Tutorial, Mechanics; Historical & Scientific Context re Formal Logic, AI, and Logic Machines

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Intermediate Formal Logic & AI (IFLAI2)
9/3/2020

Mechanics …

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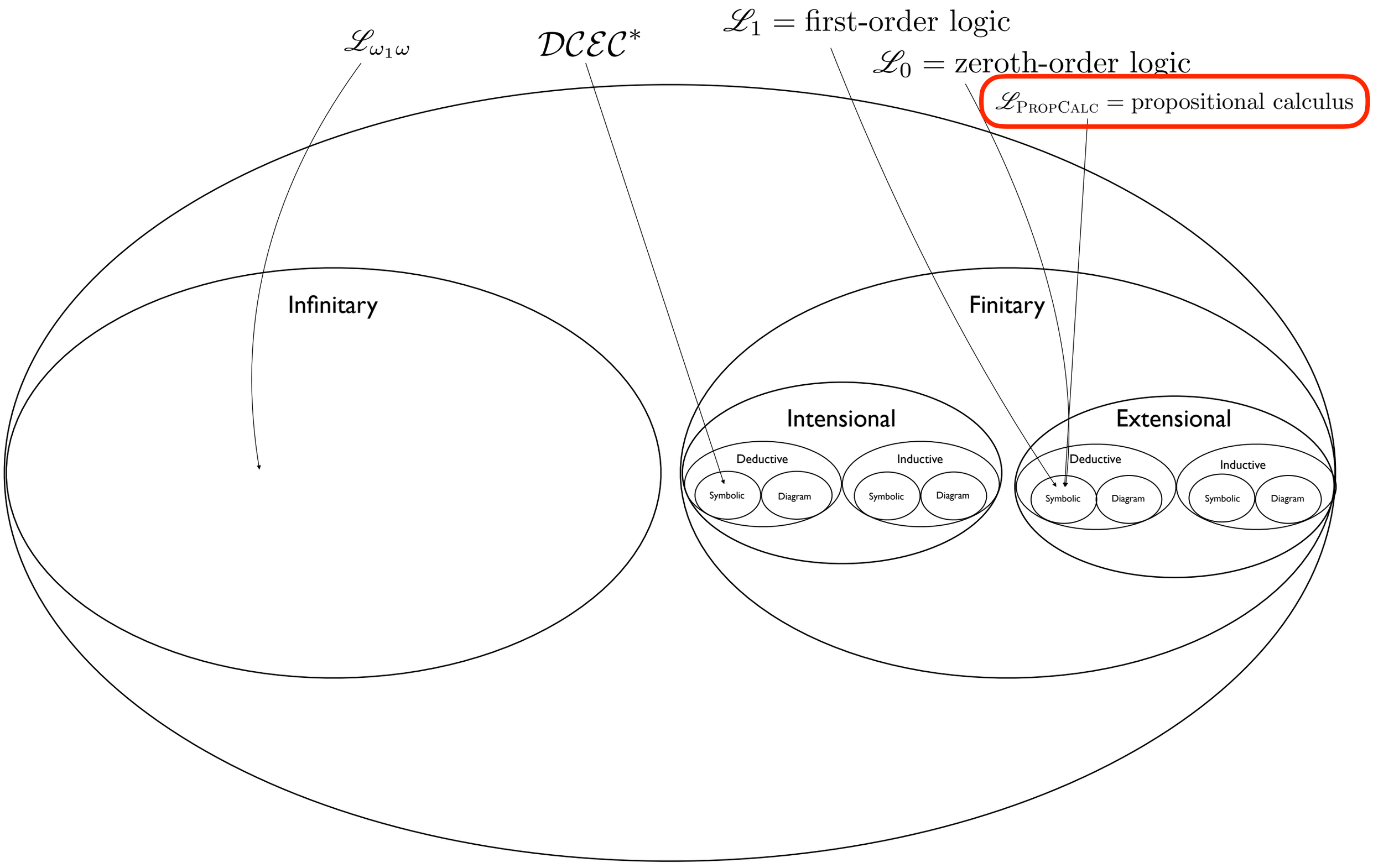
Mechanics …

IFLAI2 web page now page up.

Some Review/ Diagnostics …

The Universe of Logics



A criminal genius nearly a match for Sherlock Holmes (Do you recognize the Dr?) has built a massive hydrogen bomb, and life on Earth is hanging in the balance, hinging on whether you make the logical prediction. Dr M gives you a sporting chance to: make the right prediction, snip or not snip accordingly, and prove that you're right …

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If one of the following assertions is true then so is the other:

(1) If the red wire runs to the bomb, then the blue wire runs to the bomb; and, if the blue wire runs to the bomb, then the red wire runs to the bomb.

(2) The red wire runs to the bomb.

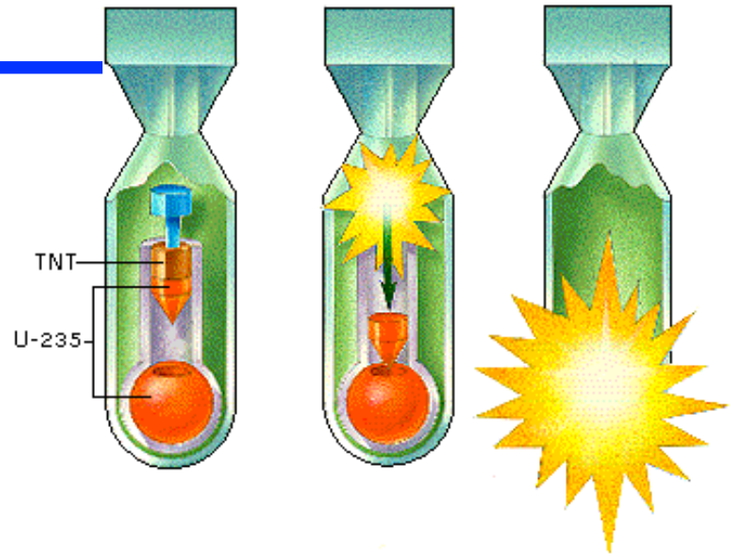
Given this perfectly reliable clue from Dr Moriarty, if either wire is more likely to run to the bomb, that wire *do*es run to the bomb, and the bomb is ticking, with only a minute left! If both are equiprobable, neither runs to the bomb, and you are powerless. Make your prediction as to what will happen when a wire is snipped, and then make your selected snip by clicking on the wire you want to snip! Or leave well enough alone!

Red more likely.

Blue more likely.

Equiprobable.

Snip



Life on Earth has ended.

advance one more slide to see a proof that you indeed made an irrational decision…

Proposition: The blue wire is more likely!

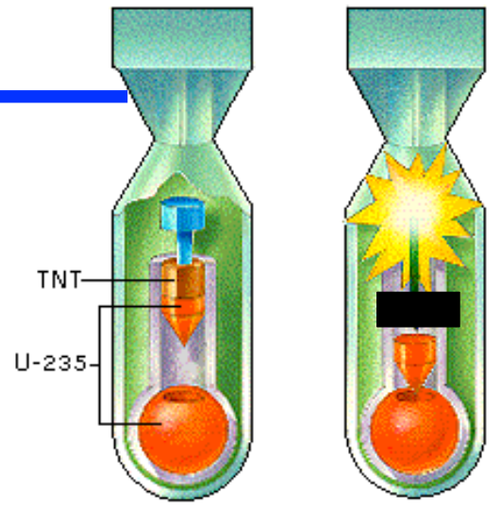
Proof: (1) can be treated as a biconditional, obviously (R <=> B).

There are two top-level cases to consider: (1) and (2) are both true; or both are false. In the case where they are both true, it's trivial to deduce both R and B. So far, then, R and B are equiprobable. What happens in the case where (1) and (2) are both false? We immediately have ~R from the denial of (2). But a biconditional is true just in case both sides are true, or both sides are false; so we have two sub-cases to consider.

Consider first the case where R is true and B is false. We have an immediate contradiction in this sub-case, so both R and B can both be deduced here, and we have not yet departed from equiprobable. So what about the case where R is false and B is true? The falsity of R is not new information (we already have that from the denial of (2)), but we can still derive B. Hence the blue wire is more likely. **QED**

STOP

Snip



Life on Earth is saved!

if you can now hand Dr M a proof that your decision was the rational one!

Advance one more slide to see a proof from Bringsjord that yours had better match up to …

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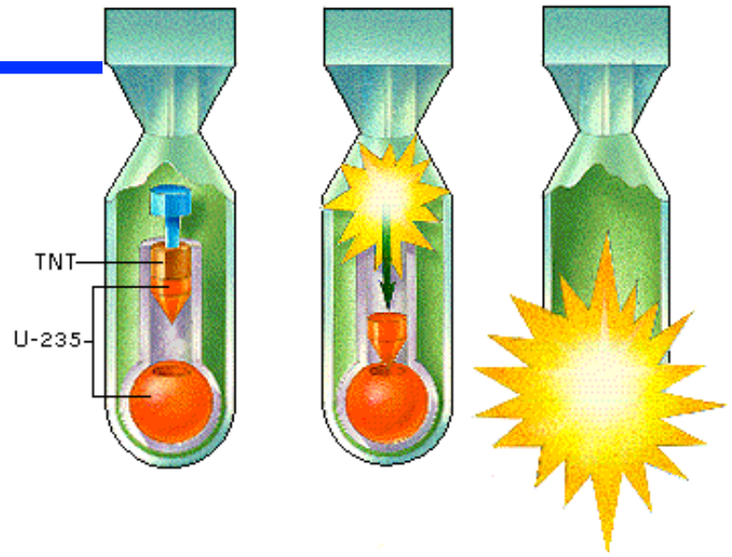

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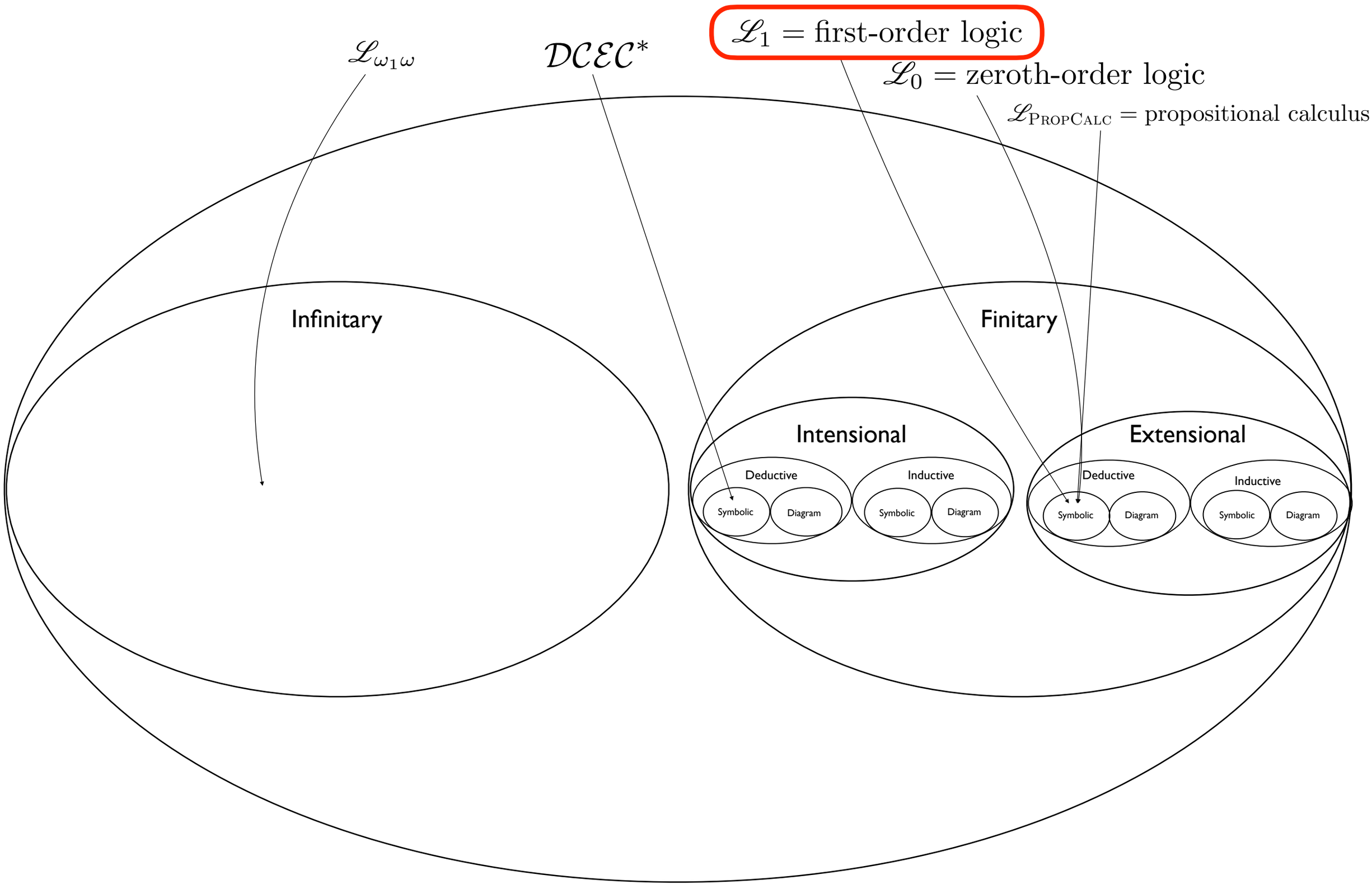

Special Llamas Disjunction

There's a thing such that it's both a llama and a non-llama;
or
there's a thing such that if it's a llama, everything is a llama;
or
there's a thing such that every llama is a non-llama.

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Background Claim

$\mathcal{R}$ Humans, at least neurobiologically normal ones, are fundamentally rational, where rationality is constituted by certain logico-mathematically based reasoning and decision-making in response to real-world stimuli, including stimuli given in the form of focused tests; but mere animals are not fundamentally rational, since, *contra* Darwin, their minds are fundamentally qualitatively inferior to the human mind. As to whether computing machines/robots are fundamentally rational, the answer is "No." For starters, if x can't read, write, and create, x can't be rational; computing machines/robots can neither read nor write nor create; ergo, they aren't fundamentally rational.

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recursion

self-reference

To infinity and beyond! — routinely

Background Claim

intensional reasoning

recursion

self-reference

To infinity and beyond! — routinely

quantification

intensional reasoning

recursion

self-reference

To infinity and beyond! — routinely

abstract-and-valid inference schemata

quantification

intensional reasoning

recursion

self-reference

To infinity and beyond! — routinely

abstract-and-valid inference schemata

quantification

intensional reasoning

recursion

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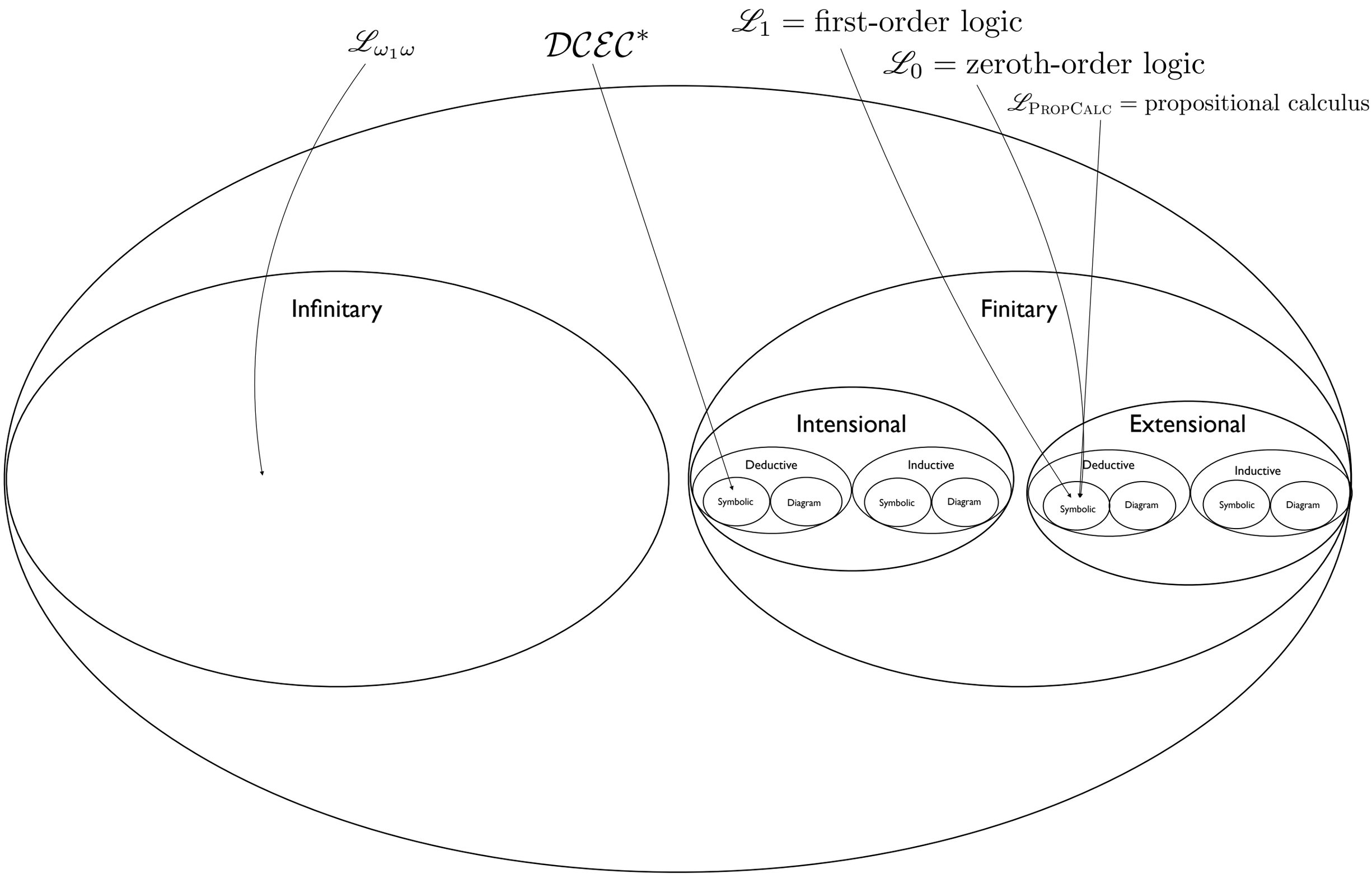
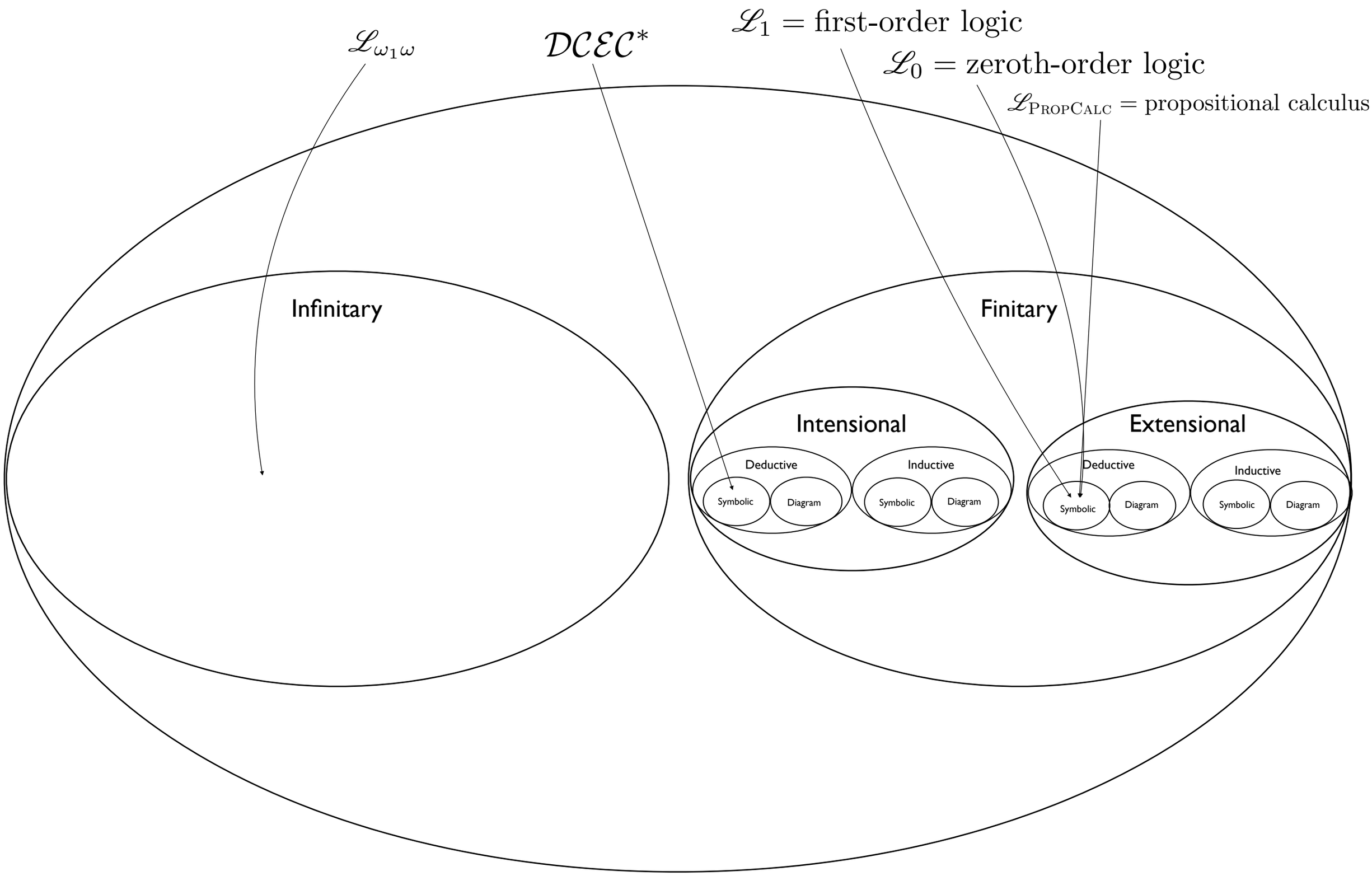
To infinity and beyond! — routinely

