Could AI Ever Match Gödel's Greatness?

(Part II of the Chapter; Part I is on "The Gödel Game," for IFLAI1)

Selmer Bringsjord

Intro to Formal Logic (& AI) (IFLAI1)

4/21/25

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Rensselaer AI and Reasoning Lab

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Monographic Context
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Gödel's Great Theorems (OUP)

by Selmer Bringsjord

- Introduction ("The Wager")
- Brief Preliminaries (e.g. the propositional calculus & FOL)
- The Completeness Theorem
- The First Incompleteness Theorem
- The Second Incompleteness Theorem
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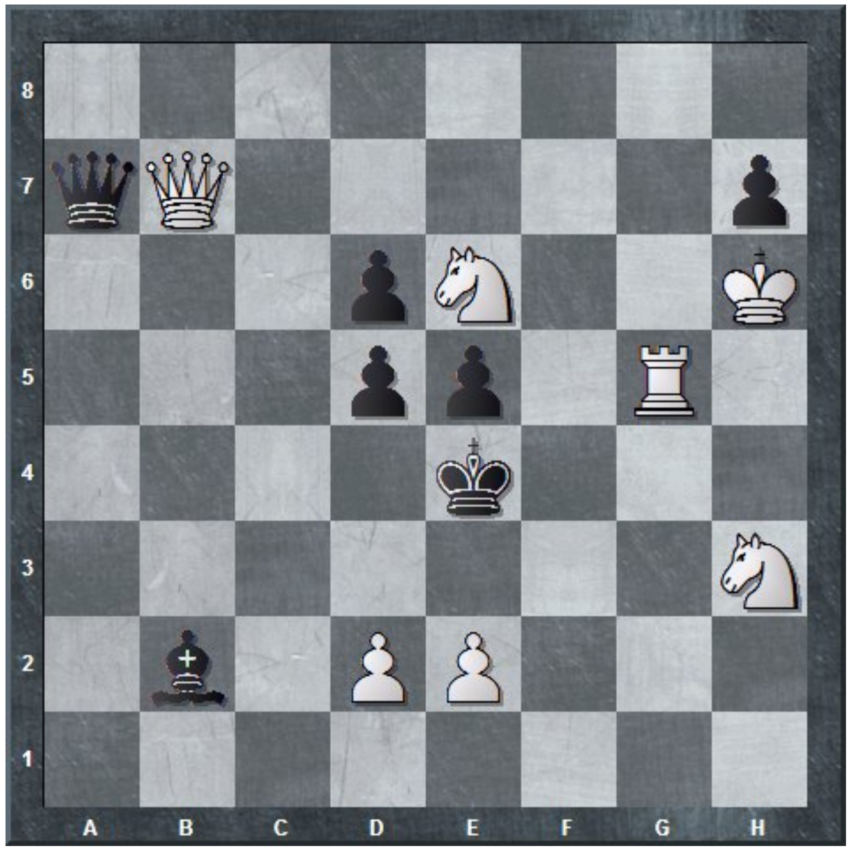
Gödel's Greatness & Games

. . .

Mate in 2 Problem



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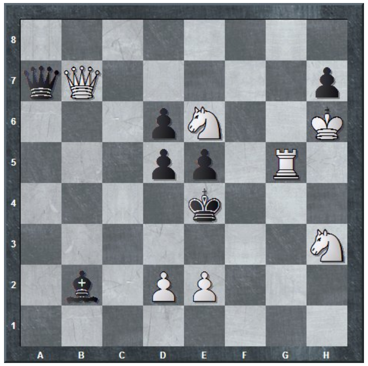

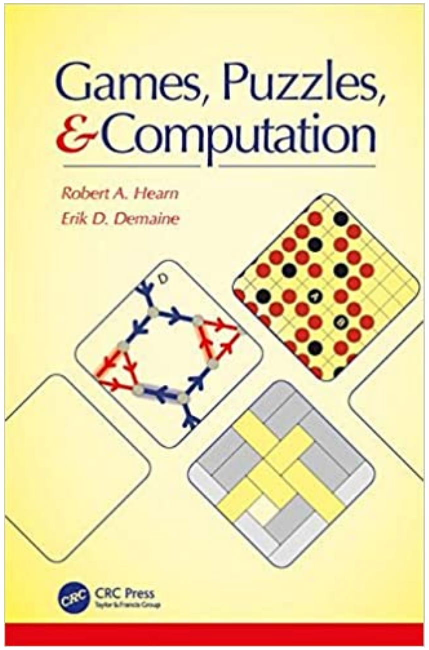

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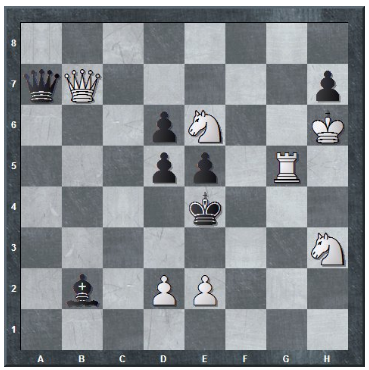
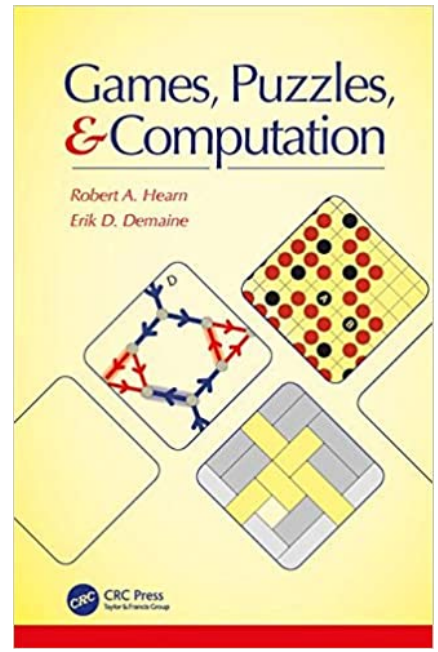
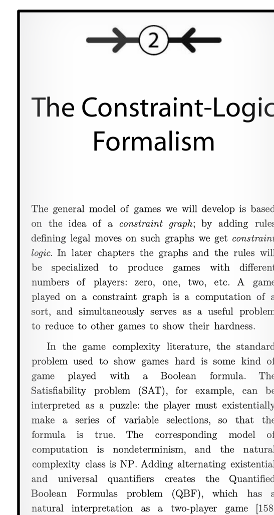




