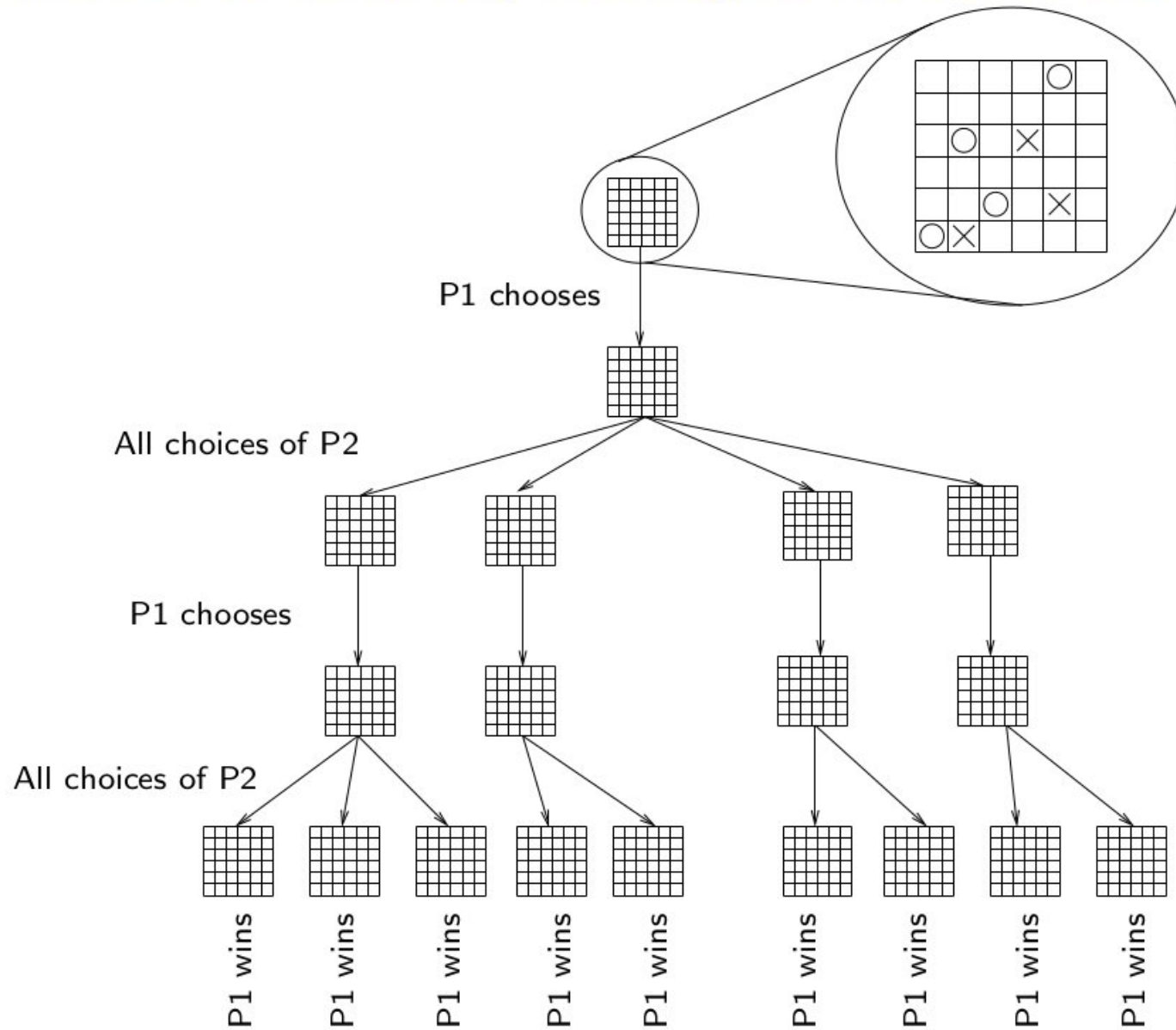
1997:
DeepBlue defeats Kasparov 3,5:2,5



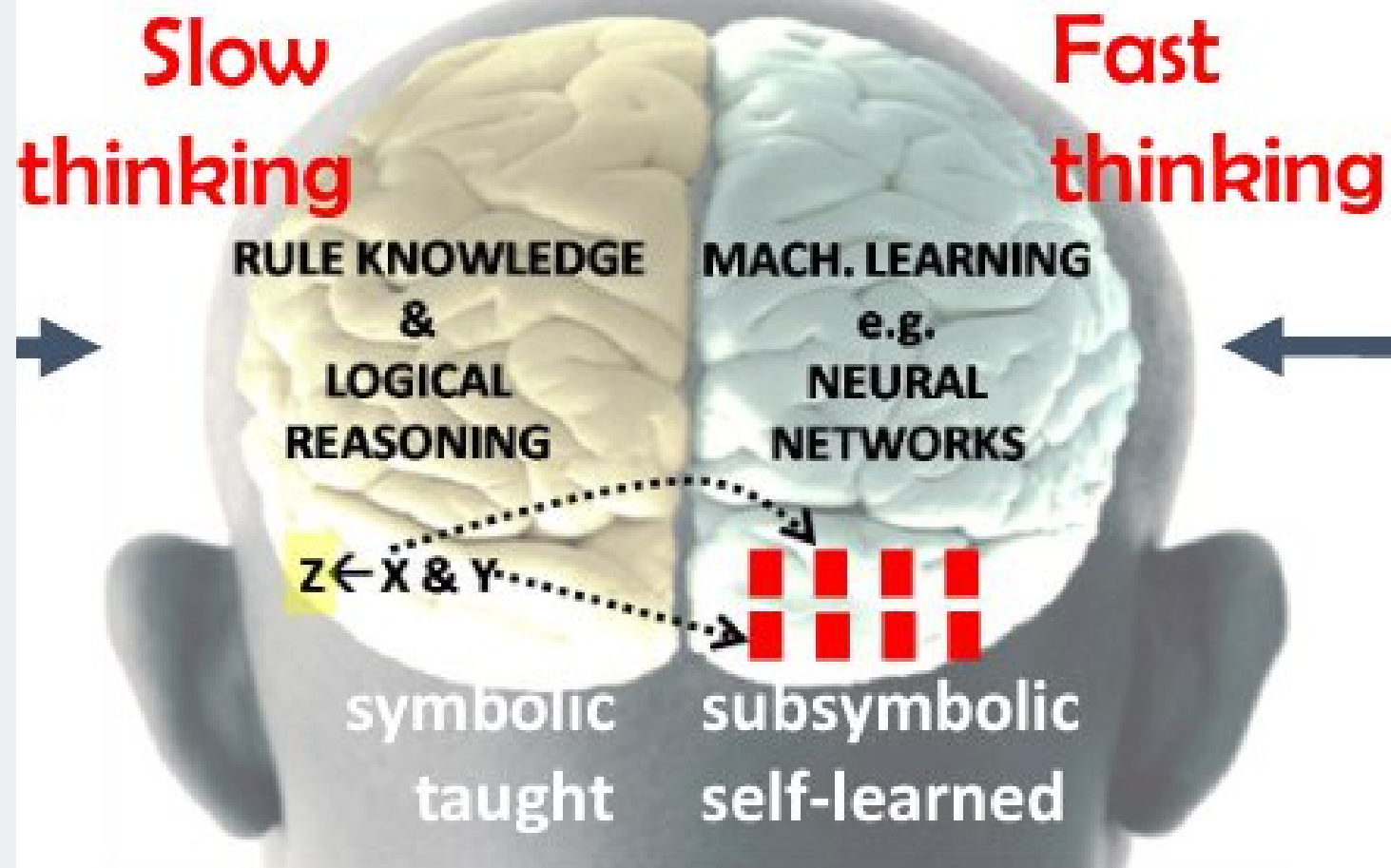
2016:
AlphaGo beats Lee Sedol 4:1

2017: AlphaGo Zero wins 100:0 against AlphaGo

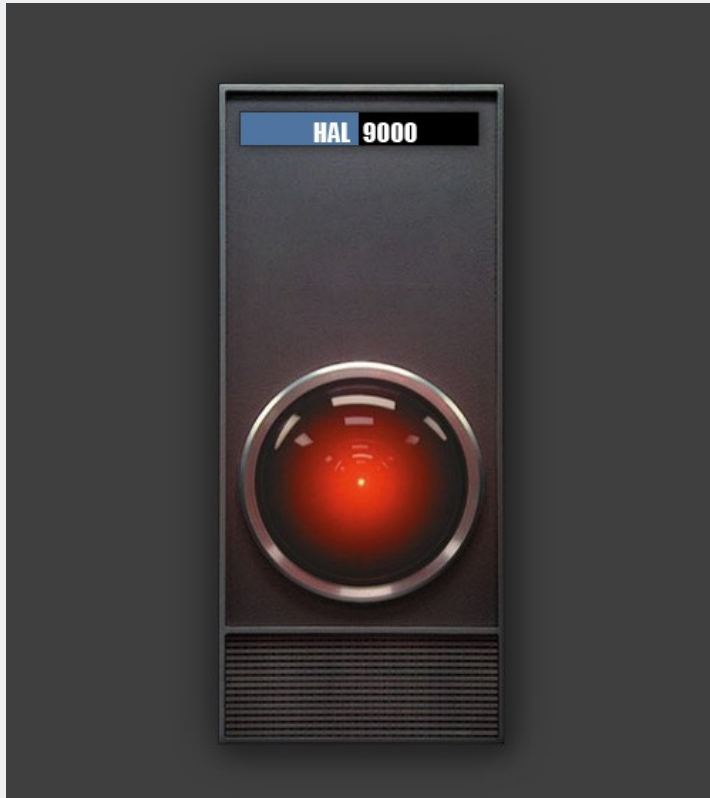
Symbolic AI: Winning Strategies for Gen. Tic-Tac-Toe



Symbolic AI	Subsymbolic AI
Rule-driven	Data-driven
Explicit representation	Implicit representation
Logic and search	Statistics
Explainable results	Black-Box
Combinatorial Explosion	Training on Huge Datasets
Heuristics / structural features	Parallelisation
Applications: Planning, Expert Systems, Configuration, Scheduling, Logical Reasoning, Games, ...	Applications: Clustering, Image/Music/... Recognition, Generative AI, Recommender Systems, Games ...



Artificial General Intelligence