The Universe of Logics

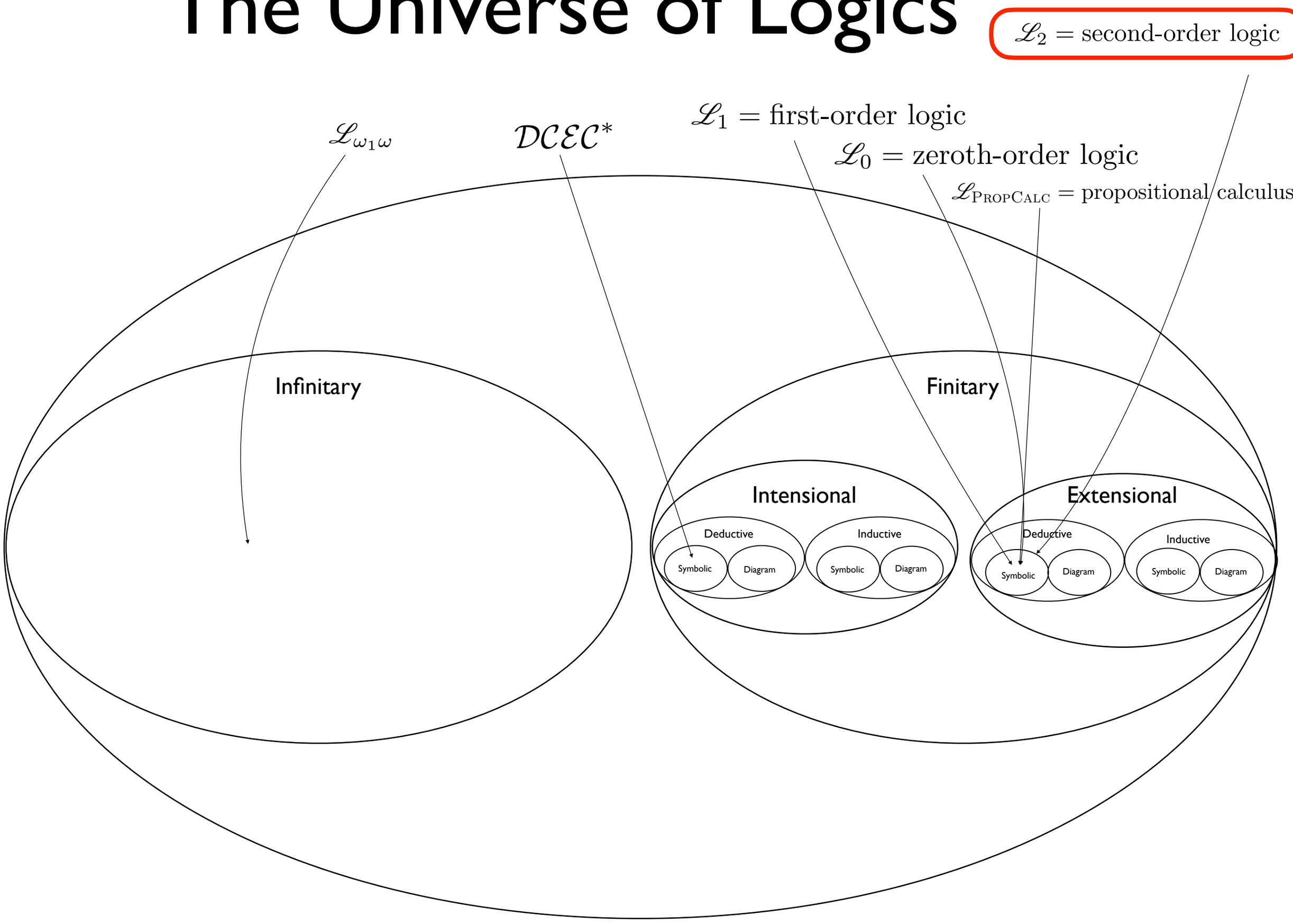


The Universe of Logics

$\mathscr{L}_2$ = second-order logic



The Universe of Logics



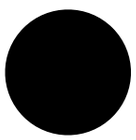
3 HG® Problems

- In addition to switching_conjuncts_fine, used for the signin tutorial, there are now 3 problem due Tues Sep 8:
  - RipsSaysNo2 ($\mathscr{L}_{pc}$)
  - OnlyMediumOrLargeLlamas ($\mathscr{L}_1$)
  - DoubleMindedMan ($\mathscr{L}_2$)

An Anchoring Timeline

• • •

2020



2020

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$\mathcal{DCEC}^*$

Syntax

$$
\begin{aligned}
S ::= {} & \text{Object} \mid \text{Agent} \mid \text{Self} \sqsubset \text{Agent} \mid \text{ActionType} \mid \text{Action} \sqsubseteq \text{Event} \mid \\
& \text{Moment} \mid \text{Boolean} \mid \text{Fluent} \mid \text{Numeric} \\
\\
& \mathit{action} : \text{Agent} \times \text{ActionType} \rightarrow \text{Action} \\
& \mathit{initially} : \text{Fluent} \rightarrow \text{Boolean} \\
& \mathit{holds} : \text{Fluent} \times \text{Moment} \rightarrow \text{Boolean} \\
& \mathit{happens} : \text{Event} \times \text{Moment} \rightarrow \text{Boolean} \\
& \mathit{clipped} : \text{Moment} \times \text{Fluent} \times \text{Moment} \rightarrow \mathit{Boolean} \\
f ::= {} & \mathit{initiates} : \text{Event} \times \text{Fluent} \times \text{Moment} \rightarrow \text{Boolean} \\
& \mathit{terminates} : \text{Event} \times \text{Fluent} \times \text{Moment} \rightarrow \text{Boolean} \\
& \mathit{prior} : \text{Moment} \times \text{Moment} \rightarrow \text{Boolean} \\
& \mathit{interval} : \text{Moment} \times \text{Boolean} \\
& * : \text{Agent} \rightarrow \text{Self} \\
& \mathit{payoff} : \text{Agent} \times \text{ActionType} \times \text{Moment} \rightarrow \text{Numeric} \\
\\
t ::= {} & x : S \mid c : S \mid f(t_1, \ldots, t_n) \\
\\
& t : \text{Boolean} \mid \neg\phi \mid \phi \wedge \psi \mid \phi \vee \psi \mid \\
& \mathbf{P}(a,t,\phi) \mid \mathbf{K}(a,t,\phi) \mid \mathbf{C}(t,\phi) \mid \mathbf{S}(a,b,t,\phi) \mid \mathbf{S}(a,t,\phi) \\
\phi ::= {} & \mathbf{B}(a,t,\phi) \mid \mathbf{D}(a,t,holds(f,t')) \mid \mathbf{I}(a,t,happens(action(a^*,\alpha),t')) \\
& \mathbf{O}(a,t,\phi,happens(action(a^*,\alpha),t'))
\end{aligned}
$$

Rules of Inference

$$\frac{}{\mathbf{C}(t,\mathbf{P}(a,t,\phi) \rightarrow \mathbf{K}(a,t,\phi))}\ [R_1] \qquad \frac{}{\mathbf{C}(t,\mathbf{K}(a,t,\phi) \rightarrow \mathbf{B}(a,t,\phi))}\ [R_2]$$

$$\frac{\mathbf{C}(t,\phi)\ t \leq t_1 \ldots t \leq t_n}{\mathbf{K}(a_1,t_1,\ldots\mathbf{K}(a_n,t_n,\phi)\ldots)}\ [R_3] \qquad \frac{\mathbf{K}(a,t,\phi)}{\phi}\ [R_4]$$

$$\frac{}{\mathbf{C}(t,\mathbf{K}(a,t_1,\phi_1 \rightarrow \phi_2)) \rightarrow \mathbf{K}(a,t_2,\phi_1) \rightarrow \mathbf{K}(a,t_3,\phi_2)}\ [R_5]$$

$$\frac{}{\mathbf{C}(t,\mathbf{B}(a,t_1,\phi_1 \rightarrow \phi_2)) \rightarrow \mathbf{B}(a,t_2,\phi_1) \rightarrow \mathbf{B}(a,t_3,\phi_2)}\ [R_6]$$

$$\frac{}{\mathbf{C}(t,\mathbf{C}(t_1,\phi_1 \rightarrow \phi_2)) \rightarrow \mathbf{C}(t_2,\phi_1) \rightarrow \mathbf{C}(t_3,\phi_2)}\ [R_7]$$

$$\frac{}{\mathbf{C}(t,\forall x.\ \phi \rightarrow \phi[x \mapsto t])}\ [R_8] \qquad \frac{}{\mathbf{C}(t,\phi_1 \leftrightarrow \phi_2 \rightarrow \neg\phi_2 \rightarrow \neg\phi_1)}\ [R_9]$$

$$\frac{}{\mathbf{C}(t,[\phi_1 \wedge \ldots \wedge \phi_n \rightarrow \phi] \rightarrow [\phi_1 \rightarrow \ldots \rightarrow \phi_n \rightarrow \psi])}\ [R_{10}]$$

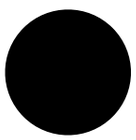
$$\frac{\mathbf{B}(a,t,\phi)\ \ \phi \rightarrow \psi}{\mathbf{B}(a,t,\psi)}\ [R_{11a}] \qquad \frac{\mathbf{B}(a,t,\phi)\ \ \mathbf{B}(a,t,\psi)}{\mathbf{B}(a,t,\psi \wedge \phi)}\ [R_{11b}]$$

$$\frac{\mathbf{S}(s,h,t,\phi)}{\mathbf{B}(h,t,\mathbf{B}(s,t,\phi))}\ [R_{12}]$$

$$\frac{\mathbf{I}(a,t,happens(action(a^*,\alpha),t'))}{\mathbf{P}(a,t,happens(action(a^*,\alpha),t))}\ [R_{13}]$$

$$\frac{\begin{array}{l}\mathbf{B}(a,t,\phi)\ \ \mathbf{B}(a,t,\mathbf{O}(a^*,t,\phi,happens(action(a^*,\alpha),t'))) \\ \mathbf{O}(a,t,\phi,happens(action(a^*,\alpha),t'))\end{array}}{\mathbf{K}(a,t,\mathbf{I}(a^*,t,happens(action(a^*,\alpha),t')))}\ [R_{14}]$$

$$\frac{\phi \leftrightarrow \psi}{\mathbf{O}(a,t,\phi,\gamma) \leftrightarrow \mathbf{O}(a,t,\psi,\gamma)}\ [R_{15}]$$



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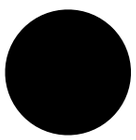

2020

IFLAI2 @ RPI

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2020

IFLAI2 @ RPI

350 BC

2020

IFLAI2 @ RPI

350 BC

Euclid

2020

IFLAI2 @ RPI

Euclidean "Magic"

Theorem: There are infinitely many primes.

Proof: We take an indirect route. Let $\Pi = p_1 = 2, p_2 = 3, p_3 = 5, \ldots, p_k$ be a finite, exhaustive consecutive sequence of prime numbers. Next, let $\mathbf{M}_\Pi$ be $p_1 \times p_2 \times \cdots \times p_k$, and set $\mathbf{M}'_\Pi$ to $\mathbf{M}_\Pi + 1$. Either $\mathbf{M}'_\Pi$ is prime, or not; we thus have two (exhaustive) cases to consider.

C1 Suppose $\mathbf{M}'_\Pi$ is prime. In this case we immediately have a prime number beyond any in Π — contradiction!

C2 Suppose on the other hand that $\mathbf{M}'_\Pi$ is *not* prime. Then some prime p divides $\mathbf{M}'_\Pi$. (Why?) Now, p itself is either in Π, or not; we hence have two sub-cases. Supposing that p is in Π entails that p divides $\mathbf{M}_\Pi$. But we are operating under the supposition that p divides $\mathbf{M}'_\Pi$ as well. This implies that p divides 1, which is absurd (a contradiction). Hence the prime p is outside Π.

Hence for *any* such list Π, there is a prime outside the list. That is, there are infinitely many primes. **QED**

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Euclid

2020

Intro to (Formal) Logic @ RPI

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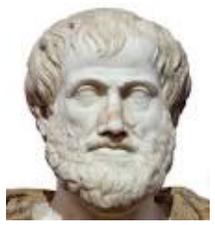

2020

350 BC

300 BC

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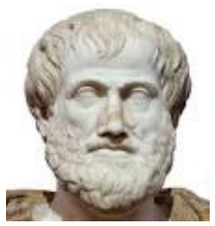

I don't believe in magic! Why exactly is that so convincing? What exactly is he doing?!?

Euclid

350 BC

Euclid

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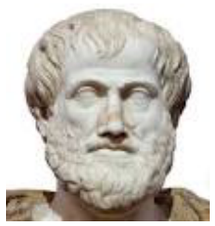

Organon

2020

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He's using syllogisms!

E.g.,

All As are Bs.
All Bs are Cs.

All As are Cs.

350 BC

Euclid

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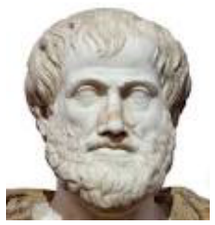

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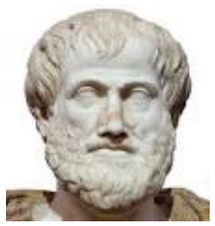

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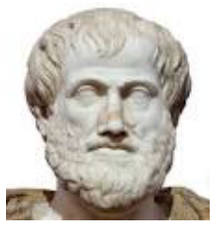

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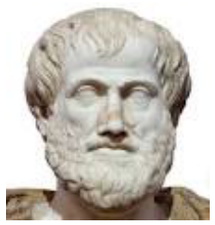

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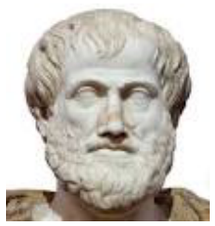
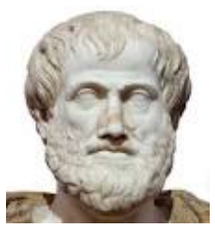


Organon

350 BC

300 BC

1666



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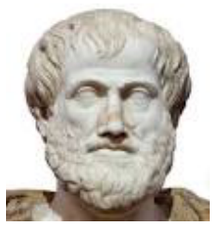

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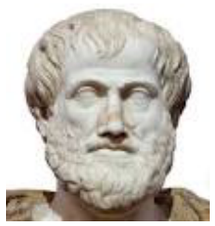

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"Universal Computational Logic"

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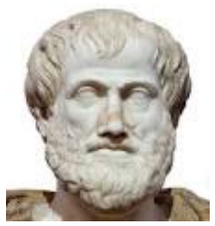

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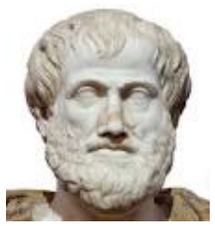

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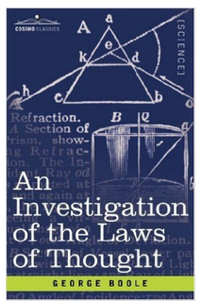

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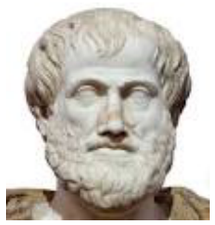

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“Astonishing” Logic Theorist Proof @ Dawn of AI

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1	$(\phi \vee \phi) \rightarrow \phi$	axiom
2	$(\neg\phi \vee \neg\phi) \rightarrow \neg\phi$	substitution
3	$(\phi \rightarrow \neg\phi) \rightarrow \neg\phi$	a “replacement rule”
4	$(A \rightarrow \neg A) \rightarrow \neg A$	substitution

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At dawn of AI: 10 seconds.

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At dawn of AI: 10 seconds.

AI of today, e.g. PC provability oracle in HyperSlate®, *vanishingly* small amount of time.

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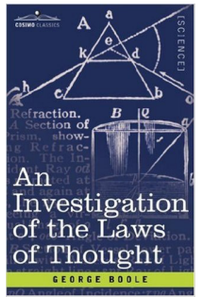

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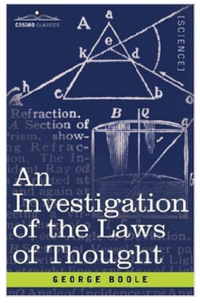

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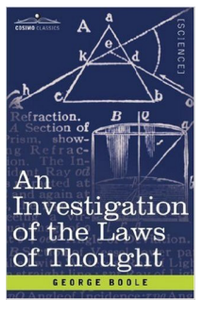

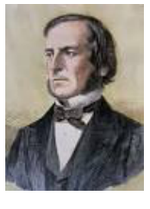

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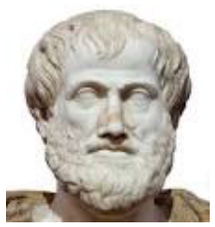

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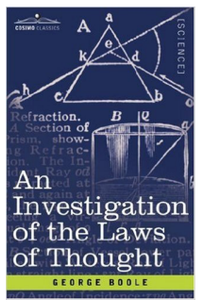

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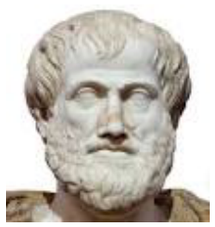

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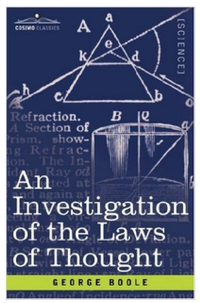

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Exceeds Leibniz & de-mystifies Euclid: the "compellingness" of these proofs consists in their being, at bottom, formal proofs in first-order logic (FOL).