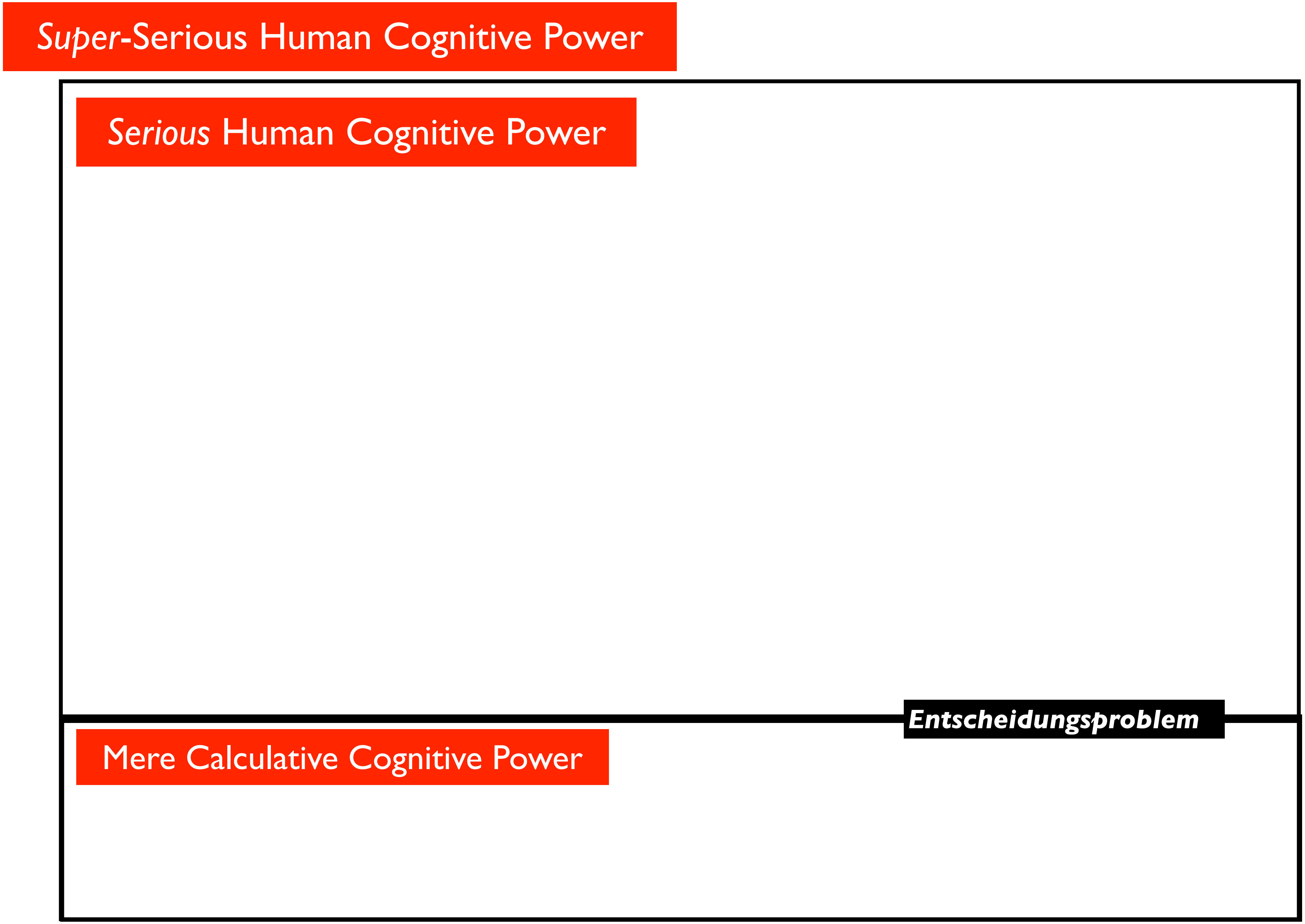

2

The Constraint-Logic Formalism

The general model of games we will develop is based on the idea of a *constraint graph*; by adding rules defining legal moves on such graphs we get *constraint logic*. In later chapters the graphs and the rules will be specialized to produce games with different numbers of players: zero, one, two, etc. A game played on a constraint graph is a computation of a sort, and simultaneously serves as a useful problem to reduce to other games to show their hardness.

In the game complexity literature, the standard problem used to show games hard is some kind of game played with a Boolean formula. The Satisfiability problem (SAT), for example, can be interpreted as a puzzle: the player must existentially make a series of variable selections, so that the formula is true. The corresponding model of computation is nondeterminism, and the natural complexity class is NP. Adding alternating existential and universal quantifiers creates the Quantified Boolean Formulas problem (QBF), which has a natural interpretation as a two-player game [158,

Logico-Mathematical Landscape that Has Gödel Turning in His Grave



Logico-Mathematical Landscape that Has Gödel Turning in His Grave

Super-Serious Human Cognitive Power

Serious Human Cognitive Power

Gödel

Entscheidungsproblem

Mere Calculative Cognitive Power

Logico-Mathematical Landscape that Has Gödel Turning in His Grave

Super-Serious Human Cognitive Power

Serious Human Cognitive Power

Gödel

Turing

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Podcast: The Turing Test is Dead. Long Live the Lovelace Test.

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Gödel

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Polynomial Hierarchy

Logico-Mathematical Landscape that Has Gödel Turning in His Grave

Analytical Hierarchy

Arithmetical Hierarchy

Gödel

Entscheidungsproblem

Polynomial Hierarchy

$$\mathbf{P} \subseteq \mathbf{NP} \subseteq \mathbf{PSPACE} = \mathbf{NPSPACE} \subseteq \mathbf{EXPTIME} \subseteq \mathbf{NEXPTIME} \subseteq \mathbf{EXPSPACE}$$

Logico-Mathematical Landscape that Has Gödel Turning in His Grave

Analytical Hierarchy

Arithmetical Hierarchy

Gödel

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

Σ_0

Entscheidungsproblem

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Arithmetical Hierarchy

Gödel

Go: AlphaGo

$\vdots$

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Arithmetical Hierarchy

Gödel

Jeopardy!:

Go: AlphaGo

$\vdots$

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Σ_2

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Logico-Mathematical Landscape that Has Gödel Turning in His Grave

Analytical Hierarchy

Arithmetical Hierarchy

Gödel

Chess: Deep Blue

Jeopardy!:

Go: AlphaGo

$\vdots$

Π_2

Σ_2

Π_1

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Σ_0

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Analytical Hierarchy

Arithmetical Hierarchy

Gödel

Checkers: Chinook

Chess: Deep Blue

Jeopardy!:

Go: AlphaGo

$\vdots$

Π_2

Σ_2

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Σ_0

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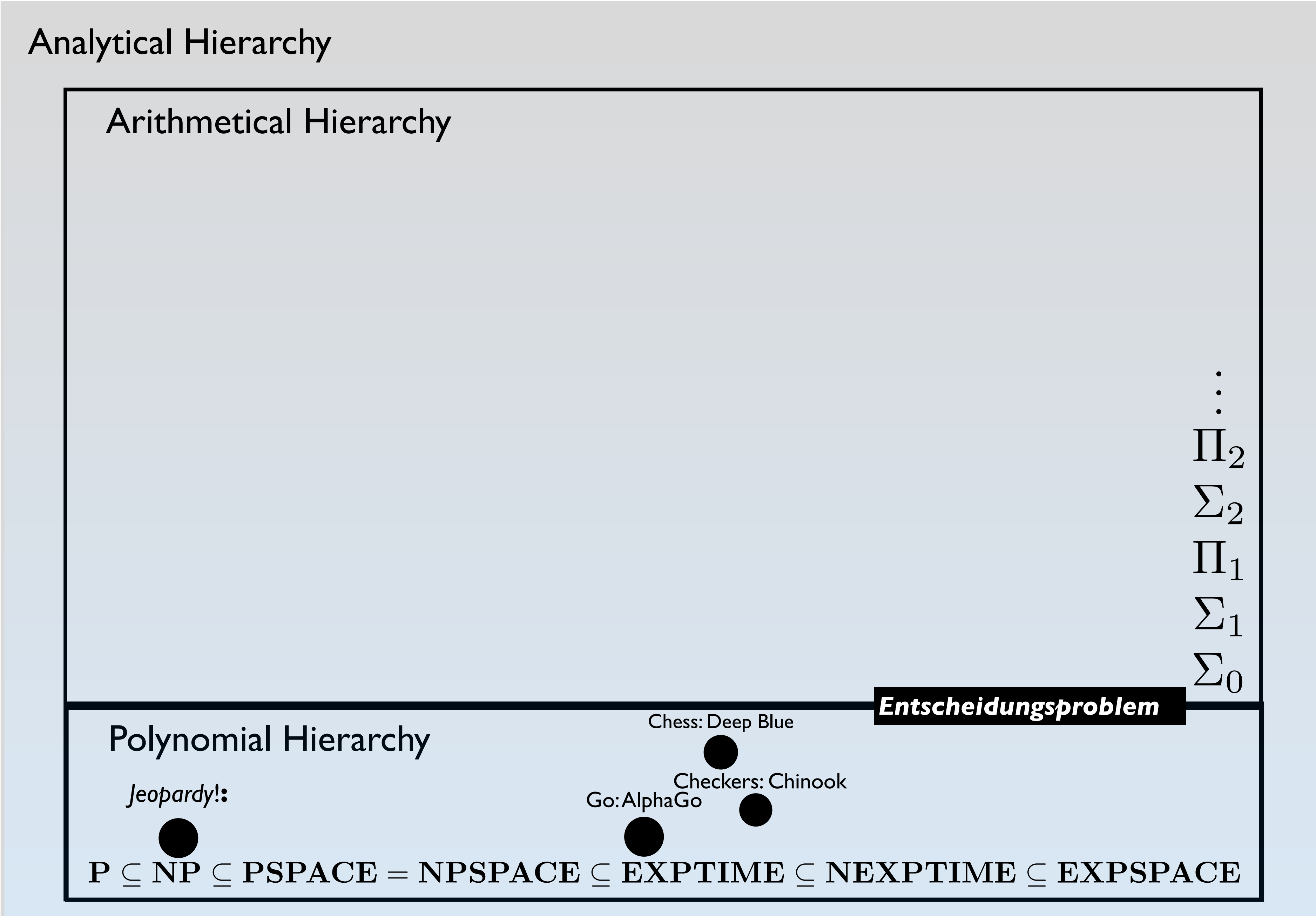
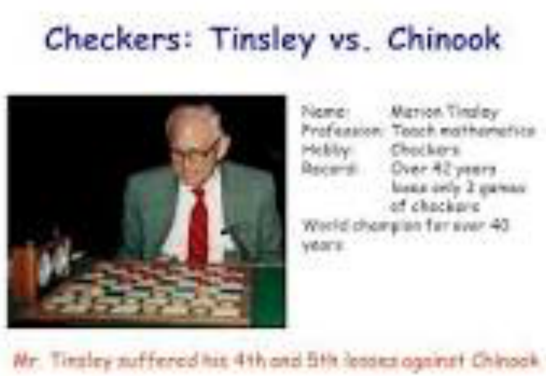


1994


Checkers: Tinsley vs. Chinook
Name: Marion Tinsley
Profession: Teach mathematics
Hobby: Checkers
Record: Over 42 years
of checkers
World champion for over 40 years
Mr. Tinsley suffered his 4th and 5th losses against Chinook

1994


Checkers: Tinsley vs. Chinook
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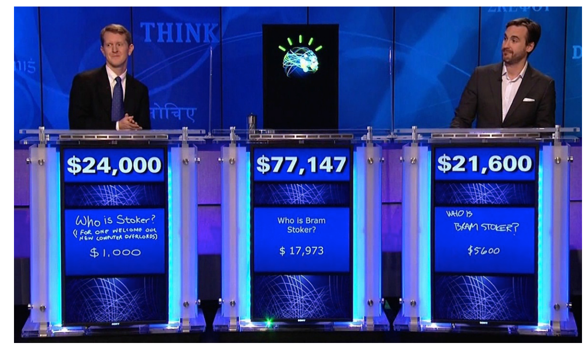
Record: Over 42 years loses only 3 games of checkers
World champion for over 40 years
Mr. Tinsley suffered his 4th and 5th losses against Chinook

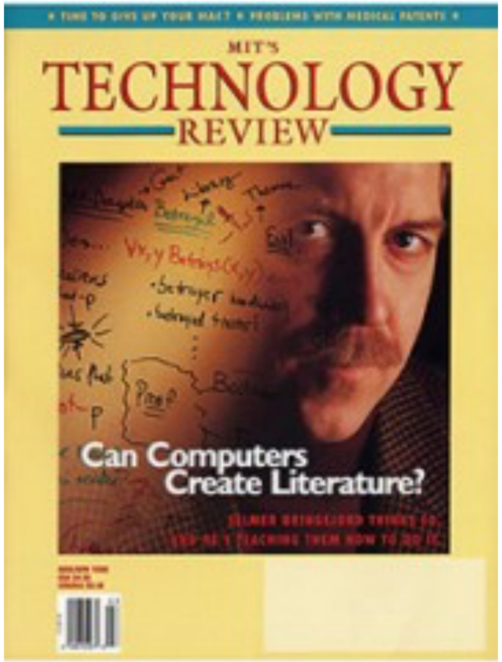
1997

1994

1997

2011

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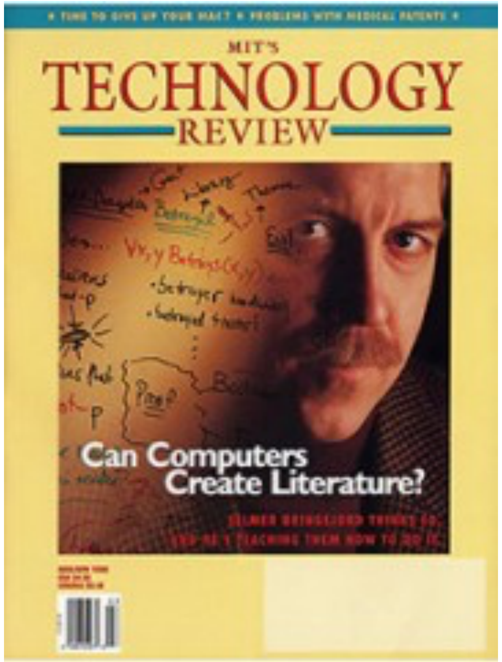
TECHNOLOGY
REVIEW
Can Computers
Create Literature?