Goal: perform any intellectual task that a human being can

Current AI only capable of performing specific tasks

Main obstacles:

- Abstraction
- Common-Sense Reasoning
- Synthesis of Paradigms

Symbolic AI

Symbolic Artificial Intelligence is the term for the collection of all methods in artificial intelligence research that are based on **high-level** "symbolic" (human-readable) **representations** of problems, **logic** and **search**.



Marvin Minsky



John Haugeland gave the name GOFAI ("Good Old-Fashioned Artificial Intelligence") to symbolic AI in his 1985 book *Artificial Intelligence: The Very Idea*.

„One path to human-level AI uses mathematical logic to formalise common-sense knowledge in such a way that common-sense problems can be solved by logical reasoning.“ (John McCarthy)



Propositional Logic

- atomic propositions (which can be true or false) are combined via connectives
- truth value of compound formula is given by the assertions to atomic propositions and the semantics of the connectives

EXAMPLE:

AI ... Study artificial intelligence

DH ... Study digital humanism

Formula1: (AI or DH)

Formula2: (AI or DH) and not (AI and DH)

Formula3: (AI $\rightarrow$ DH) and (DH $\rightarrow$ AI)

Formula4: Formula2 and Formula3



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Zahlenrätsel

Der längste Mathe-Beweis der Welt

Drei Mathematiker haben ein Zahlenrätsel geknackt - mithilfe eines Supercomputers. Der Beweis umfasst 200 Terabyte. Sie wollen wissen, warum es geht? Okay, versuchen wir es.