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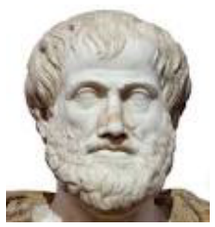

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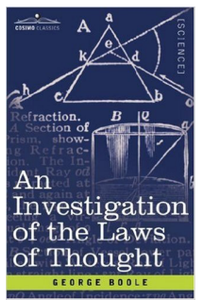

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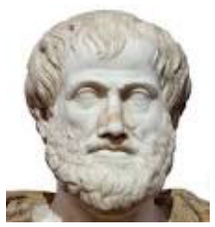

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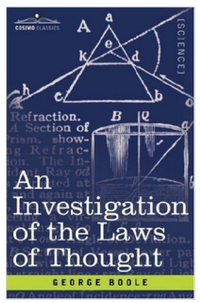

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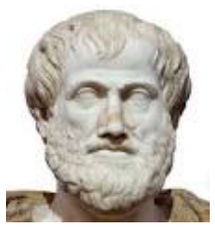

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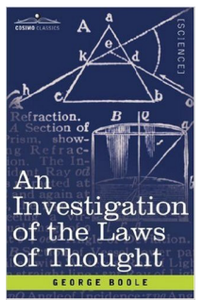

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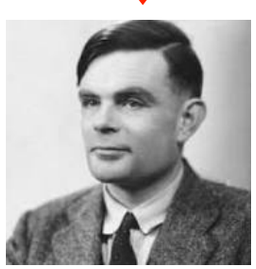

Turing

Post

Intro to Logic @ RPI

Here's what a computer is, and given that, sorry, the *Entscheidungsproblem* can't be solved by such a machine!

2020

2021

Thesingularity?

First, the Theoremhood Decision Problem (THEOREM$_{PC}$) for the Propositional Calculus

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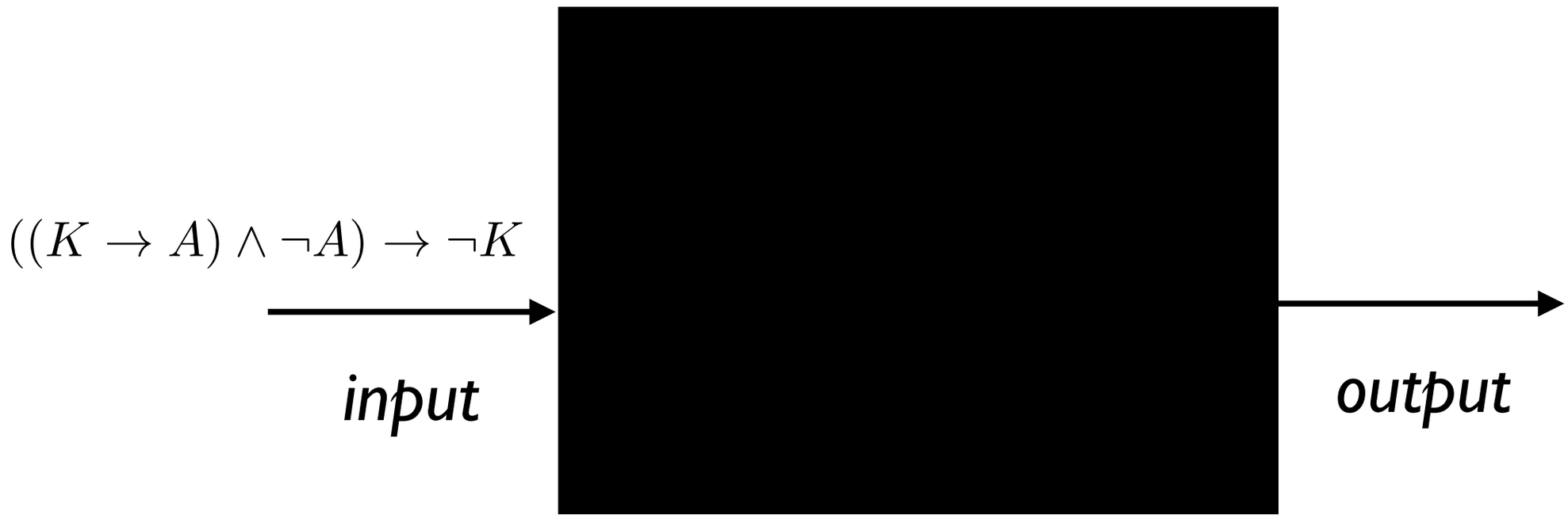

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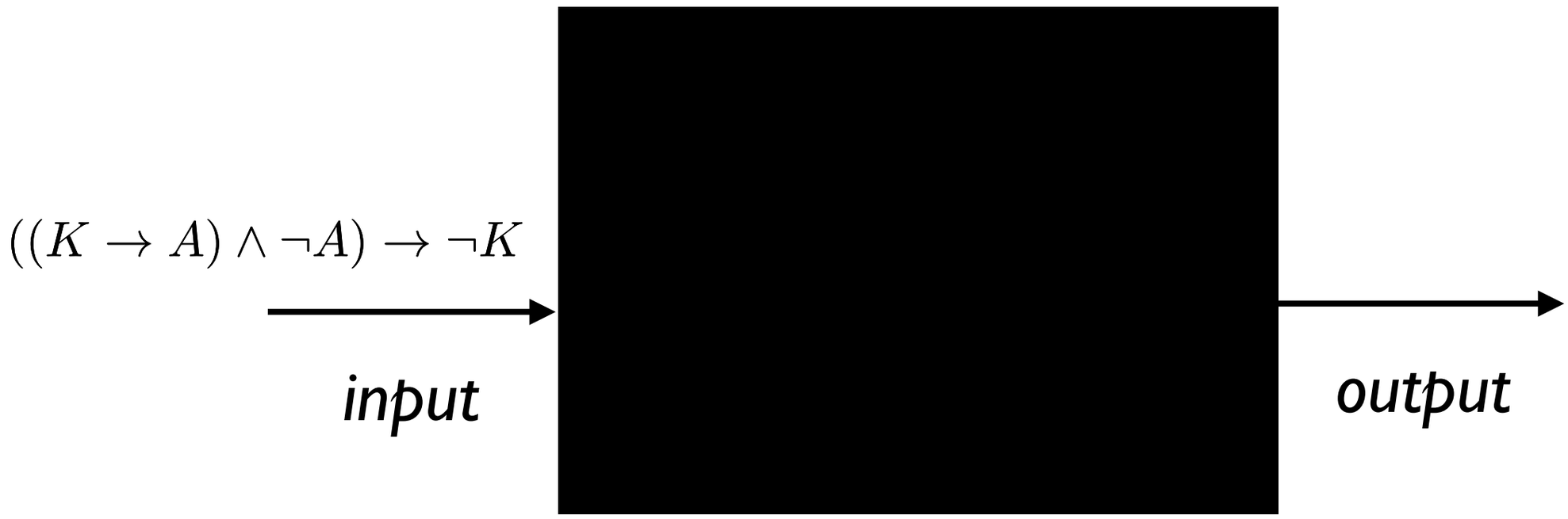

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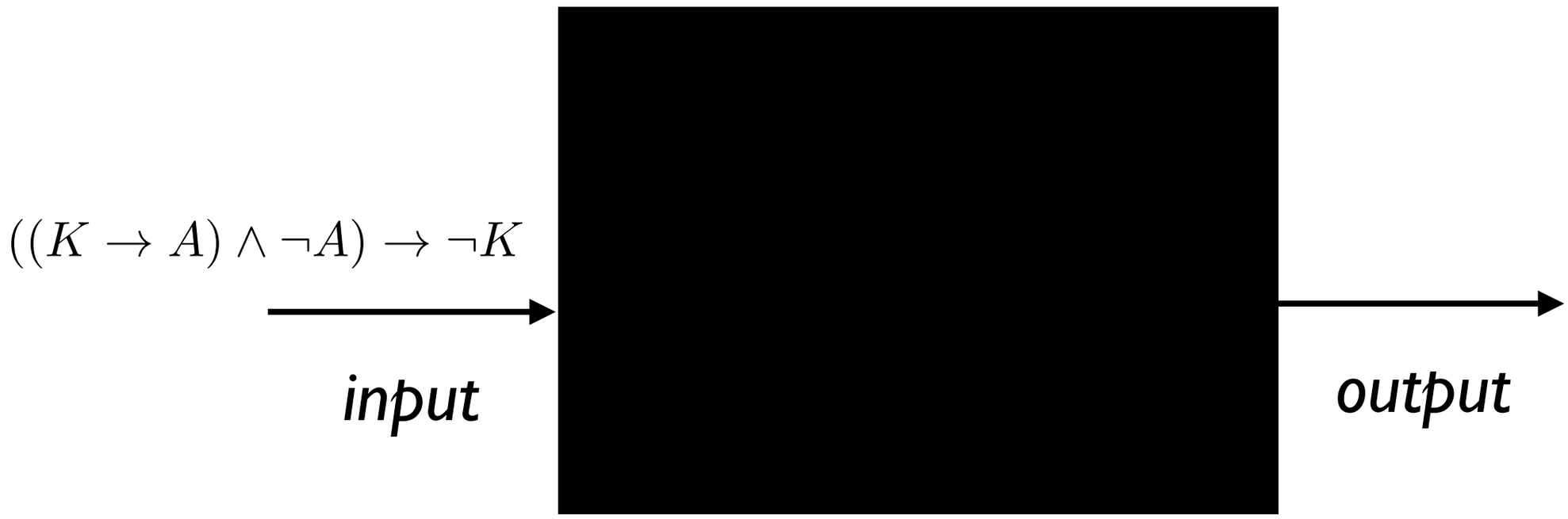

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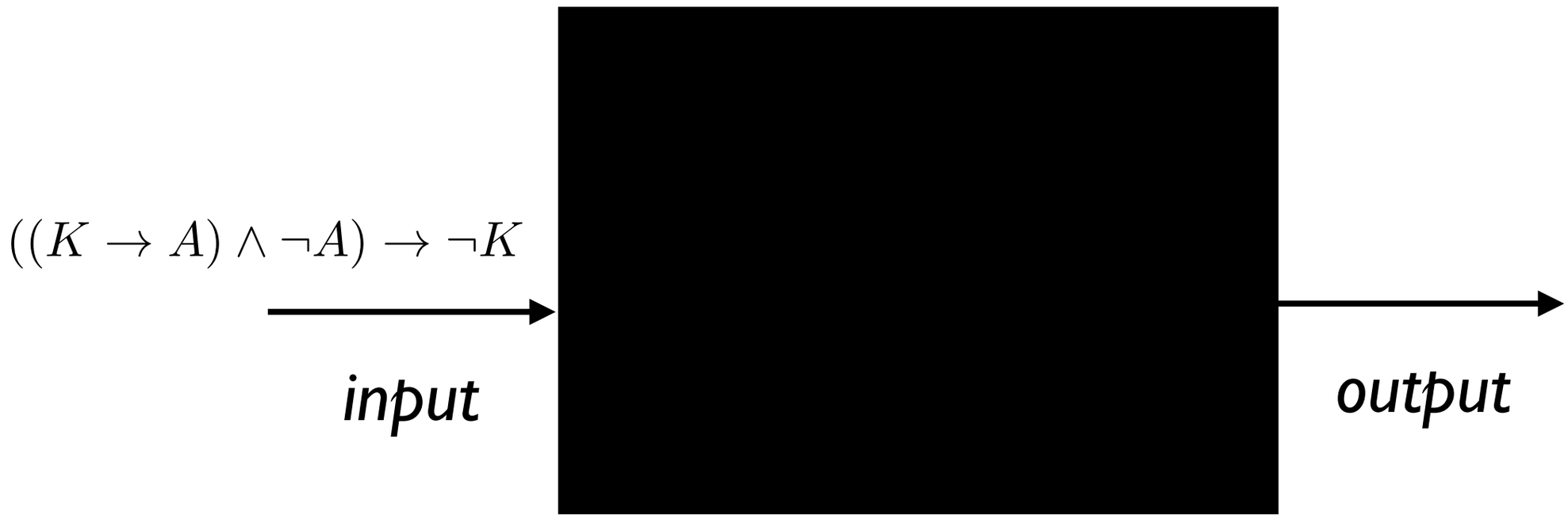

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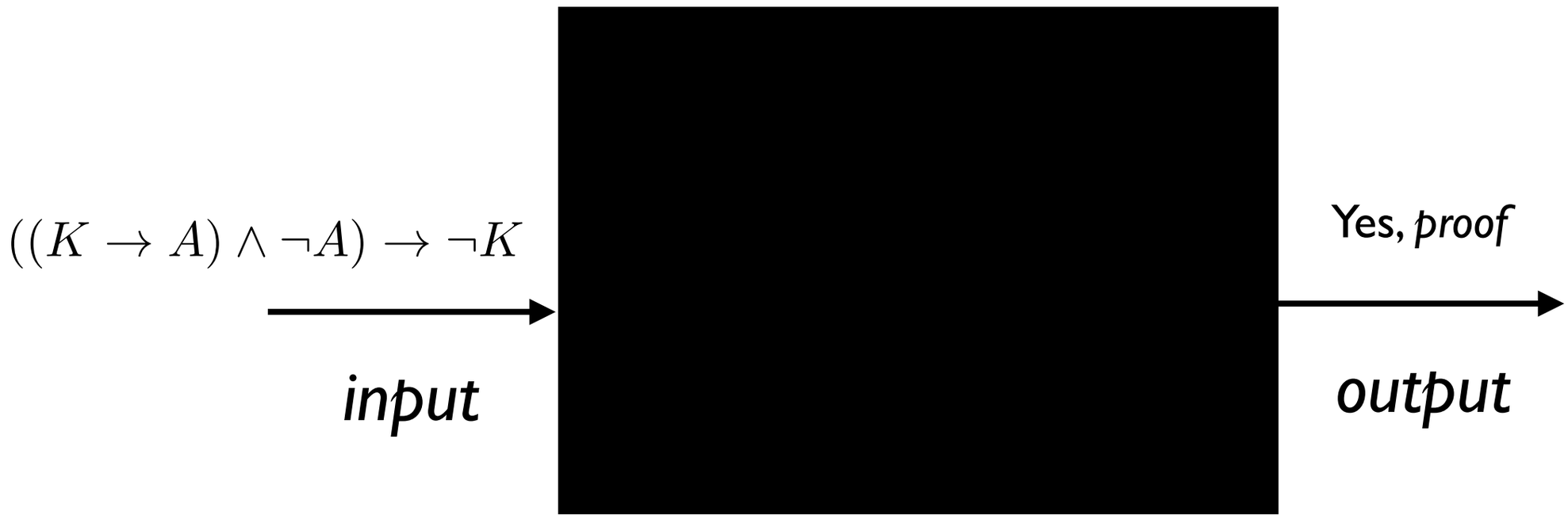

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for First-Order Logic (FOL)

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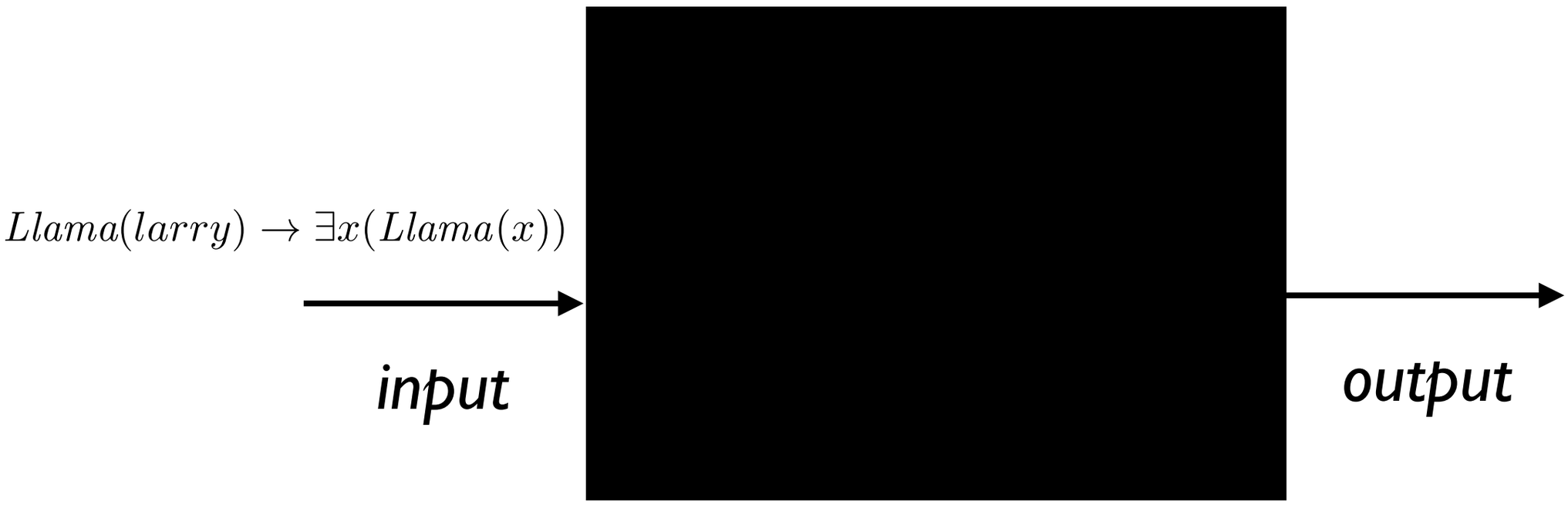

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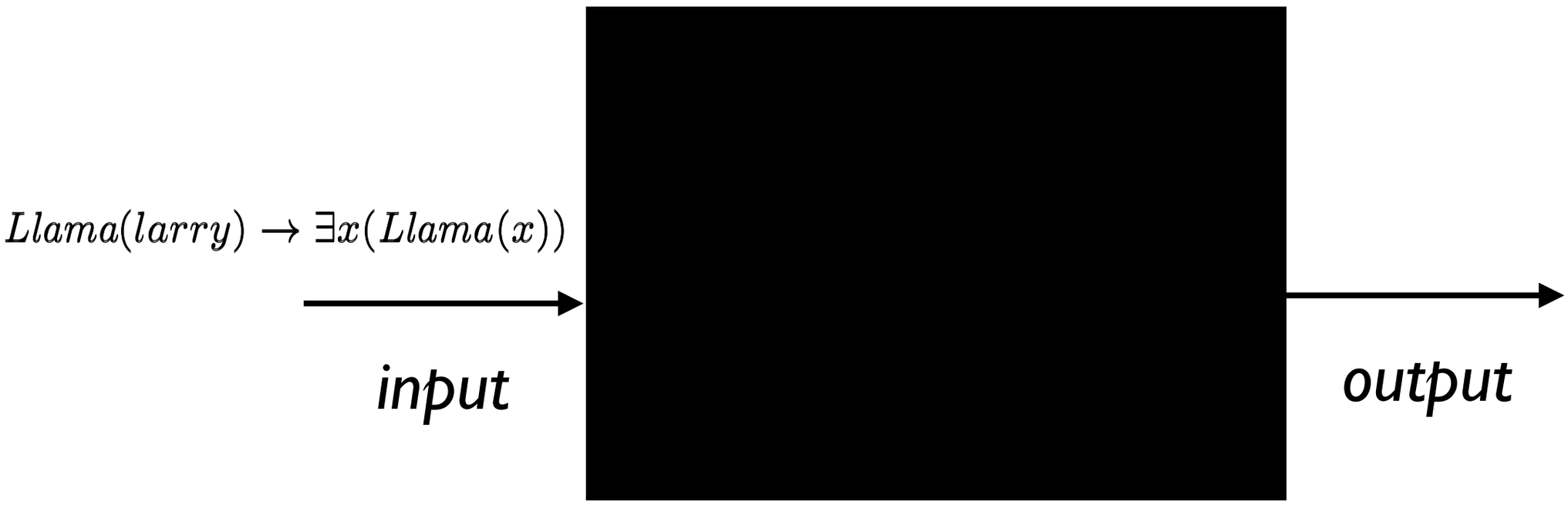