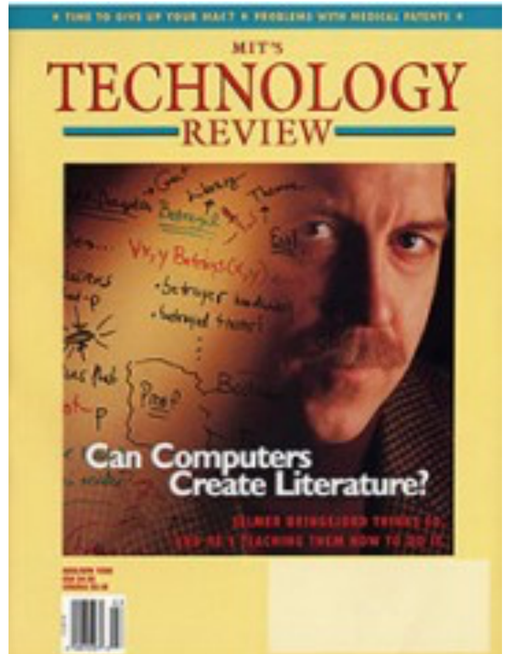
1998

“Chess is Too Easy”



1998

“Chess is Too Easy”



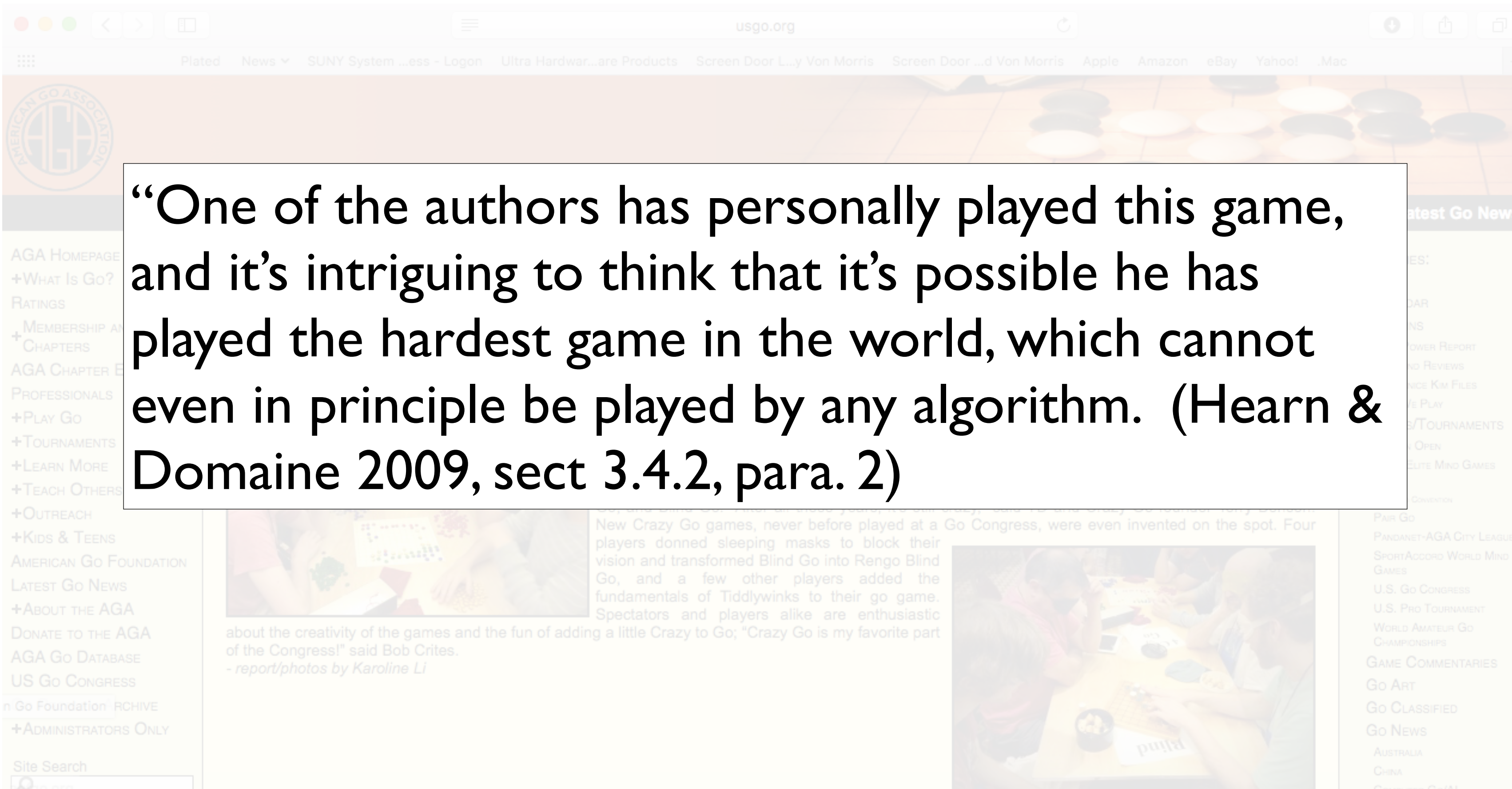
1998

Some of Gödel’s great work is at the level of chess.