Von *Holger Dambeck* ▼

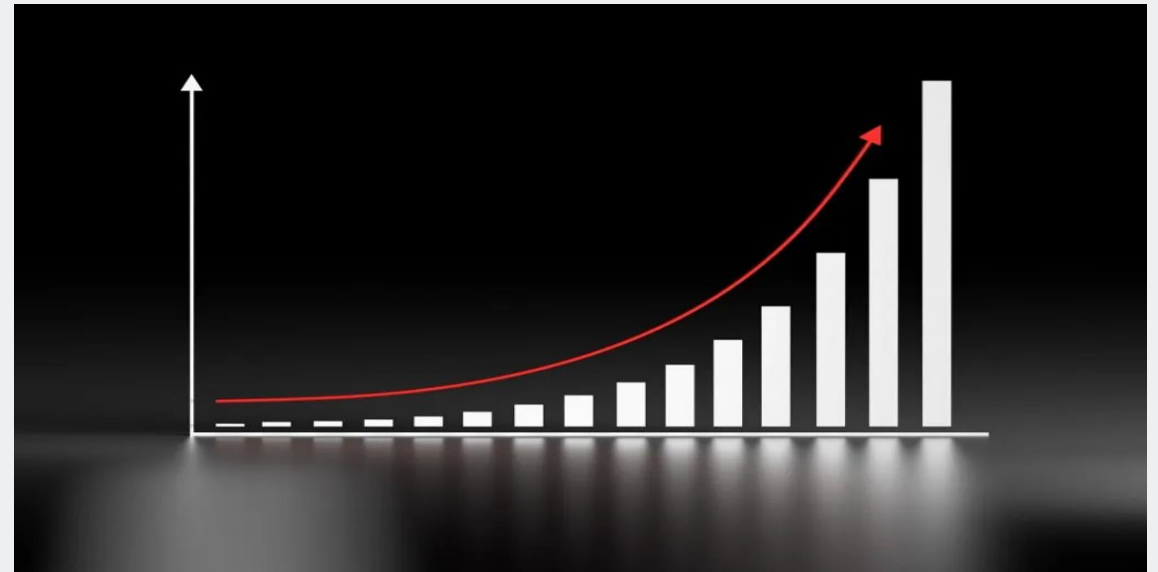


Capturing Combinatorial Explosion - NP-Hardness

Propositional formula over k atoms:
 2^K different candidates that can make formula true

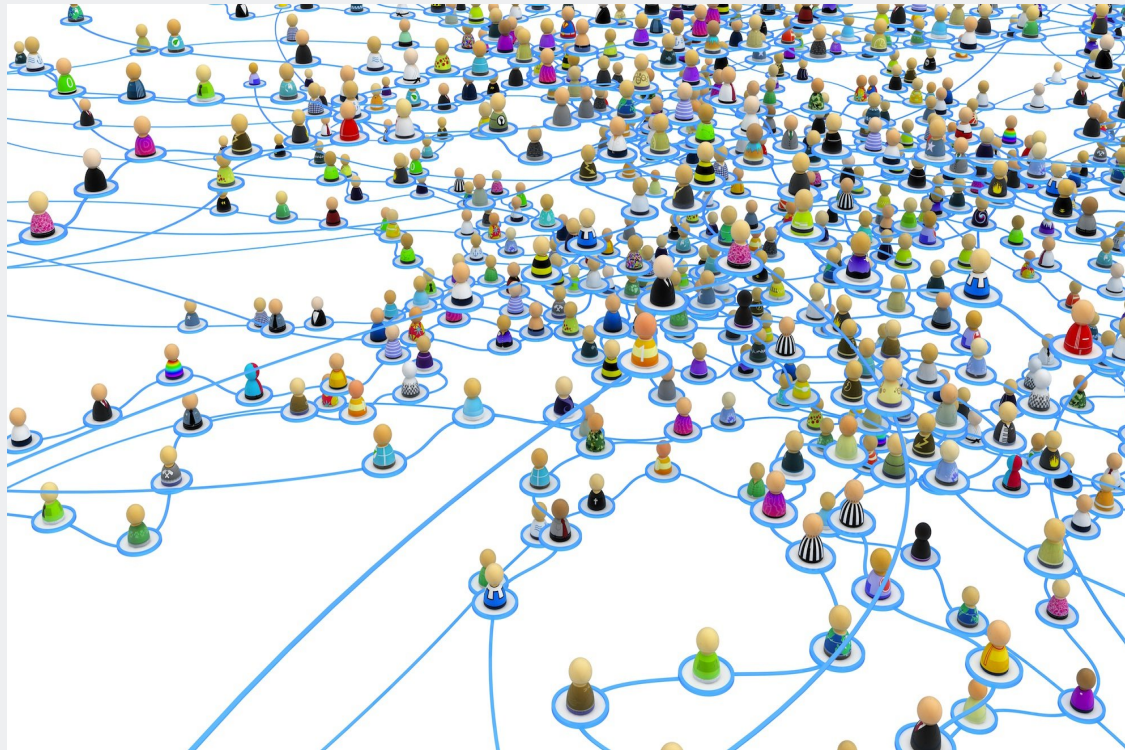
number of atoms in universe ... around 2^{280}