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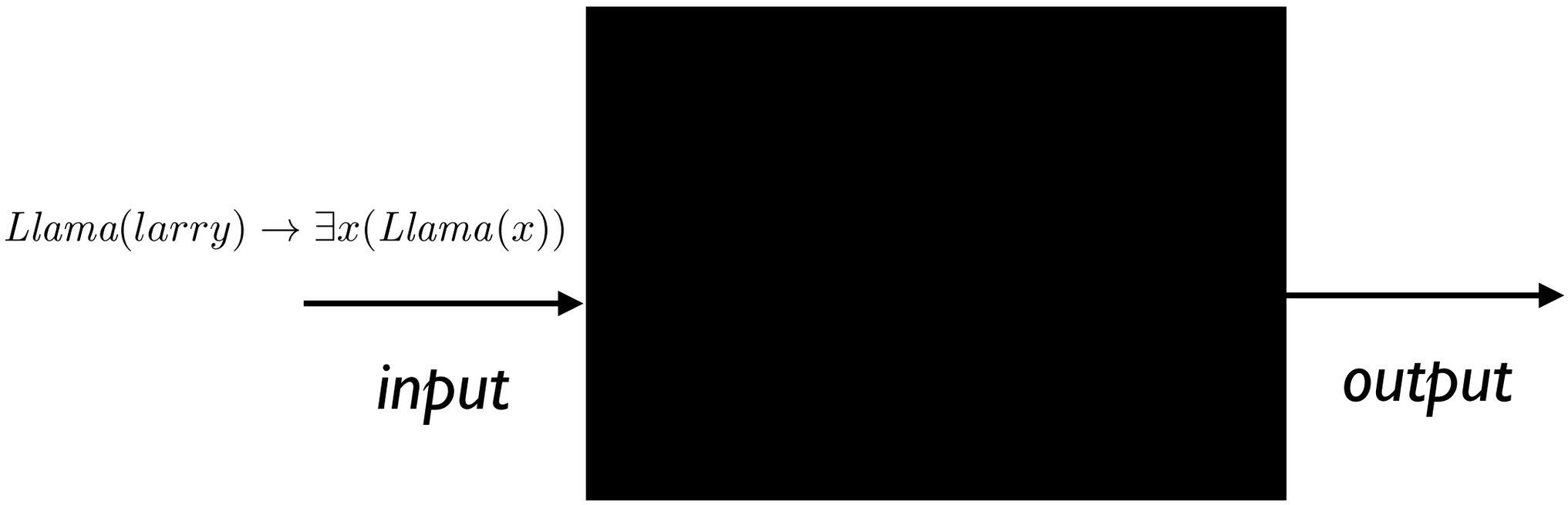

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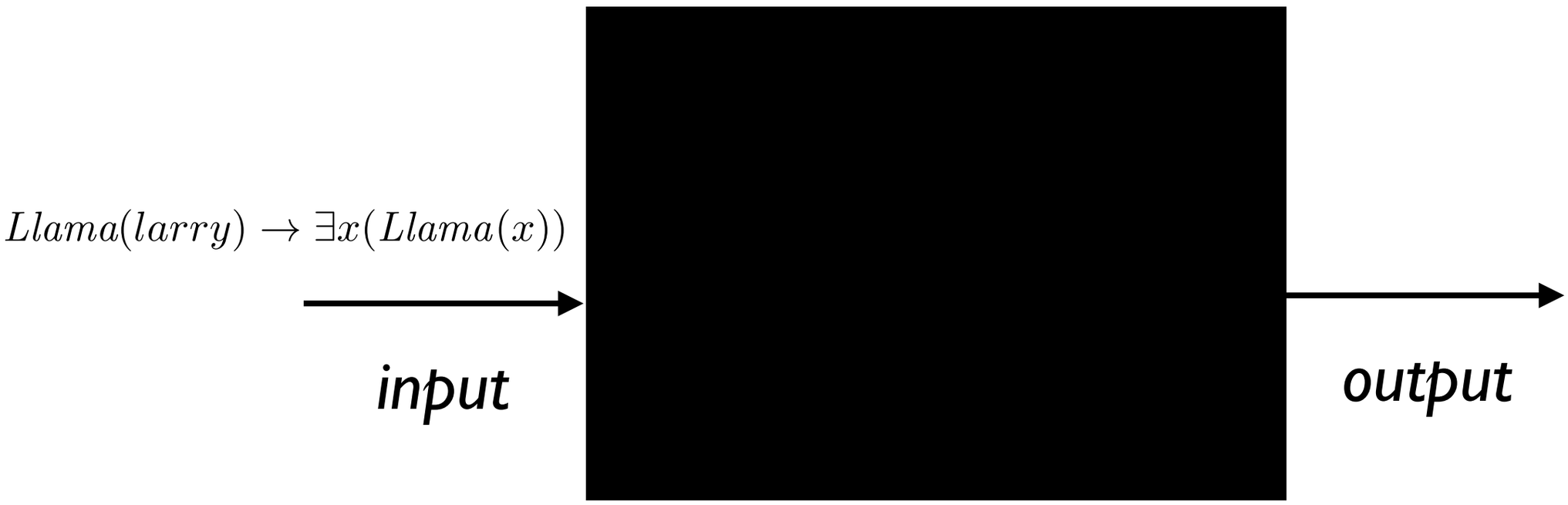

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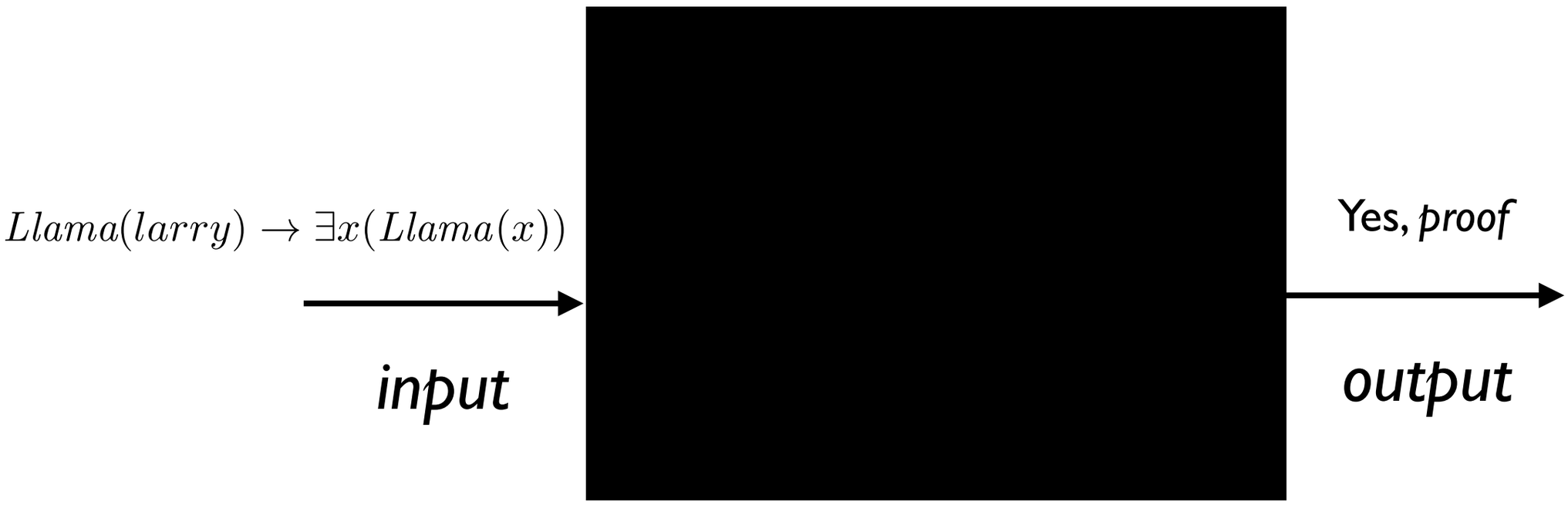

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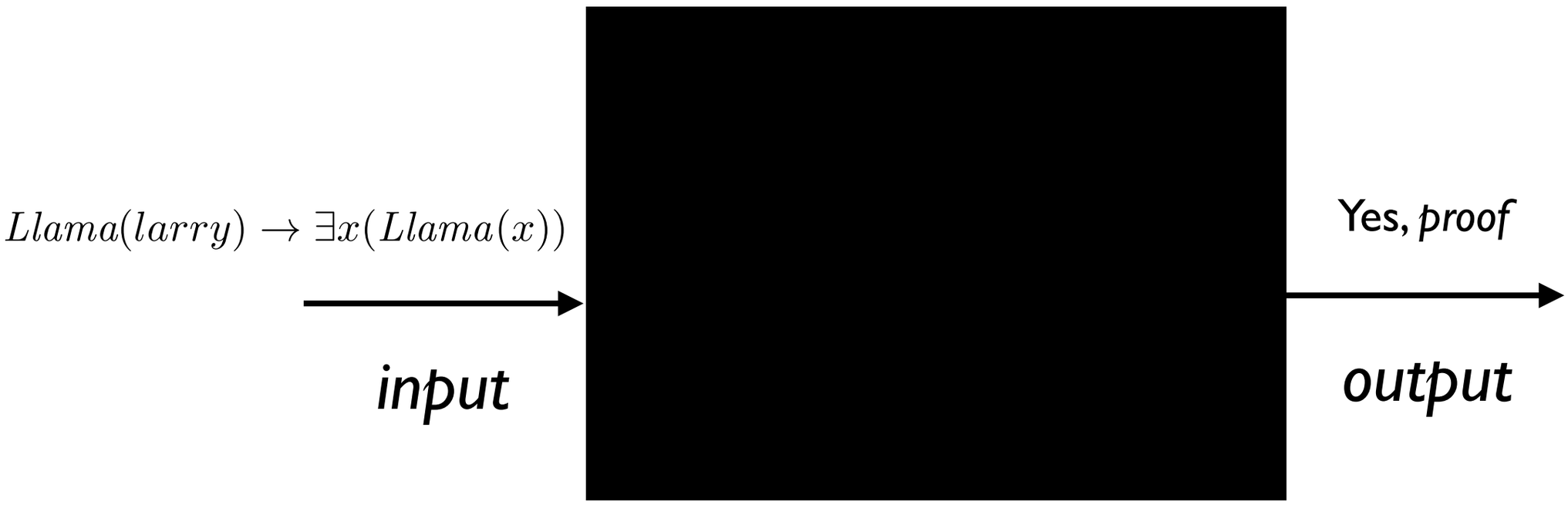
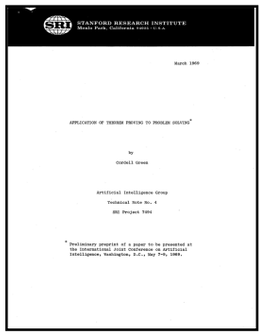


Not just hard: *impossible* for a (and this needed to be *invented* in the course of clarifying and solving the problem) standard computing machine.

On Logic & AI,

Specifically …



STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 U.S.A.

March 1969

APPLICATION OF THEOREM PROVING TO PROBLEM SOLVING*

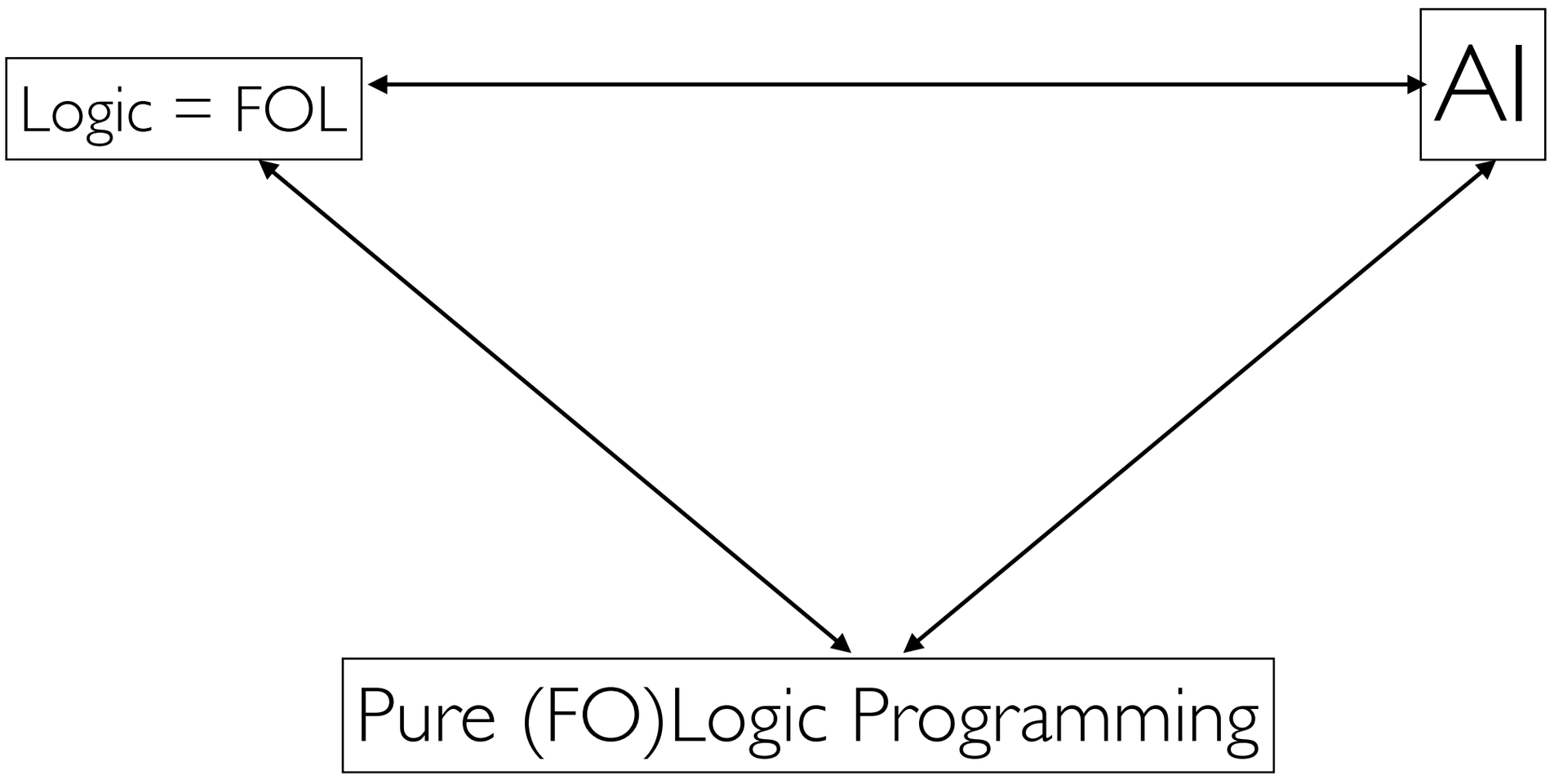
by

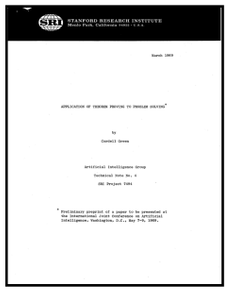
Cordell Green

Artificial Intelligence Group
Technical Note No. 4
SRI Project 7494

* Preliminary preprint of a paper to be presented at the International Joint Conference on Artificial Intelligence, Washington, D.C., May 7-9, 1969.

The Terrific Triad circa 1965





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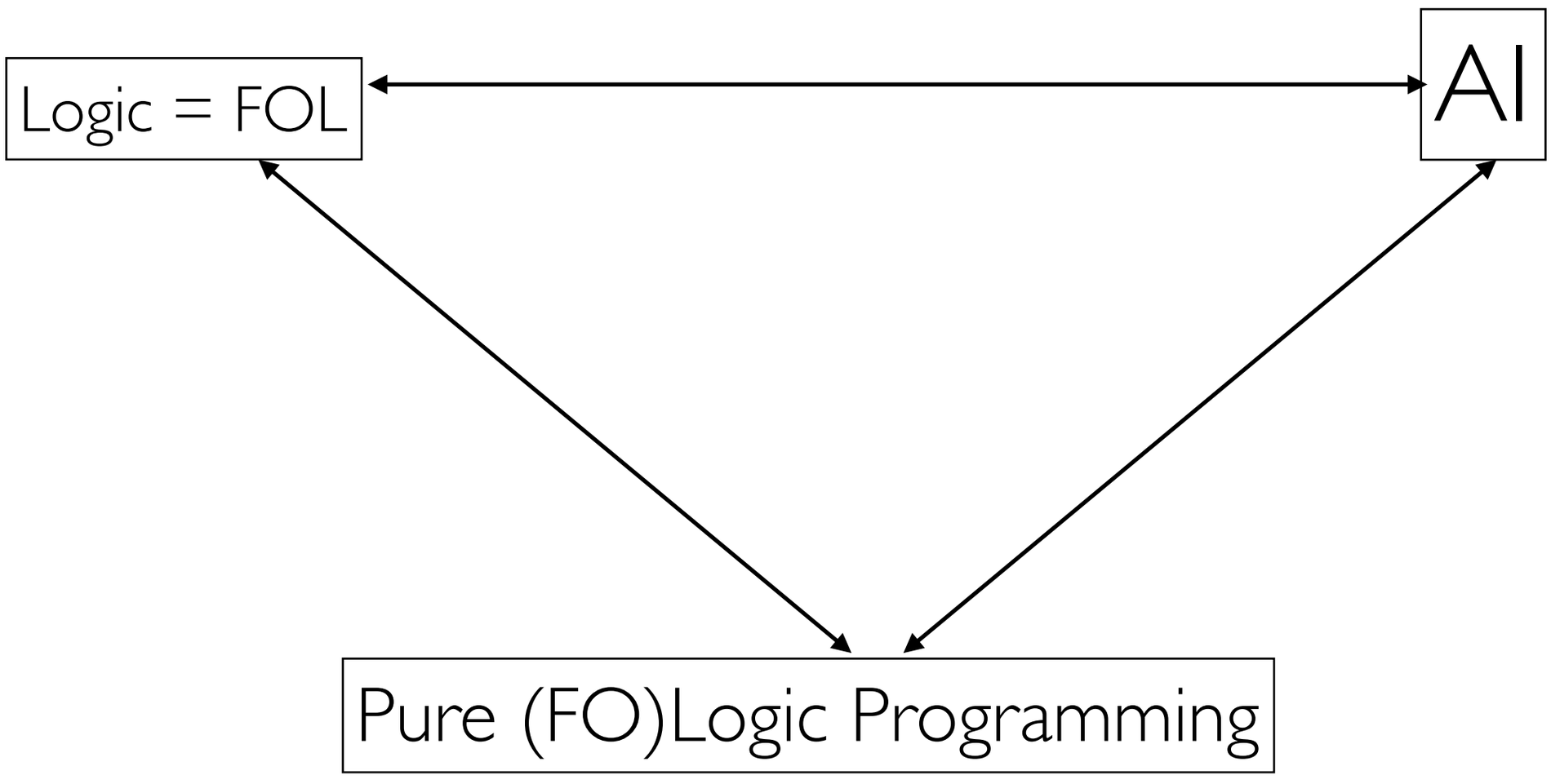
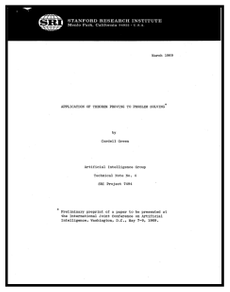
* Preliminary preprint of a paper to be presented at the International Joint Conference on Artificial Intelligence, Washington, D.C., May 7-9, 1969.