But to *fully* “gamify” Gödel, we need a harder game! …

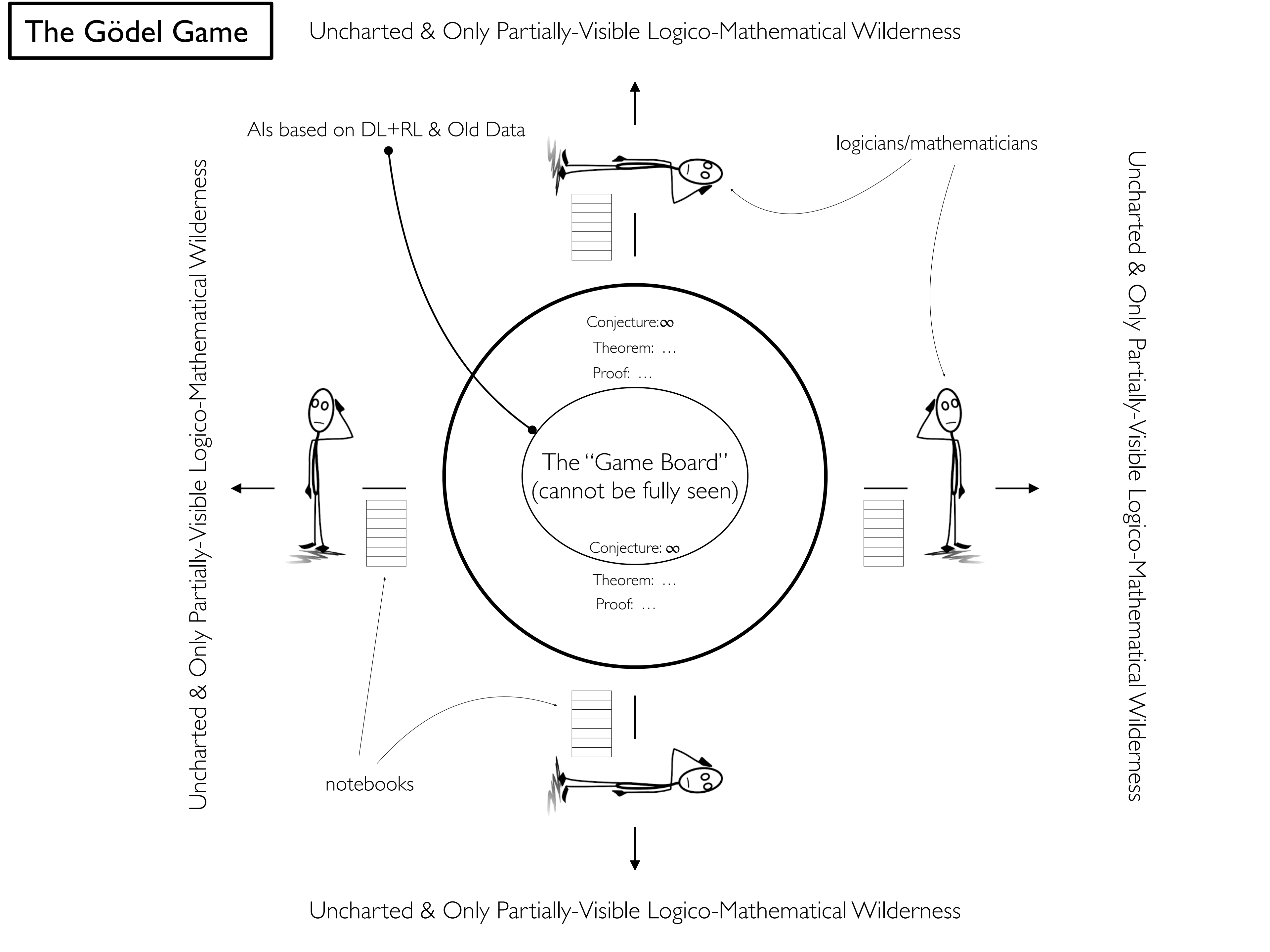
Rengo Kriegspiel

Rengo Kriegspiel



"One of the authors has personally played this game, and it's intriguing to think that it's possible he has played the hardest game in the world, which cannot even in principle be played by any algorithm. (Hearn & Domaine 2009, sect 3.4.2, para. 2)

The Gödel Game



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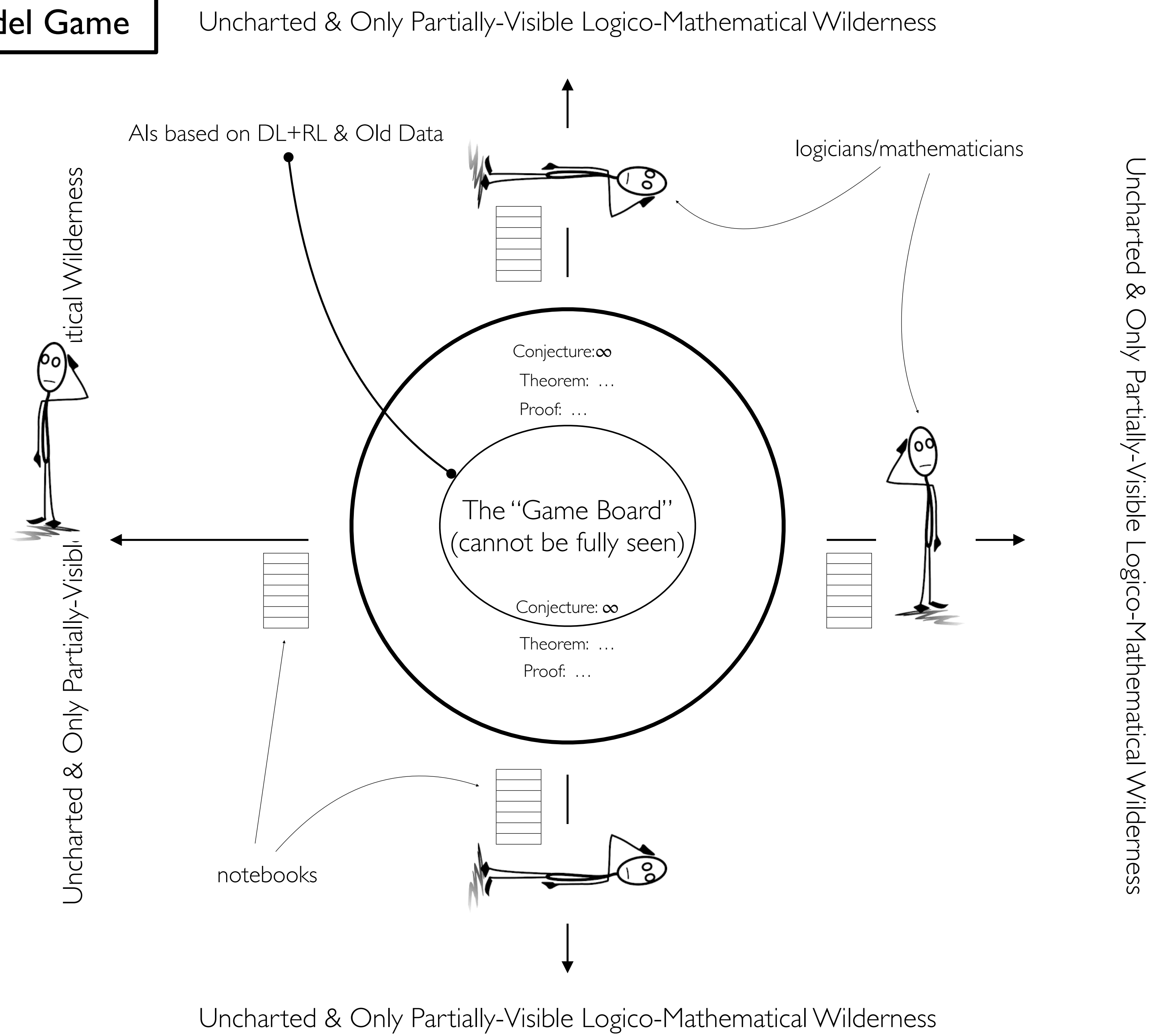