Even worse: finding winning strategies



Taming Combinatorial Explosion

Instances in different domains typically have different properties



Networks of Major High Speed Rail Operators in Europe
Situation July 2019

Only services which run at least 5 times per week, per direction are included
Seasonal services not included

- Allegro (Korean Trains)
- Italo (NIV)*
- Trenitalia (Trenitalia)
- Thello*
- FluxTrain (Leo Express)*
- Eurostar**
- Thylys***
- Railjet**
- TGV InOui (SNCF)
- Osigo (SNCF)
- Sapsan (RZD / Russian Railways)
- AVE/Alvia/Avant (RENFE)**
- X 2000 / SJ 3000 (SJ)
- Dartford (VR)
- Viasbahn**
- MTR Express**
- Alfa Pendular (Comboios de Portugal)
- Intercity (Virgin Trains)
- Intercity (East Midlands)
- Intercity (First Great Western)
- Intercity (LNER)
- Intercity Direct (NS)
- Sollinger**
- Intercity (OSE)
- Southeastern High Speed
- Yakutsk High Train (TCDD / Turkish Railways)
- Express Intercity Premium (PKP)
- Other rail lines / operators (Selection)

* Open access operator
** Joint operation between ÖBB, DB, SBB, ČD and MAV
*** Includes other RENFE services on high speed rail
**** Partially owned by SNCF, independently operated
***** International services operated by various partnerships



- + implicitly exploited via heuristics
- + parameterized algorithmics

Nonmontonic Logics → Answer-Set Programming (ASP)

(Schaub,Woltran: Special Issue on ASP. Künstliche Intelligenz 32, 2018)

Answer-Set Programming (ASP): Declarative high-level modeling language that comes with highly efficient solving engines



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Train Scheduling with Hybrid ASP

Dirk Abels², Julian Jordi², Max Ostrowski¹, Torsten Schaub^{1,3,4,5},
Ambra Toletti², and Philipp Wanko^{1,3}

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⁴ Simon Fraser University, Burnaby, Canada

⁵ Griffith University, Brisbane, Australia

Abstract. We present an ASP-based solution to real-world train scheduling problems, involving routing, scheduling, and optimization. To this end, we pursue a hybrid approach that extends ASP with difference constraints to account for a fine-grained timing. More precisely, we exemplarily show how the hybrid ASP system *clingo*[DL] can be used to tackle demanding planning-and-scheduling problems. In particular, we investigate how to boost performance by combining distinct ASP solving techniques, such as approximation, heuristic, and optimization strategies.



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Solving Object-oriented Configuration Scenarios with ASP *

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Abstract

The main configuration scenarios occurring in the domain of technical products and systems are consistency checking, completing a partial configuration, reconfiguration of an inconsistent configuration and finding the best knowledge base for future reconfigurations. This paper presents OOASP a framework for the description of object-oriented

technical systems with a long life-span, where parts of existing configurations have to be adapted continuously.

Reconfiguration is especially challenging if an existing system has to be extended with new functionality that was not part of the original system design. In this case, some relations between new and existing components have to be created or some of the existing relations have to be changed in order to meet modified configuration requirements. [Falkner and



ASP in Action ...

<https://potassco.org/clingo/run/>





"The development of full artificial intelligence could spell the end of the human race."

"WITH ARTIFICIAL INTELLIGENCE
WE ARE SUMMONING THE DEMON."
-ELON MUSK

"First the machines will do **A LOT** of jobs for us and not be super intelligent..."

A few decades after that though the intelligence is strong enough to be a concern."
-Bill Gates

HUFF
POST

HUFF
POST

“Machines do only what we tell them to do; they're not going to suddenly wake up and decide to take over the planet. The problem with machines is that they do exactly what we tell them to do.”

Toby Walsh



Further Readings

+ Thomas Haigh: Conjoined Twins: Artificial Intelligence and the Invention of Computer Science. Commun. ACM 66(6): 33–37 (2023)

+ Johannes Klaus Fichte, Daniel Le Berre, Markus Hecher, Stefan Szeider: The Silent (R)evolution of SAT. Commun. ACM 66(6): 64-72 (2023)