The Disastrous Disunion





STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025

March 1969

APPLICATION OF THEOREM PROVING TO PROBLEM SOLVING*

by

Cordell Green

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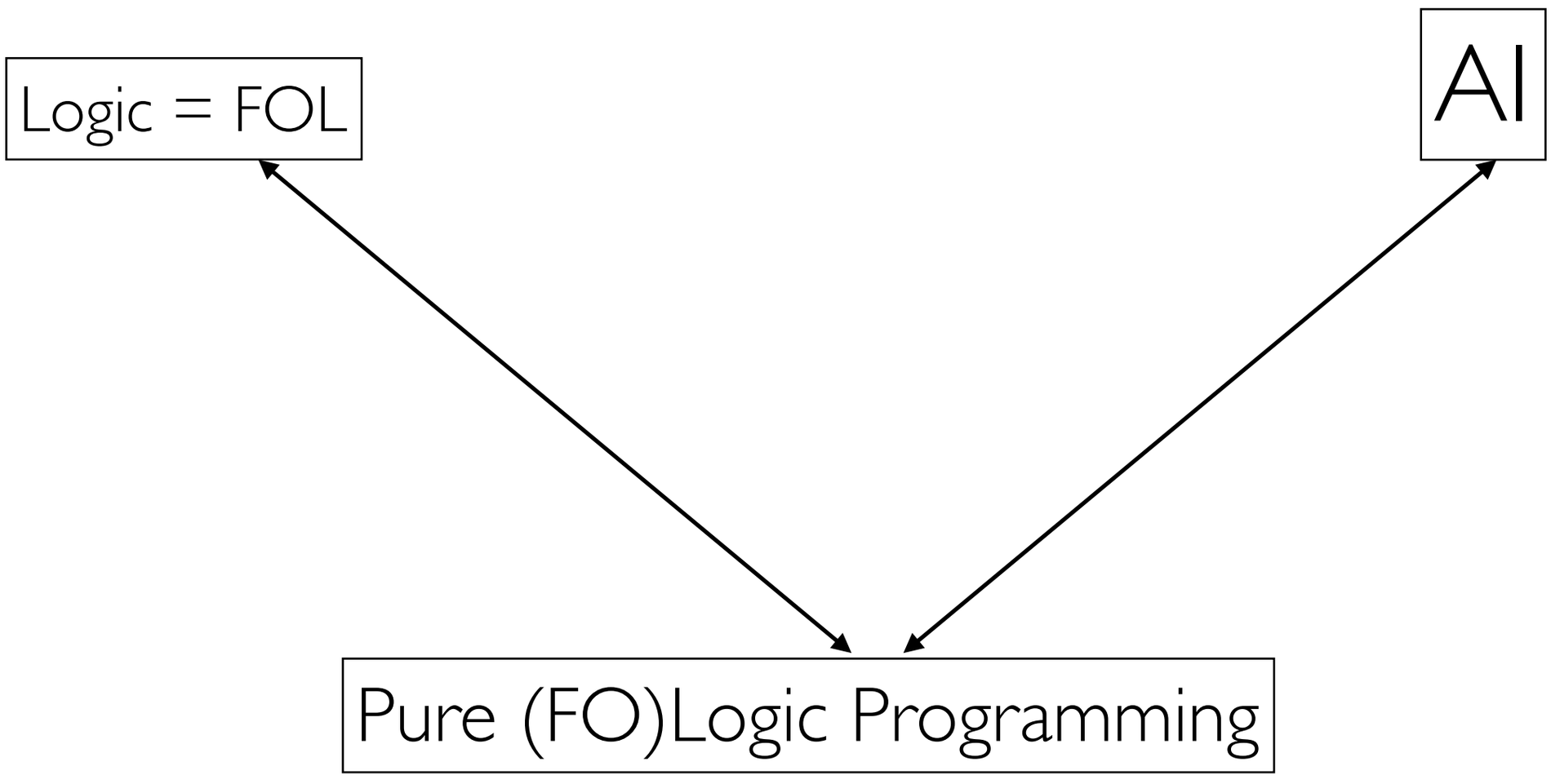

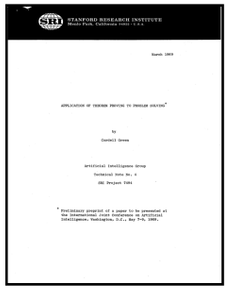

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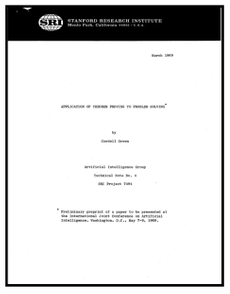
AI

Pure (FO)Logic Programming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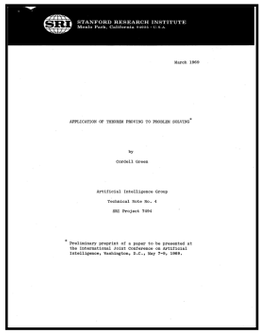

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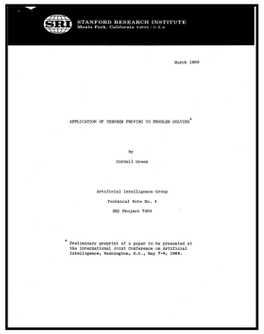

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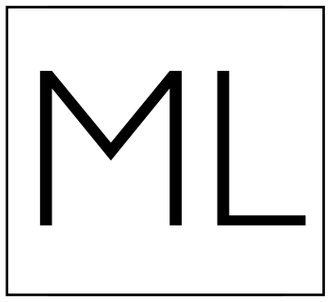

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Some Disastrous Consequences …

Disastrous Consequence #1:
Mindless Procedure is Venerated & Pushed

Computational Thinking

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ingrained in everyone's lives when words like algorithm and precondition are part of everyone's vocab-

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Computer science is the scientific (or STEM) study of:

what problems can be solved,
what tasks can be accomplished,
and what features of the world can be understood …

… *computationally*, that is, using a language with only:

2 nouns (‘0’, ‘1’),
3 verbs (‘move’, ‘print’, ‘halt’),
3 grammar rules (sequence, selection, repetition),
and nothing else,

and then to provide algorithms to show how this can be done:

efficiently,
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– Rapaport, “phics" book

Disastrous Consequence #2: Impenetrable, Dangerous Code

The Coming Software Apocalypse

A small group of programmers wants to change how we code—before catastrophe strikes.

In September 2007, Jean Bookout was driving on the highway with her best friend in a Toyota Camry when the accelerator seemed to get stuck. When she took her foot off the pedal, the car didn't slow down. She tried the brakes but they seemed to have lost their power. As she swerved toward an off-ramp going 50 miles per hour, she pulled the emergency brake. The car left a skid mark 150 feet long before running into an embankment by the side of the road. The passenger was killed. Bookout woke up in a hospital a month later.

The incident was one of many in a nearly decade-long investigation into claims of so-called unintended acceleration in Toyota cars. Toyota blamed the incidents on poorly designed floor mats, "sticky" pedals, and driver error, but outsiders suspected that faulty software might be responsible. The National Highway Traffic Safety Administration enlisted software experts from NASA to perform an intensive review of Toyota's code. After nearly 10 months, the NASA team hadn't found evidence that software was the cause—but said they couldn't prove it wasn't.

It was during litigation of the Bookout accident that someone finally found a convincing connection. Michael Barr, an expert witness for the plaintiff, had a team of software experts spend 18 months with the Toyota code, picking up where NASA left off. Barr described what they found as "spaghetti code," programmer lingo for software that has become a tangled mess. Code turns to spaghetti when it accretes over many years, with feature after feature piling on top of, and being woven around, what's already there; eventually the code becomes impossible to follow, let alone to test exhaustively for flaws.

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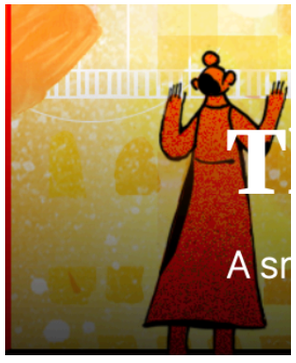

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Disastrous Consequence #3: Black-Box Machine-Learning Machines that Don't Learn Anything At All

Since Plato:

Knowledge is justified, true belief — where justifications (arguments and proofs) are necessarily based on logic.

But Plato has been trampled.

Do Machine-Learning Machines Learn?

Selmer Bringsjord and Naveen Sundar Govindarajulu and Shreya Banerjee and John Hummel

Abstract We answer the present paper's title in the negative. We begin by introducing and characterizing "real learning" ($\mathcal{RL}$) in the formal sciences, a phenomenon that has been firmly in place in homes and schools since at least Euclid. The defense of our negative answer pivots on an integration of *reductio* and proof by cases, and constitutes a general method for showing that any contemporary form of machine learning (ML) isn't real learning. Along the way, we canvass the many different conceptions of "learning" in not only AI, but psychology and its allied disciplines; none of these conceptions (with one exception arising from the view of cognitive development espoused by Piaget), aligns with real learning. We explain in this context by four steps how to broadly characterize and arrive at a focus on $\mathcal{RL}$.

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8 Appendix: The Formal Method

The following deduction uses fonts in an obvious and standard way to sort between functions ($\mathfrak{f}$), agents ($\mathfrak{a}$), and computing machines ($\mathfrak{m}$) in the Arithmetical Hierarchy. Ordinary italicized Roman is used for particulars under these sorts (e.g. f is a particular function). In addition, '$\mathcal{C}$' denotes any collection of conditions constituting jointly necessary-and-sufficient conditions for a form of current ML, which can come from relevant textbooks (e.g. Luger, 2008; Russell and Norvig, 2009) or papers; we leave this quite up to the reader, as no effect upon the validity of the deductive inference chain will be produced by the preferred instantiation of '$\mathcal{C}$.' It will perhaps be helpful to the reader to point out that the deduction eventuates in the proposition that no machine in the ML fold that in this style learns a relevant function $\mathfrak{f}$ thereby also real-learns $\mathfrak{f}$. We encode this target as follows:

$$(\star)\quad \neg\exists \mathfrak{m}\ \exists \mathfrak{f}\ [\phi := \mathit{MLlearns}(\mathfrak{m},\mathfrak{f}) \wedge \psi := \mathit{RLlearns}(\mathfrak{m},\mathfrak{f}) \wedge \mathcal{C}_{\phi}(\mathfrak{m},\mathfrak{f}) \vdash^{*} (\mathrm{ci}')\text{–}(\mathrm{ciii})_{\psi}(\mathfrak{m},\mathfrak{f})]$$

Note that $(\star)$ employs meta-logical machinery to refer to particular instantiations of $\mathcal{C}$ for a particular, arbitrary case of ML (ϕ is the atomic sub-formula that can be instantiated to make the particular case), and particular instantiations of the triad (ci′)–(ciii) for a particular, arbitrary case of $\mathcal{RL}$ (ψ is the atomic sub-formula that can be instantiated to make the particular case). Meta-logical machinery also allows us to use a provability predicate to formalize the notion that real learning is produced by the relevant instance of ML. If we "pop" ϕ/ψ to yield ϕ'/ψ' we are dealing with the particular instantiation of the atomic sub-formula.

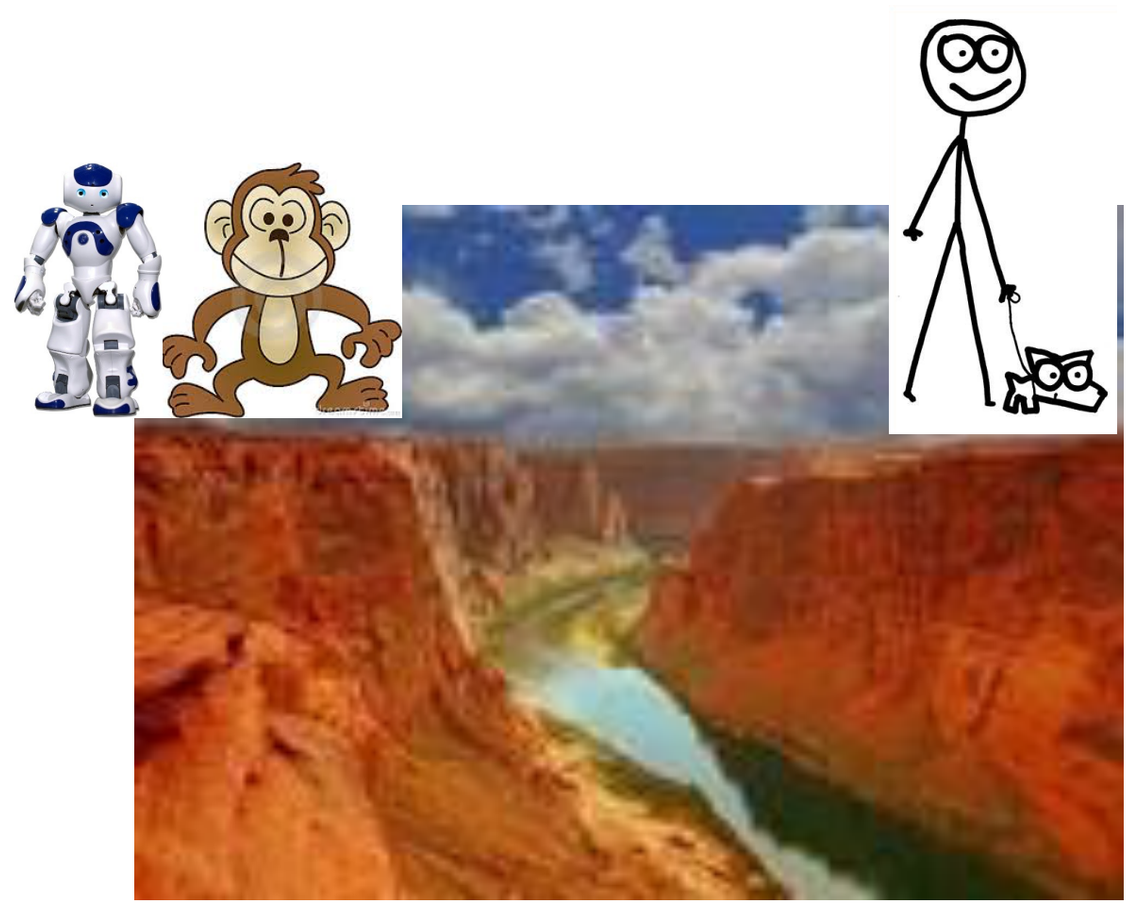
The deduction, as noted in earlier when the informal argument was given, is indirect proof by cases; accordingly, we first assume $\neg(\star)$, and then proceed as follows under this supposition.

	(1)	$\forall \mathfrak{f},\mathfrak{a}\ [\mathfrak{f} : \mathbb{N} \mapsto \mathbb{N} \rightarrow (\mathit{RLlearns}(\mathfrak{a},\mathfrak{f}) \rightarrow \mathrm{(i)}\text{–}\mathrm{(iii)})]$	Def of Real Learning
	(2)	$\mathit{MLlearns}(m,f) \wedge \mathit{RLlearns}(m,f) \wedge f : \mathbb{N} \mapsto \mathbb{N}$	supp (for $\exists$ elim on $(\star)$)
	(3)	$\forall \mathfrak{m},\mathfrak{f}\ [\mathfrak{f} : \mathbb{N} \mapsto \mathbb{N} \rightarrow (\mathit{MLlearns}(\mathfrak{m},\mathfrak{f}) \leftrightarrow \mathcal{C}(\mathfrak{m},\mathfrak{f}))]$	Def of ML
	(4)	$\forall \mathfrak{f}\ [\mathfrak{f} : \mathbb{N} \mapsto \mathbb{N} \rightarrow (\mathit{TurComp}(\mathfrak{f}) \vee \mathit{TurUncomp}(\mathfrak{f}))]$	theorem
	(5)	$\mathit{TurUncomp}(f)$	supp; Case 1
	(6)	$\neg\exists \mathfrak{m}\ \exists \mathfrak{f}\ [(\mathfrak{f} : \mathbb{N} \mapsto \mathbb{N} \wedge \mathit{TurUncomp}(\mathfrak{f}) \wedge \mathcal{C}(\mathfrak{m},\mathfrak{f})]$	theorem
$\therefore$	(7)	$\neg\exists \mathfrak{m}\ \mathit{MLlearns}(\mathfrak{m},f)$	(6), (3)
$\therefore$	(8)	$\bot$	(7), (2)
	(9)	$\mathit{TurComp}(f)$	supp; Case 2
$\therefore$	(10)	$\mathcal{C}_{\phi'}(m,f)$	(2), (3)
$\therefore$	(11)	$(\mathrm{ci}')\text{–}(\mathrm{ciii})_{\psi'}(m,f)$	from supp for $\exists$ elim on $(\star)$ and provability
$\therefore$	(12)	$\neg(\mathrm{ci}')\text{–}(\mathrm{ciii})_{\psi'}(m,f)$	inspection: proofs wholly absent from $\mathcal{C}$
$\therefore$	(13)	$\bot$	(11), (12)
$\therefore$	(14)	$\bot$	*reductio*; proof by cases

http://kryten.mm.rpi.edu/SB_NSG_SB_JH_DoMachine-LearningMachinesLearn_preprint.pdf

Disastrous Consequence #4: Animal-level AI, Let Alone AI Not Chained to Earth

The Canyon of Discontinuity (or Darwin's Dread)



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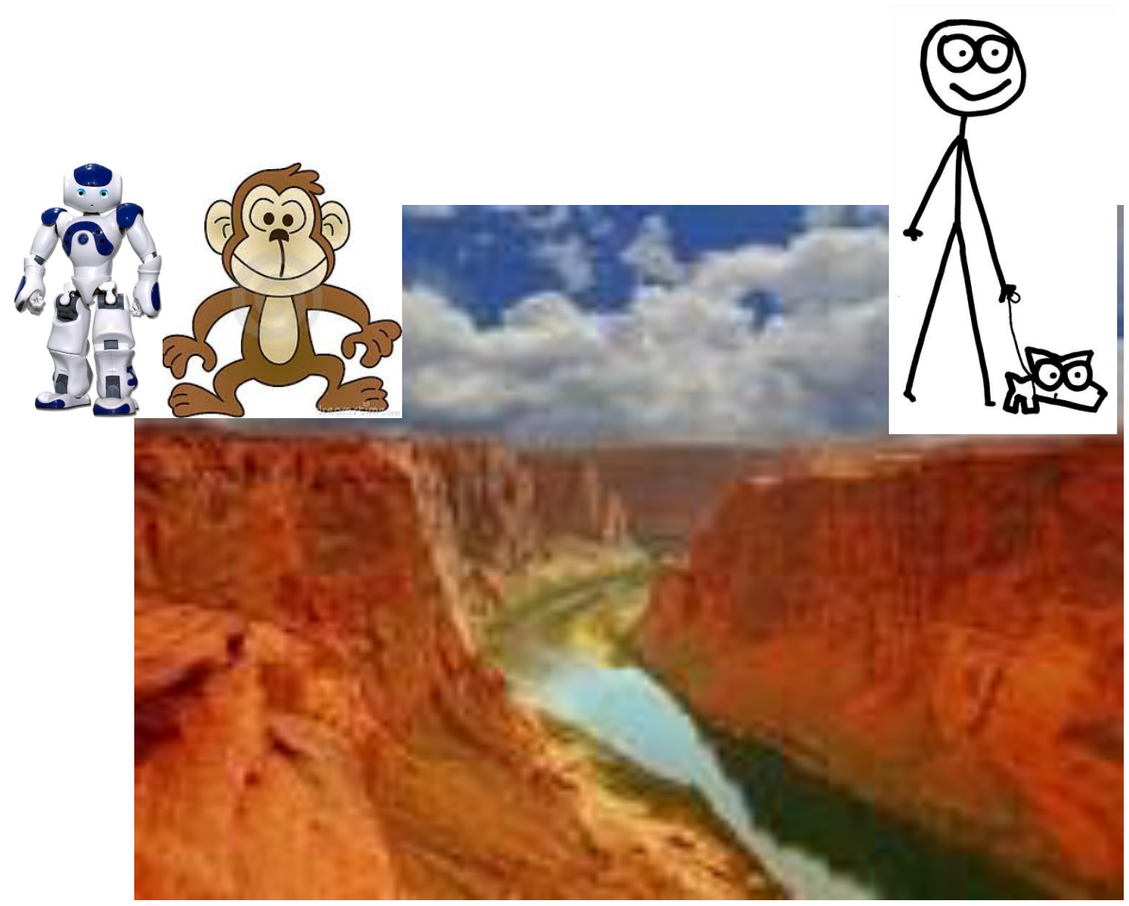