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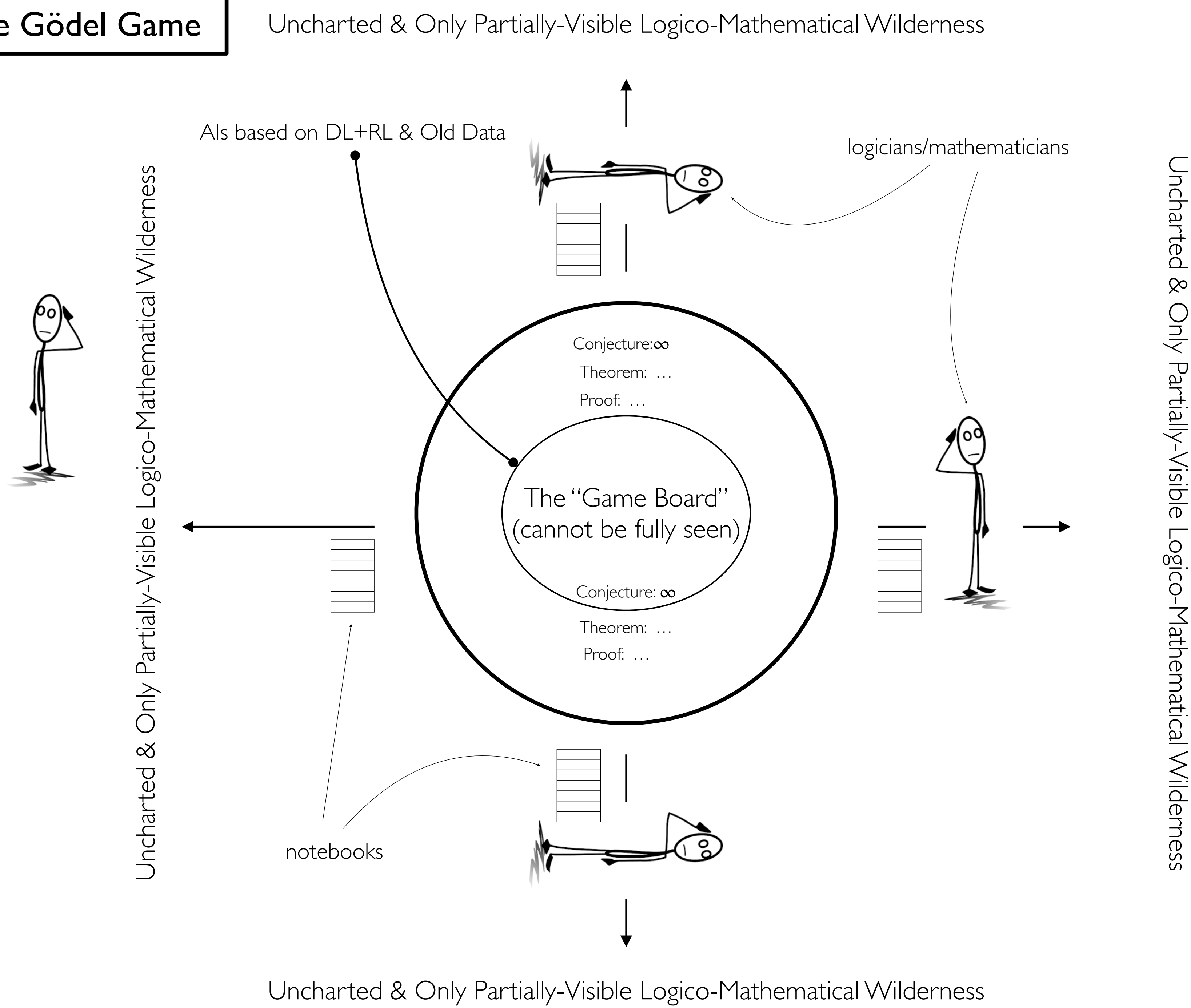

Gödel's Either/Or …

The Question

Q* Is the human mind more powerful than the class of standard computing machines?

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(= finite machines)

The Question

Q* Is the human mind more powerful than the class of standard computing machines?

(= finite machines)

(= Turing machines)

(= register machines)

(= KU machines)

…

Gödel's Either/Or

"[E]ither … the human mind (even within the realm of pure mathematics) infinitely surpasses the power of any finite machine, or else there exist absolutely [humanly?] unsolvable diophantine problems."
— Gödel, 1951, Providence RI

Gödel's Either/Or

"[E]ither … the human mind (even within the realm of pure mathematics) infinitely surpasses the power of any finite machine, or else there exist absolutely [humanly?] unsolvable diophantine problems."
— Gödel, 1951, Providence RI

More precisely, what does this mean?

PT as a Diophantine Equation

Equations of this sort were introduced to you in middle-school, when you were asked to find the hypotenuse of a right triangle when you knew its sides; the familiar equation, the famous Pythagorean Theorem that most adults will remember at least echoes of into their old age, is:

$$\text{(PT)} \quad a^2 + b^2 = c^2,$$

and this is of course equivalent to

$$\text{(PT')} \quad a^2 + b^2 - c^2 = 0,$$

which is a Diophantine equation. Such equations have at least two unknowns (here, we of course have three: a, b, c), and the equation is solved when positive integers for the unknowns are found that render the equation true. Three positive integers that render (PT') true are

$$a = 4,\ b = 3,\ c = 5.$$

It is *mathematically impossible* that there is a finite computing machine capable of solving any Diophantine equation given to it as a challenge (!).

… which means that the 10th of Hilbert's Problems is settled:

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Hilbert's problems

From Wikipedia, the free encyclopedia

Hilbert's problems are twenty-three problems in mathematics published by German mathematician David Hilbert in 1900. The problems were all unsolved at the time, and several of them were very influential for 20th-century mathematics. Hilbert presented ten of the problems (1, 2, 6, 7, 8, 13, 16, 19, 21, and 22) at the Paris conference of the International Congress of Mathematicians, speaking on August 8 in the Sorbonne. The complete list of 23 problems was published later, most notably in English translation in 1902 by Mary Frances Winston Newson in the *Bulletin of the American Mathematical Society*.[1]


David Hilbert

Contents [hide]

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10th	Find an algorithm to determine whether a given polynomial Diophantine equation with integer coefficients has an integer solution.	Resolved. Result: Impossible; Matiyasevich's theorem implies that there is no such algorithm.	1970

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It was a *team* effort, actually; it’s not due solely to Matiyasevich, and is often denoted as the ‘MRDP Theorem.’

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Julia **R**obinson Martin **D**avis Hilary **P**utnam

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Julia **R**obinson   Martin **D**avis   Hilary **P**utnam

Background

problem?[7] In his lecture, Gödel precisely defines diophantine problems, but we don't need to bother with all of the details here; we only need to appreciate the general structure of such a problem, and that can be achieved quickly as follows, given what was introduced in Chapter 2.

Each diophantine problem has at its core a polynomial $\mathcal{P}$ whose variables are comprised by two lists, $x_1, x_2, \ldots, x_n$ and $y_1, y_2, \ldots, y_m$; all variables must be integers, and the same for subscripts n and m. To represent a polynomial in a manner that announces its variables, we can write

$$\mathcal{P}(x_1, x_2, \ldots, x_k, y_1, y_2, \ldots, y_j).$$

But Gödel was specifically interested in whether, for all integers that can be set to the variables x_i, there are integers that can be set to the y_j, such that the polynomial equals 0. To make this clearer, first, here are two particular, simple equations that employ polynomials that are both instances of the needed form:

E1 $\quad 3x - 2y = 0$

E2 $\quad 2x^2 - y = 0$

All we need to do now is prefix these equations with quantifiers in the pattern Gödel gave. This pattern is quite simple: universally quantify over each x_i variable (using the now-familiar $\forall$), after which we existentially quantify over each y_i variable (using the also-now-familiar $\exists$). Thus, here are the two diophantine problems that correspond to the pair E1 and E2 from just above:

P1 $\quad$ Is it true that $\forall x \exists y (3x - 2y = 0)$?

P2 $\quad$ Is it true that $\forall x \exists y 2x^2 - y = 0$?

Great Paper!

Great Paper!

Hilbert's Tenth Problem is Unsolvable
Author(s): Martin Davis
Source: *The American Mathematical Monthly*, Vol. 80, No. 3 (Mar., 1973), pp. 233-269
Published by: Mathematical Association of America
Stable URL: http://www.jstor.org/stable/2318447

Great Paper!

1. Diophantine Sets. In this article the usual problem of Diophantine equations will be inverted. Instead of being given an equation and seeking its solutions, one will begin with the set of "solutions" and seek a corresponding Diophantine equation. More precisely:

DEFINITION. A set S of ordered n-tuples of positive integers is called **Diophantine** if there is a polynomial $P(x_1, \cdots, x_n, y_1, \cdots, y_m)$, where $m \geqq 0$, with integer coefficients such that a given n-tuple $\langle x_1, \cdots, x_n \rangle$ belongs to S if and only if there exist positive integers $y_1, \cdots, y_m$ for which

$$P(x_1, \cdots, x_n, y_1, \cdots, y_m) = 0.$$

Borrowing from logic the symbols "$\exists$" for "there exists" and "$\Leftrightarrow$" for "if and only if", the relation between the set S and the polynomial P can be written succinctly as:

$$\langle x_1, \cdots, x_n \rangle \in S \Leftrightarrow (\exists y_1, \cdots, y_m)\ [P(x_1, \cdots, x_n, y_1, \cdots, y_m) = 0],$$

or equivalently:

$$S = \{\langle x_1, \cdots, x_n \rangle \mid (\exists y_1, \cdots, y_m)\ [P(x_1, \cdots, x_n, y_1, \cdots, y_m) = 0]\}.$$

Note that P may (and in non-trivial cases always will) have negative coefficients. *The word* "**polynomial**" *should always be so construed in the article* except where the contrary is explicitly stated. Also *all numbers in this article are positive integers* unless the contrary is stated.

Great Paper!

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Great Paper!

Notice that this is a perfect fit with how we used formal logic to present and understand the Polynomial Hierarchy and the Arithmetic Hierarchy.

1. Diophantine Sets. In this article the usual problem of Diophantine equations will be inverted. Instead of being given an equation and seeking its solutions, one will begin with the set of "solutions" and seek a corresponding Diophantine equation. More precisely:

DEFINITION. A set S of ordered n-tuples of positive integers is called **Diophantine** if there is a polynomial $P(x_1, \cdots, x_n, y_1, \cdots, y_m)$, where $m \geqq 0$, with integer coefficients such that a given n-tuple $\langle x_1, \cdots, x_n \rangle$ belongs to S if and only if there exist positive integers $y_1, \cdots, y_m$ for which

$$P(x_1, \cdots, x_n, y_1, \cdots, y_m) = 0.$$

Borrowing from logic the symbols "$\exists$" for "there exists" and "$\Leftrightarrow$" for "if and only if", the relation between the set S and the polynomial P can be written succinctly as:

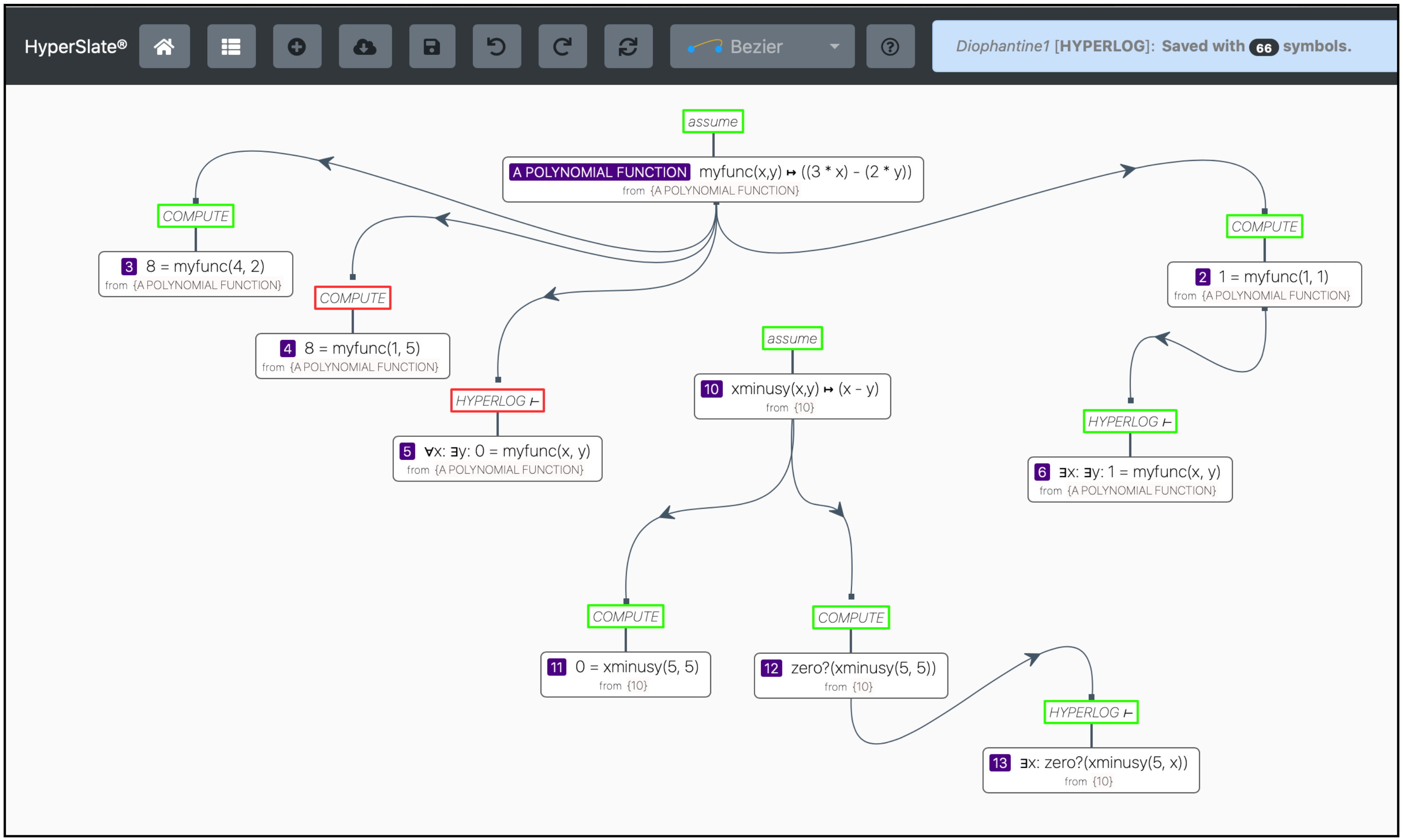
$$\langle x_1, \cdots, x_n \rangle \in S \Leftrightarrow (\exists y_1, \cdots, y_m)\ [P(x_1, \cdots, x_n, y_1, \cdots, y_m) = 0],$$

or equivalently:

$$S = \{\langle x_1, \cdots, x_n \rangle \mid (\exists y_1, \cdots, y_m)\ [P(x_1, \cdots, x_n, y_1, \cdots, y_m) = 0]\}.$$

Note that P may (and in non-trivial cases always will) have negative coefficients. *The word* "**polynomial**" *should always be so construed in the article* except where the contrary is explicitly stated. Also *all numbers in this article are positive integers* unless the contrary is stated.

Diophantine "Threat" in the Programming Language Hyperlog®



Where have we seen this before from Dr Gödel? $20

The Crux

$\exists \mathcal{P}$ s.t. no human mind could ever decide $\forall x_1 \forall x_2 \cdots \forall x_k \exists y_1 \exists y_2 \cdots \exists x_j (\mathcal{P}(x_1, x_2, \ldots, x_k, y_1, y_2, \ldots, y_j)$?

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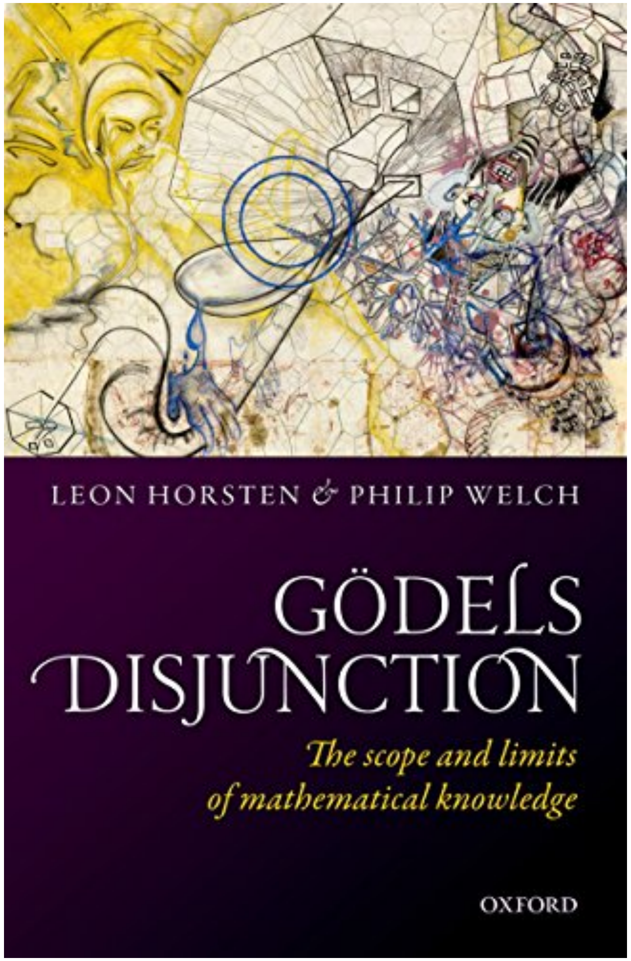

Earlier Gödelian Argument for the "No."

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Outline

Figures (1)

Tables (1)

Table 1

ELSEVIER

Applied Mathematics and Computation

Volume 176, Issue 2, 15 May 2006, Pages 516-530

A new Gödelian argument for hypercomputing minds based on the busy beaver problem ☆

Selmer Bringsjord, Owen Kellett, Andrew Shilliday, Joshua Taylor, Bram van Heuveln, Yingrui Yang, Jeffrey Baumes, Kyle Ross

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Abstract

Do human persons hypercompute? Or, as the doctrine of *computationalism* holds, are they information processors at or below the Turing Limit? If the former, given the essence of hypercomputation, persons must in some real way be capable of infinitary information processing. Using as a springboard Gödel's little-known assertion that the human mind has a power "converging to infinity", and as an anchoring problem Rado's [T. Rado, On non-computable functions, Bell System Technical Journal 41 (1963) 877–884] Turing-uncomputable "busy beaver" (or Σ) function, we present in this short paper a new argument that, in fact, human persons can hypercompute. The argument is intended to be formidable, not conclusive: it brings Gödel's intuition to a greater level of precision, and places it within a sensible case against computationalism.

Finally, finally, …

Gödel-vs-AI "Scorecard"

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Bringsjord vs. Rapaport …

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4: And finally, the sledgehammer is used: *phenomenal consciousness.*

And now let's wrap up with final logistics:

Required Problems

Test 3 — just 2!!!!!!!!!!

Visit to Final-Grades Algorithm:

E.g., for John Doe:

```
4x.10 + 4x.15 + 4.25 + 4x.10 + 4x.40 = 4 = A
```

Med nok penger, kan logikk løse alle problemer.