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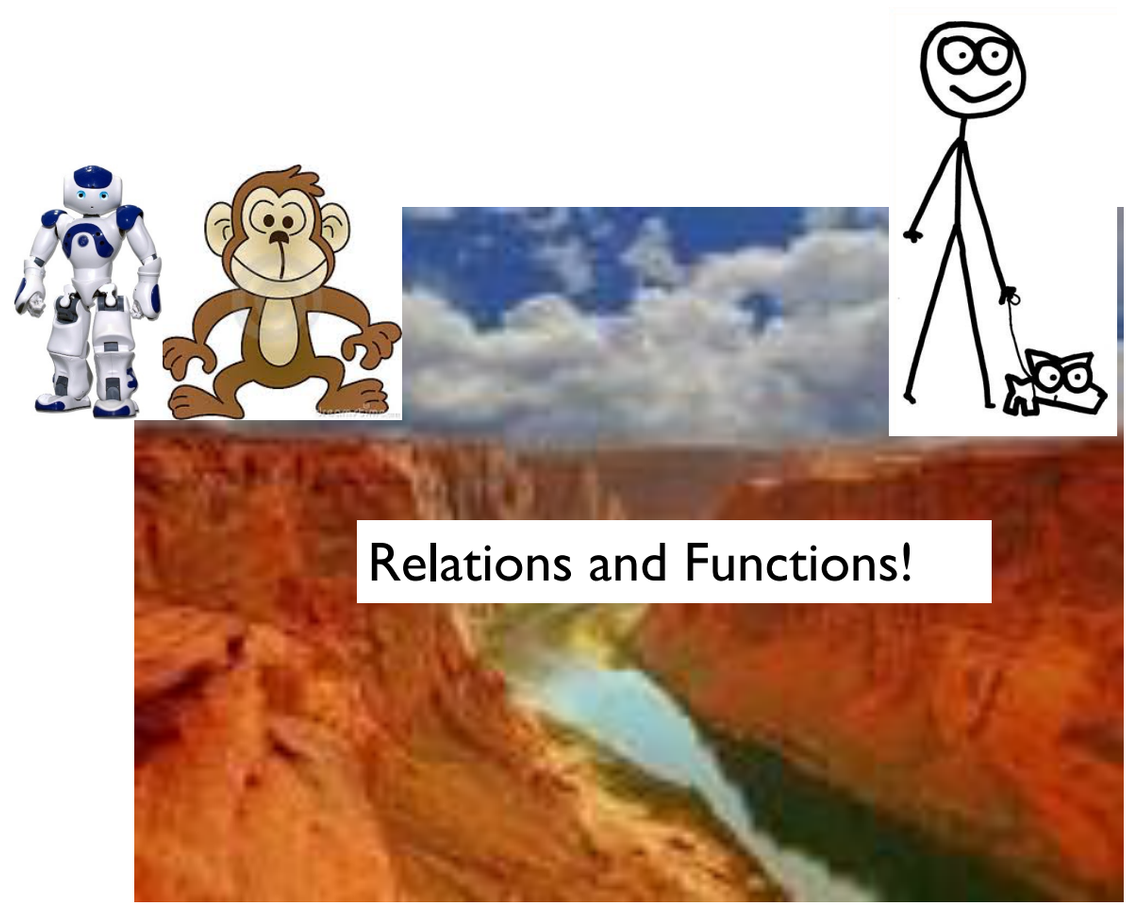

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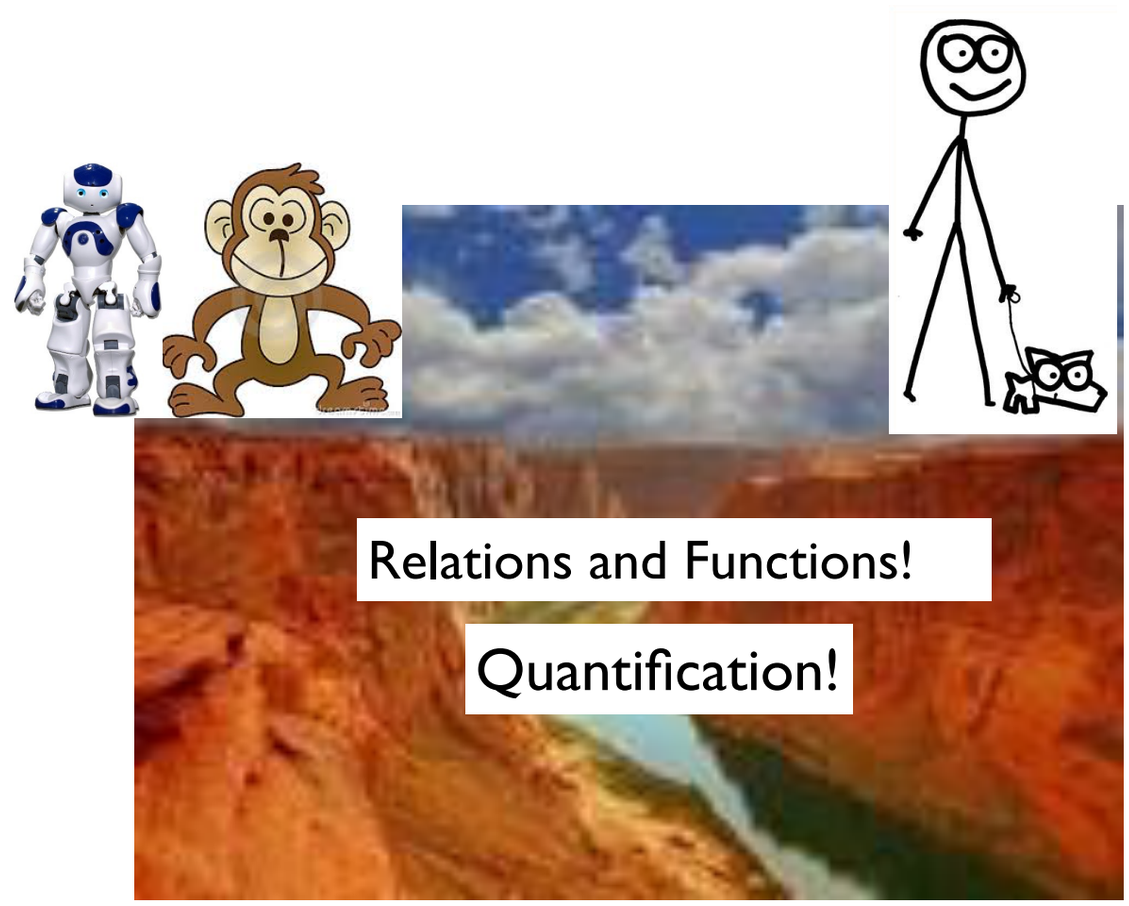

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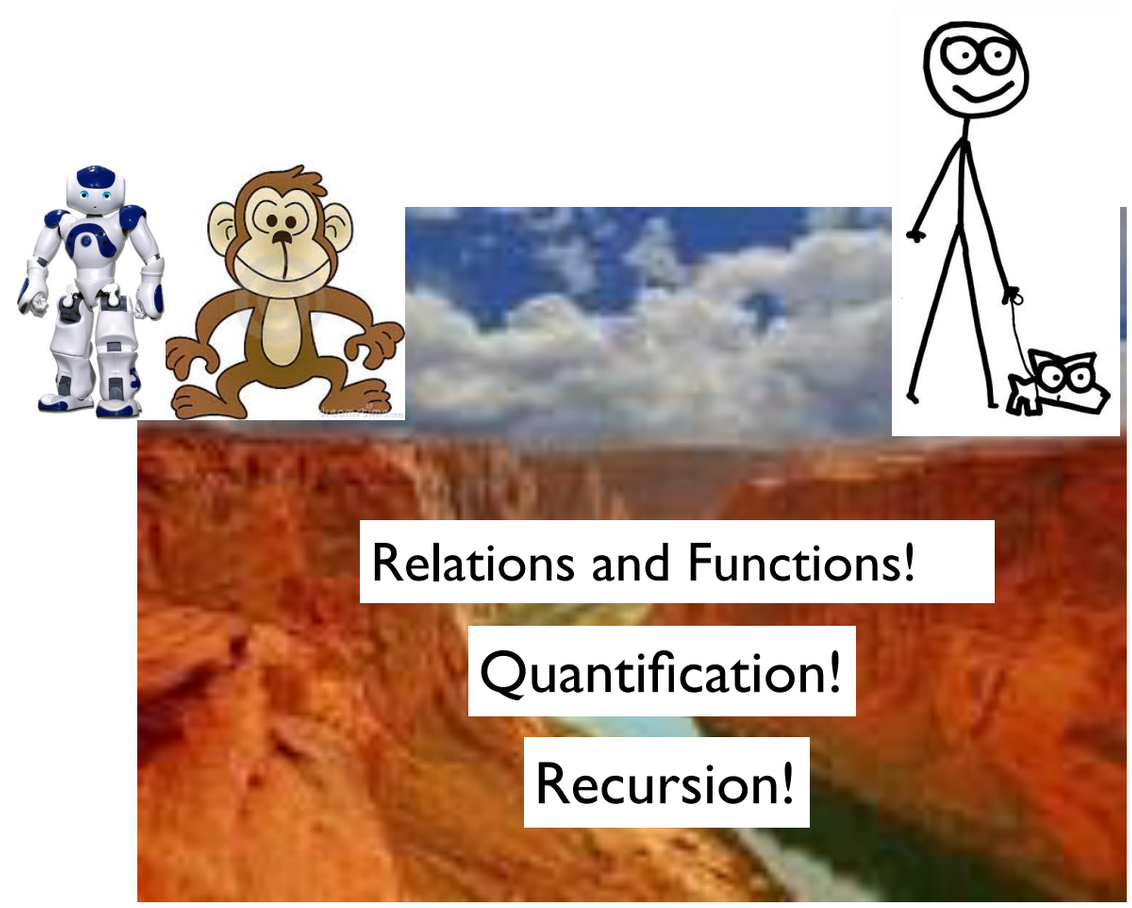

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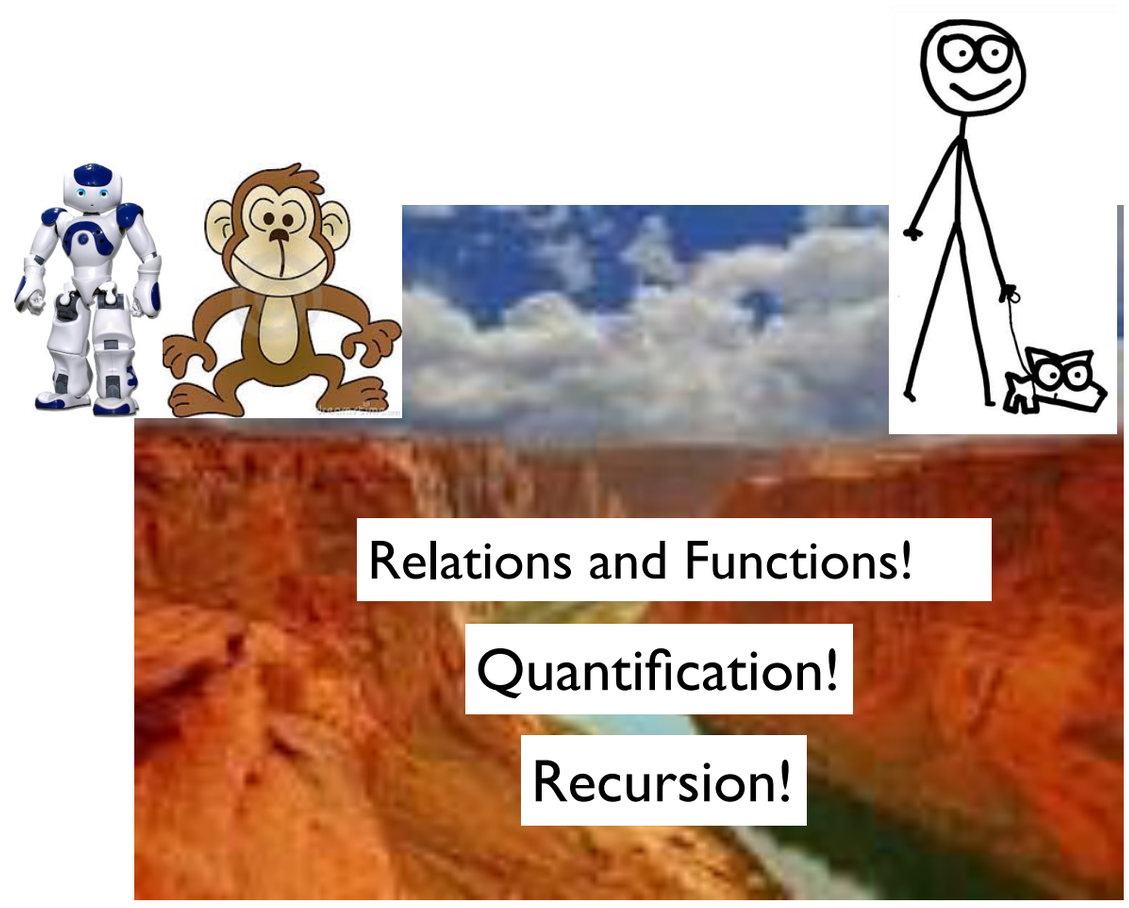

(Interesting paper: http://idiom.ucsd.edu/~ivano/SemBabble_old/LogicSeminar_15W/Material/Partee_2013_History-of-Quantifiers.pdf.)

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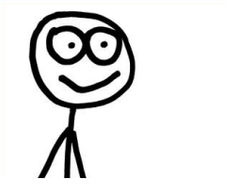
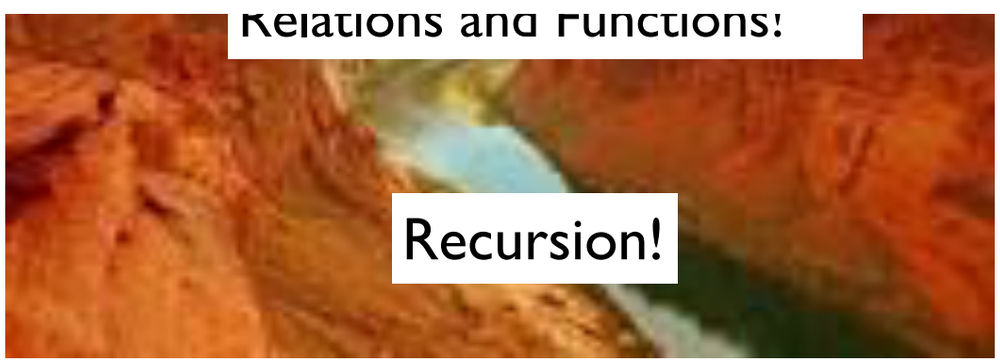


Quantification!



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Karkooking Problem …

Everyone karkooks anyone who karkooks someone.

Alvin karkooks Bill.

Can you infer that everyone karkooks Bill?

ANSWER:

JUSTIFICATION:

Karkooking Problem …

Everyone karkooks anyone who karkooks someone.

Alvin karkooks Bill.

Can you infer that everyone karkooks Bill?

ANSWER:

JUSTIFICATION:

Relations and Functions!

Quantification!

Recursion!

Animal-Level AI

Super-Serious Human Cognitive Power

Serious Human Cognitive Power

Entscheidungsproblem

Mere Calculative Cognitive Power

Animal-Level AI

Analytical Hierarchy

Serious Human Cognitive Power

Entscheidungsproblem

Mere Calculative Cognitive Power

Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

Entscheidungsproblem

Mere Calculative Cognitive Power

Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

Entscheidungsproblem

Polynomial Hierarchy

Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

Entscheidungsproblem

Polynomial Hierarchy

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

Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

Σ_0

Entscheidungsproblem

Polynomial Hierarchy

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

Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

Π_2

Σ_2

Go: AlphaGo

Π_1

Σ_1

Σ_0

Entscheidungsproblem

Polynomial Hierarchy

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Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

Π_2

Σ_2

Jeopardy!: **Watson**

Go: AlphaGo

Π_1

Σ_1

Σ_0

Entscheidungsproblem

Polynomial Hierarchy

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Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

Σ_0

Chess: Deep Blue

Jeopardy!: **Watson**

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Entscheidungsproblem

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Animal-Level AI

Analytical Hierarchy

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$\vdots$

Π_2

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Checkers: Chinook

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Entscheidungsproblem

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Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

Σ_0

Entscheidungsproblem

Polynomial Hierarchy

Chess: Deep Blue

Checkers: Chinook

Go: AlphaGo

Jeopardy!: **Watson**

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

Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

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Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

Church

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

Σ_0

Entscheidungsproblem

Polynomial Hierarchy

Chess: Deep Blue

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Jeopardy!: **Watson**

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Animal-Level AI

Analytical Hierarchy

Arithmetical Hierarchy

Church

Turing

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

Σ_0

Entscheidungsproblem

Polynomial Hierarchy

Chess: Deep Blue

Checkers: Chinook

Jeopardy!: **Watson**

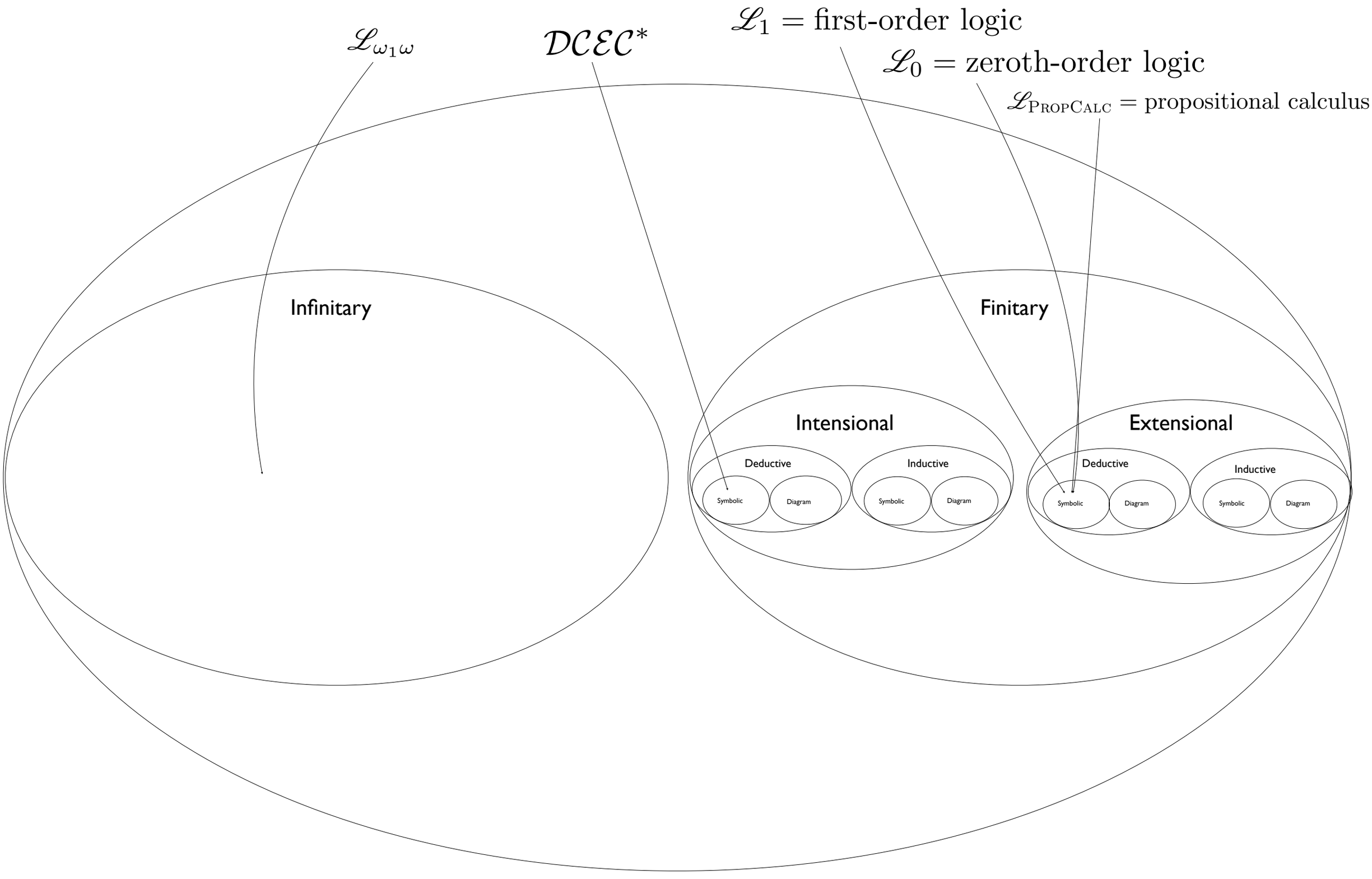
Go: AlphaGo

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

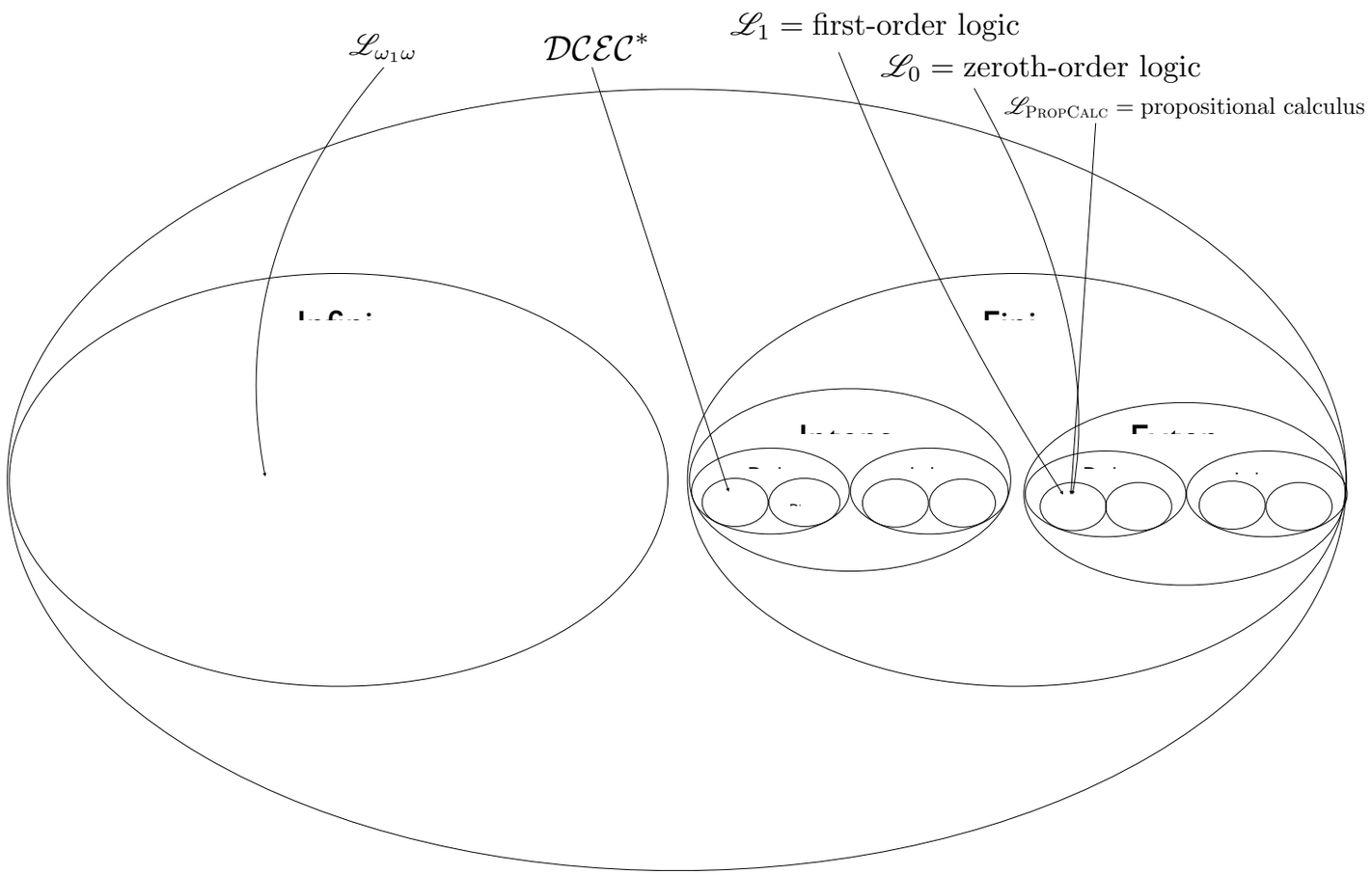
But what are the three things, in the triad, exactly?

Logic …

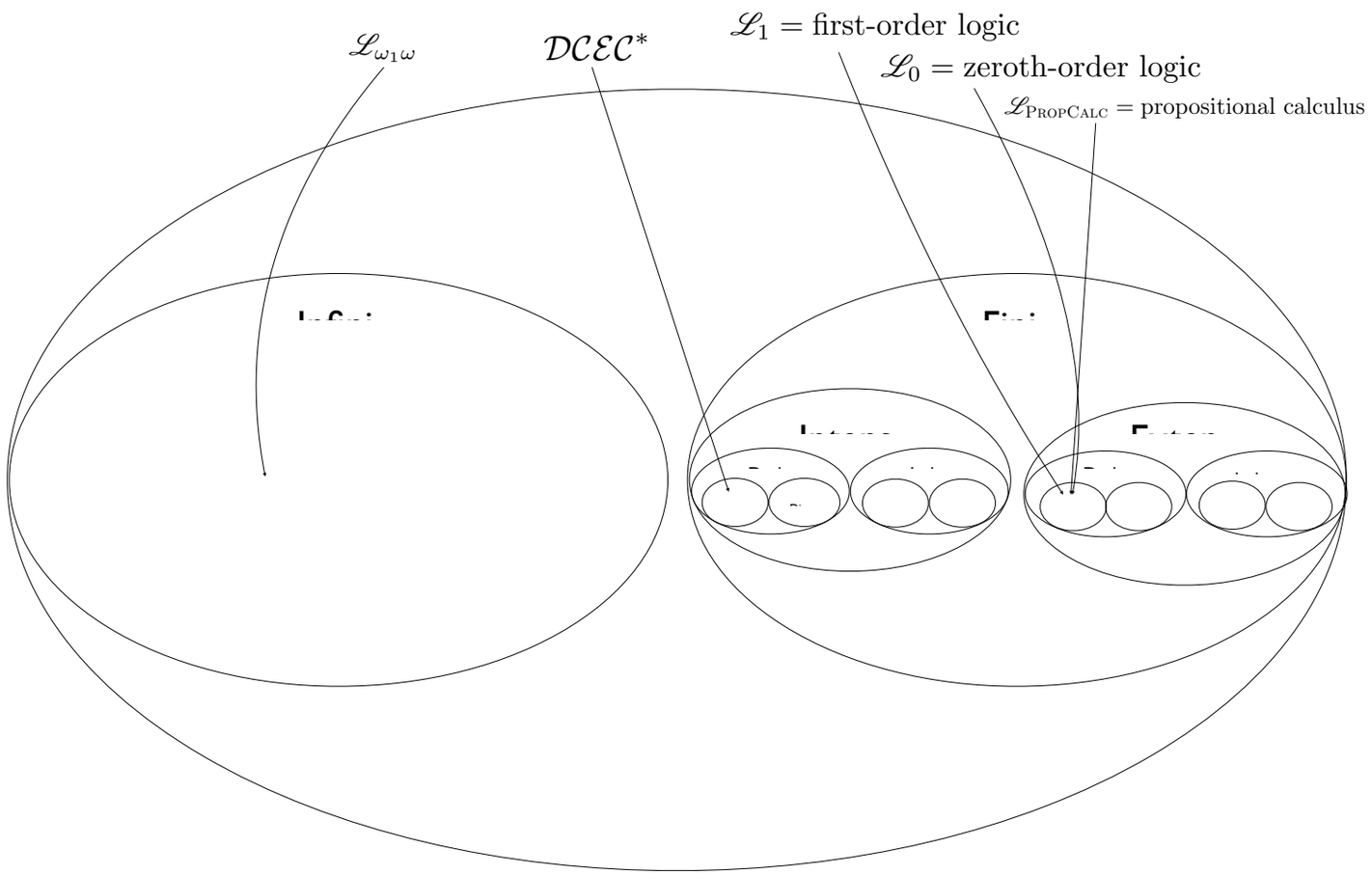
The Universe of Logics



The Universe of Logics

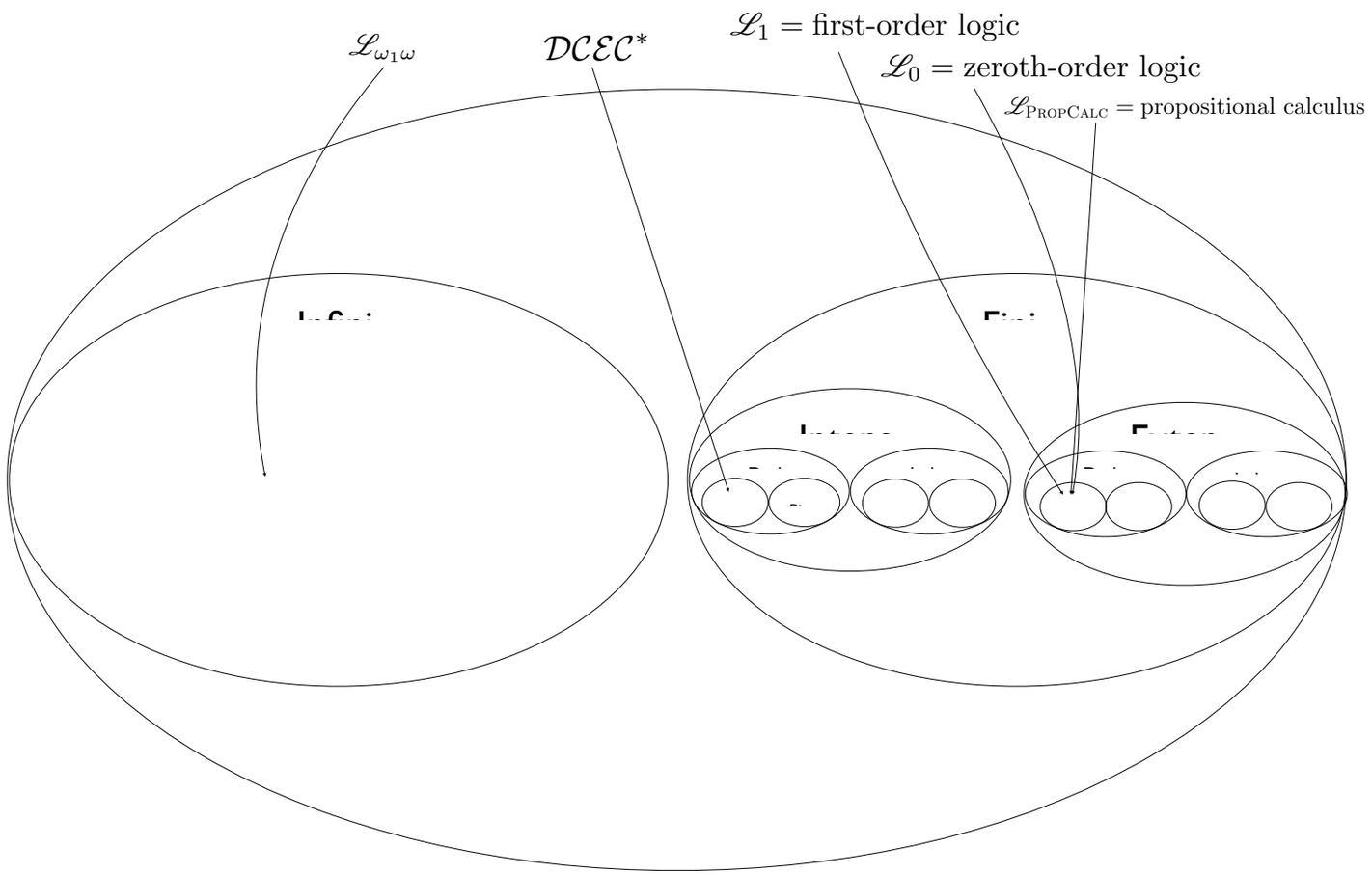


The Universe of Logics



$$\mathscr{L} := \langle L, I, S \rangle$$

The Universe of Logics



$$\mathscr{L} := \langle L, I, S \rangle$$

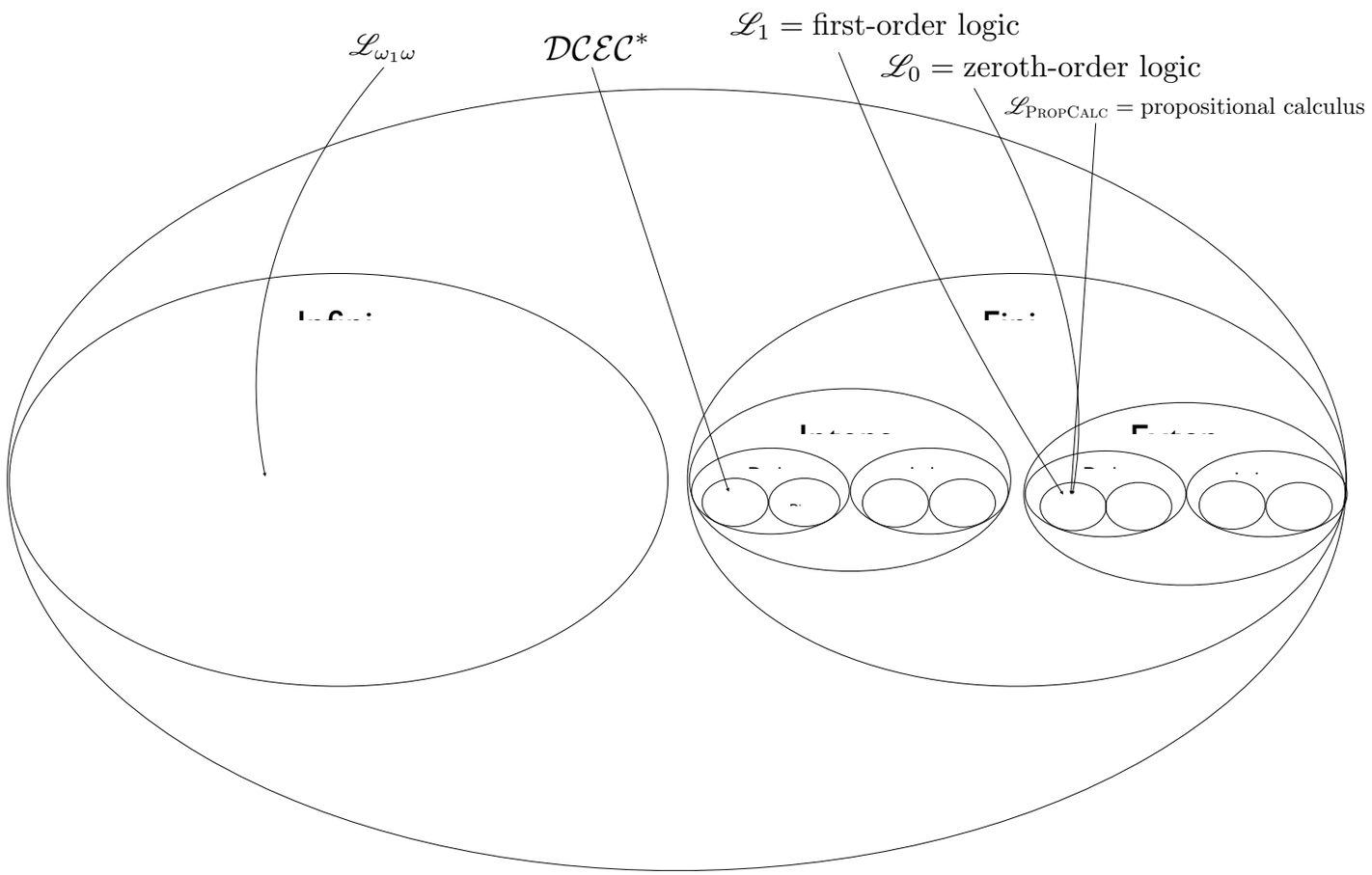
the logic

formal language

inference schemata

semantics

The Universe of Logics



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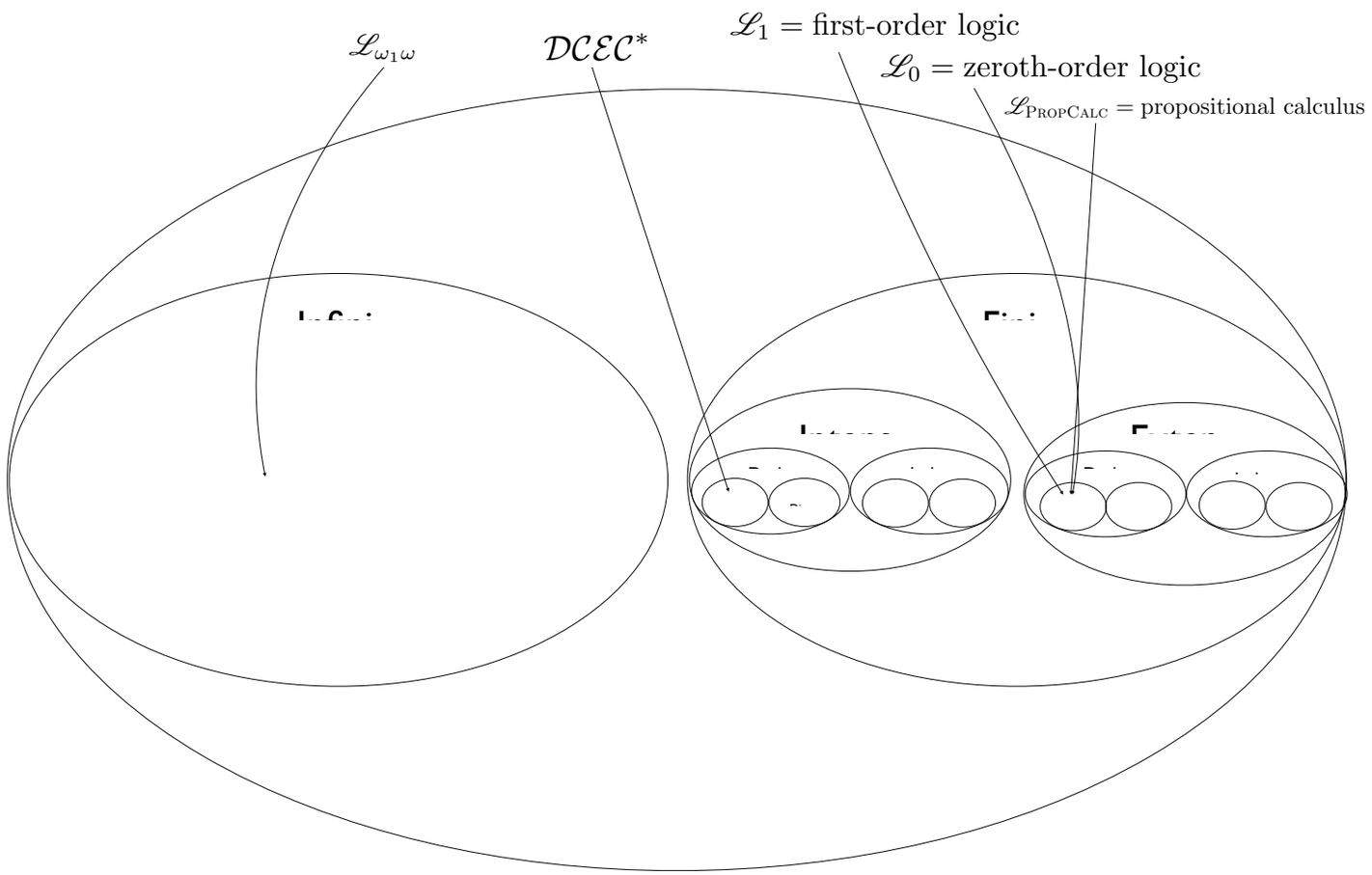

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the logic

formal language

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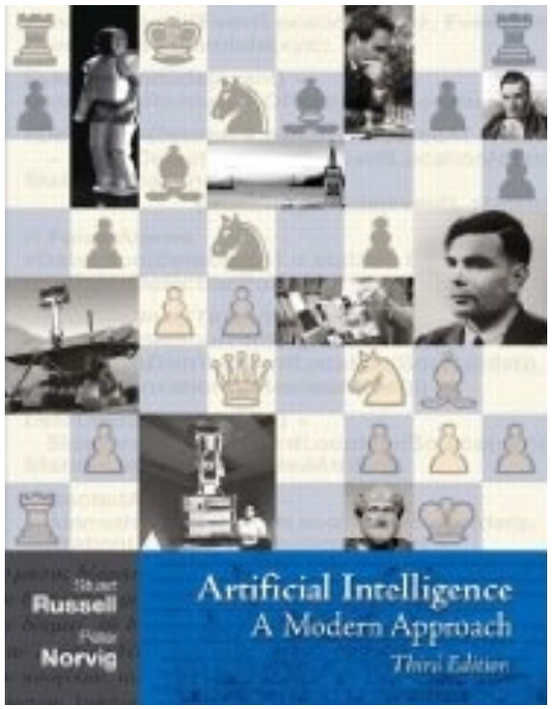
semantics

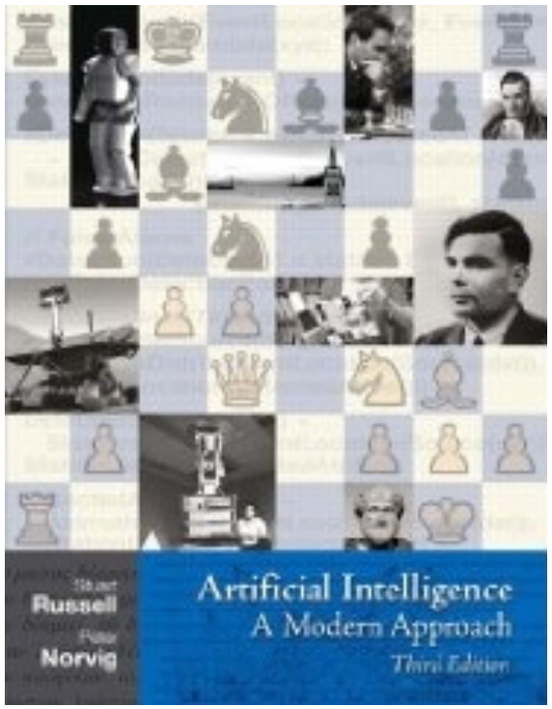
AI …

AI:

AI:


Stuart
Russell
Peter
Norvig
Artificial Intelligence
A Modern Approach
Third Edition

AI:



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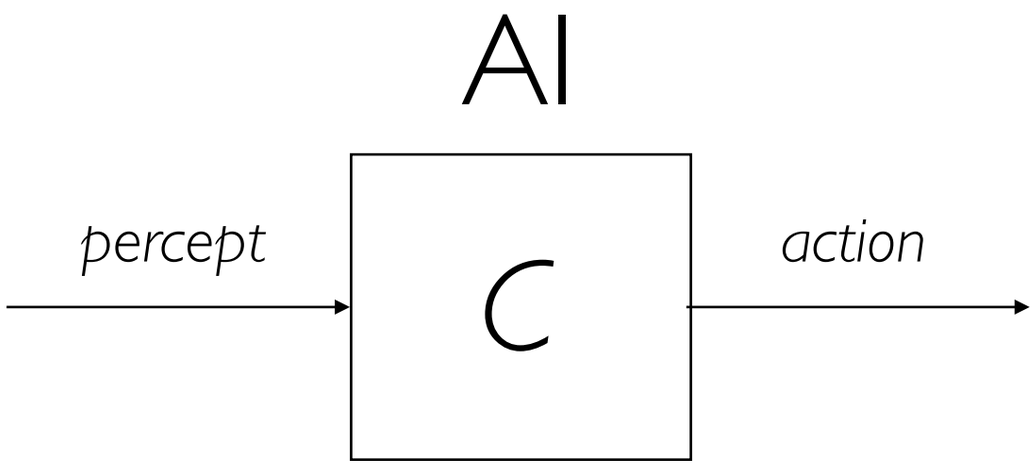
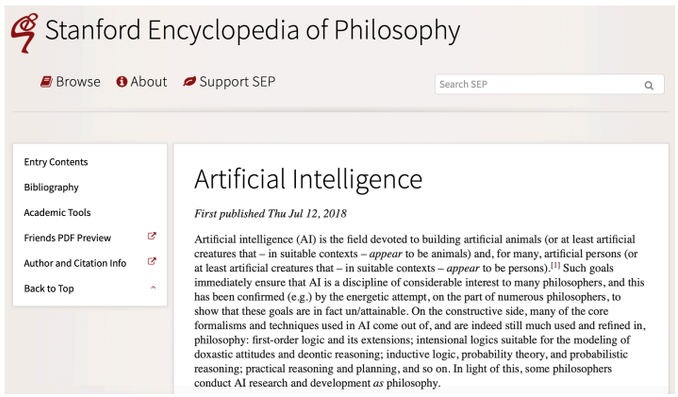
Artificial Intelligence

First published Thu Jul 12, 2018

Artificial intelligence (AI) is the field devoted to building artificial animals (or at least artificial creatures that – in suitable contexts – *appear* to be animals) and, for many, artificial persons (or at least artificial creatures that – in suitable contexts – *appear* to be persons).[1] Such goals immediately ensure that AI is a discipline of considerable interest to many philosophers, and this has been confirmed (e.g.) by the energetic attempt, on the part of numerous philosophers, to show that these goals are in fact un/attainable. On the constructive side, many of the core formalisms and techniques used in AI come out of, and are indeed still much used and refined in, philosophy: first-order logic and its extensions; intensional logics suitable for the modeling of doxastic attitudes and deontic reasoning; inductive logic, probability theory, and probabilistic reasoning; practical reasoning and planning, and so on. In light of this, some philosophers conduct AI research and development *as* philosophy.

AI:

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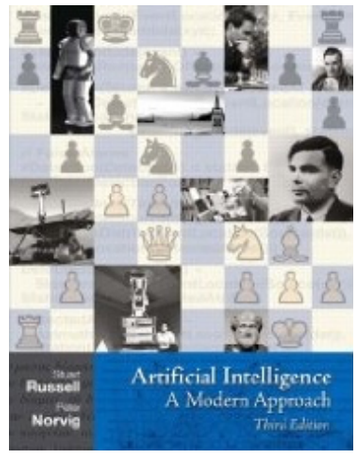
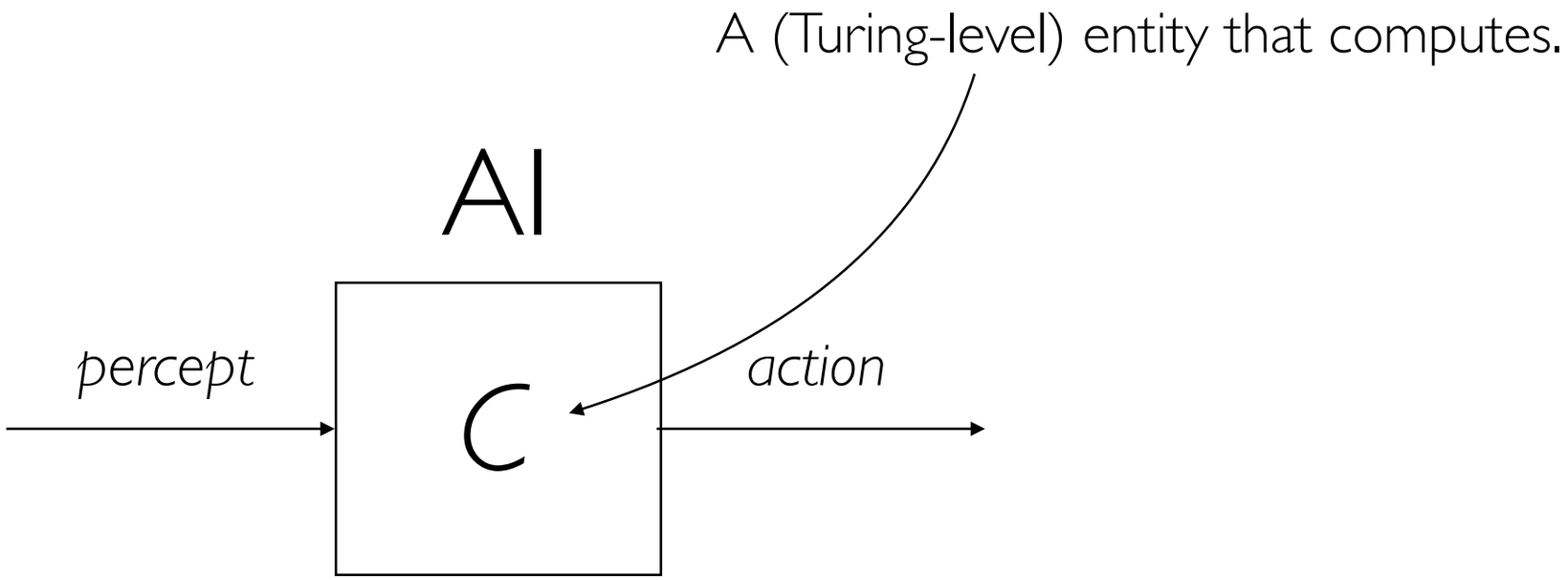
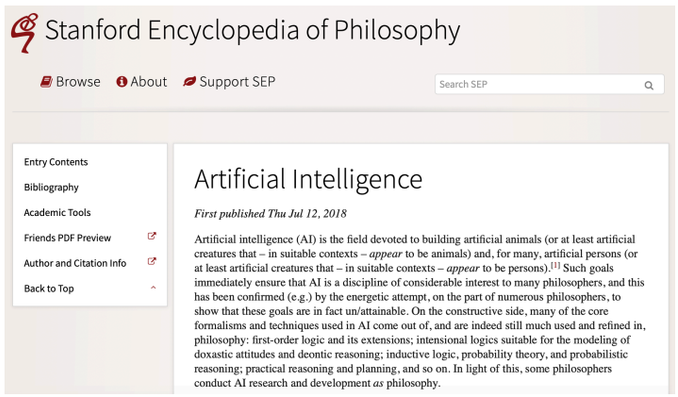


AI:

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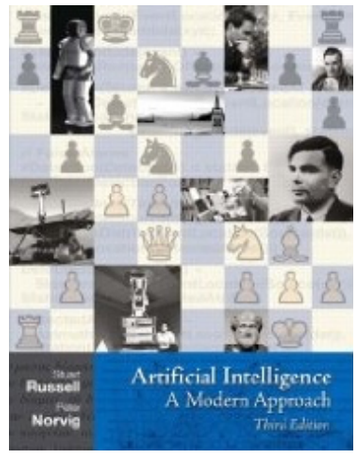
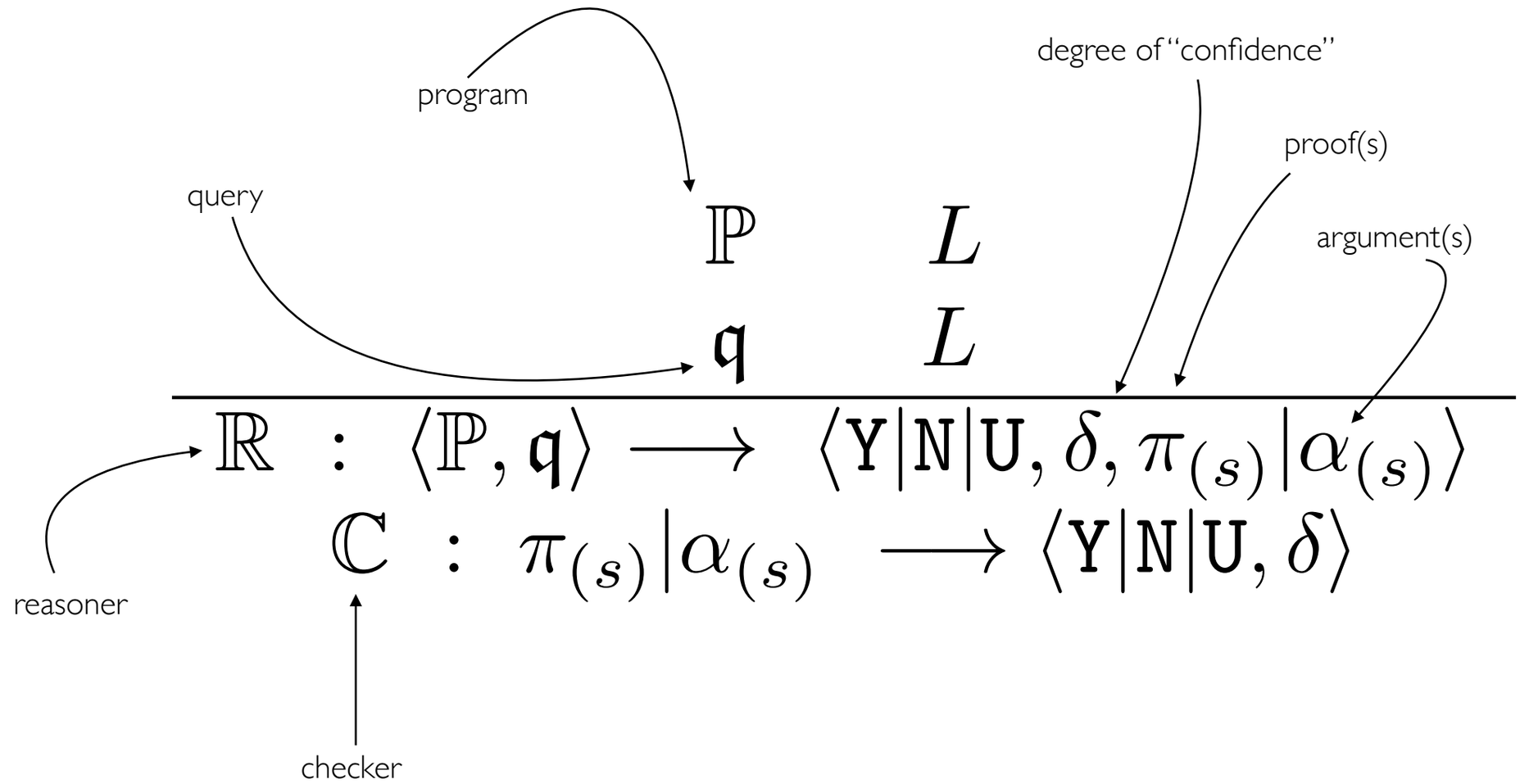


(Pure General) Logic Programming …

$$\mathcal{L} := \langle L, \mathcal{I} \rangle$$

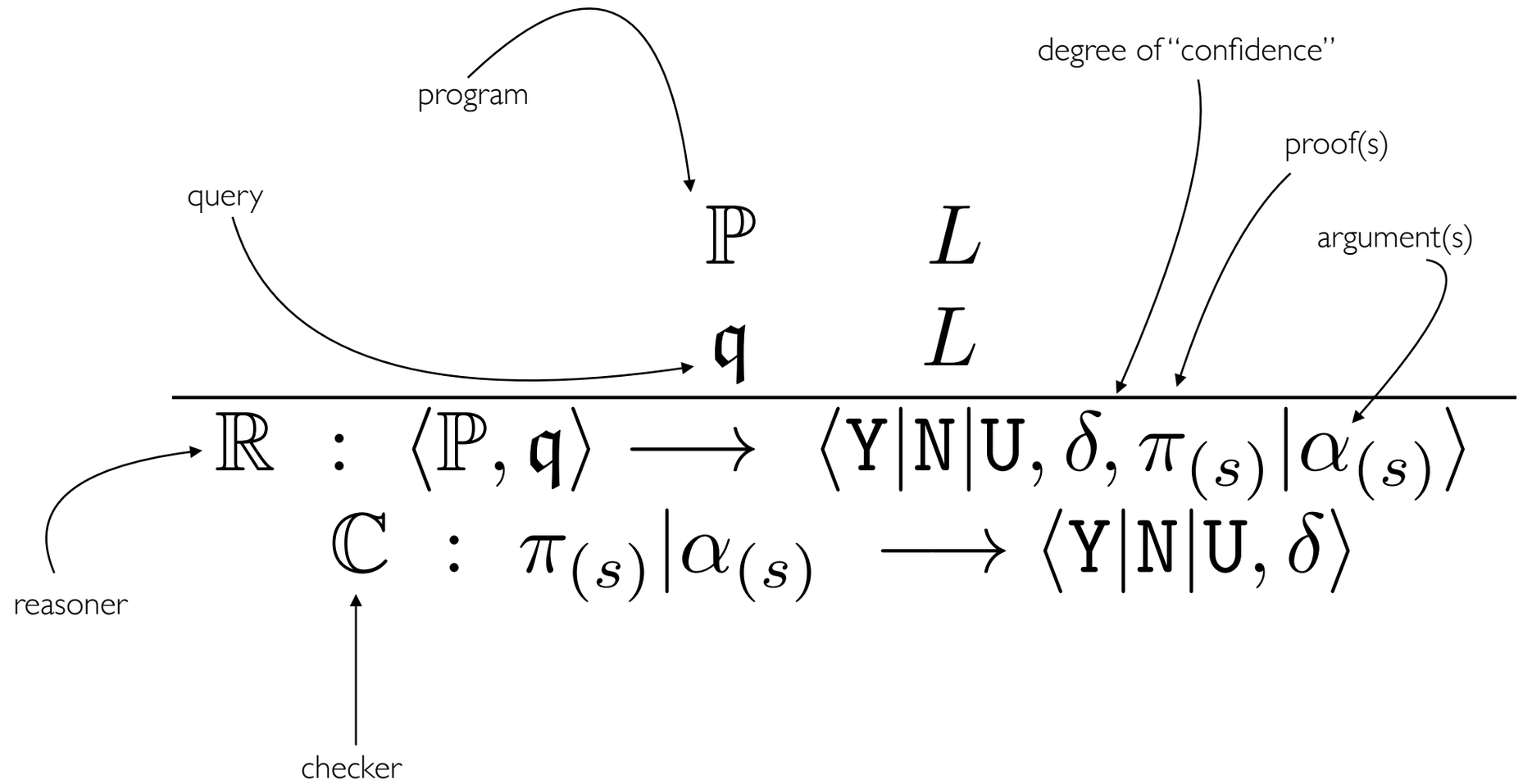
$$\frac{\begin{array}{cc} \mathbb{P} & L \\ \mathfrak{q} & L \end{array}}{\begin{array}{c} \mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle \\ \mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle \end{array}}$$

$$\mathcal{L} := \langle L, \mathcal{I} \rangle$$



For just "logic programming," and a vintage approach that goes back to circa 1970, restrict this to a FOL or a fragment thereof, and use resolution as the only inference schema.

$$\mathcal{L} := \langle L, \mathcal{I} \rangle$$



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$$\mathcal{L} := \langle L, \mathcal{I} \rangle$$

program

query

degree of "confidence"

proof(s)

argument(s)

$$\frac{\mathbb{P} \quad L \qquad \mathfrak{q} \quad L}{\mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle}$$

$$\mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle$$

reasoner

checker

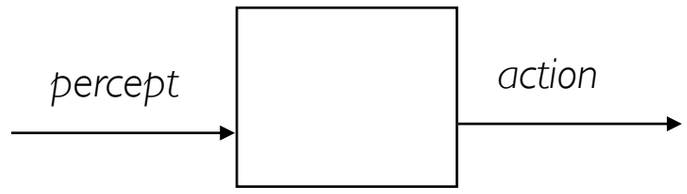
Resurrection of The Triad

The Triad Resurrected & Rebuilt, & Better

Logic

$\mathcal{L}$

AI



$$\mathcal{L} \coloneqq \langle L, \mathcal{I} \rangle \qquad \frac{\begin{array}{cc} \mathbb{P} & L \\ \mathfrak{q} & L \end{array}}{\begin{array}{c} \mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle \\ \mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle \end{array}}$$

Pure General Logic Programming

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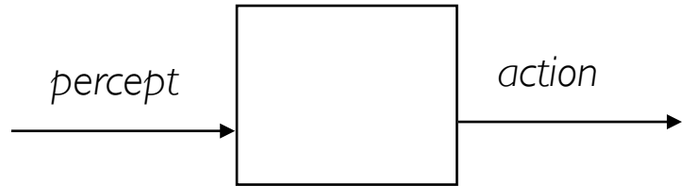
Logic

$\mathcal{L}$

AI



$$\boldsymbol{\mathcal{L}} \coloneqq \langle L, \mathcal{I} \rangle \qquad \frac{\begin{array}{cc} \mathbb{P} & L \\ \mathfrak{q} & L \end{array}}{\begin{array}{c} \mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle \\ \mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle \end{array}}$$

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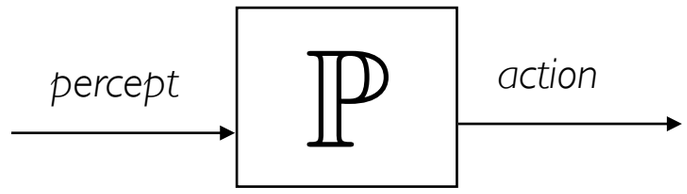

$$\boldsymbol{\mathcal{L}} := \langle L, \mathcal{I} \rangle \qquad \frac{\begin{array}{cc} \mathbb{P} & L \\ \mathfrak{q} & L \end{array}}{\begin{array}{c} \mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle \\ \mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle \end{array}}$$

Pure General Logic Programming