Introducing (= Part 1) ... Pure General Logic Programming (PGLP), in HyperSlate®:HyperLog™

Selmer Bringsjord

Rensselaer AI & Reasoning (RAIR) Lab
Department of Cognitive Science
Department of Computer Science
Lally School of Management & Technology
Rensselaer Polytechnic Institute (RPI)
Troy, New York 12180 USA

IFLAI1
2/7/2022

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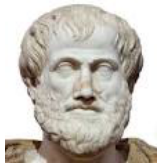
Entscheidungsproblem

"Universal Computational Logic"

Logic Theorist
(birth of modern logicist AI)

350 BC | 300 BC | 1666 | 1854 | 1956 | 2020 | 2021

Euclid



Organon

Leibniz

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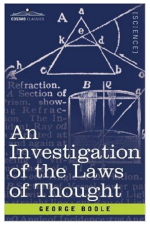

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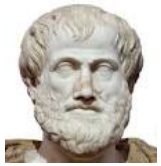

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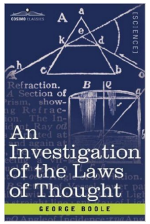

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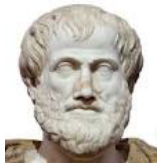

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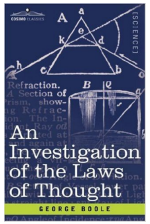

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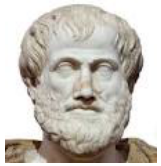

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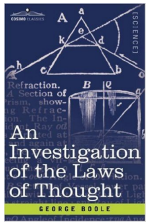

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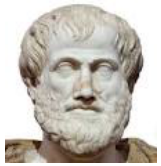

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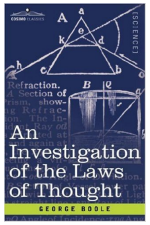

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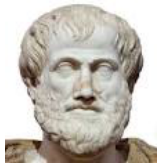

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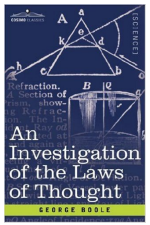

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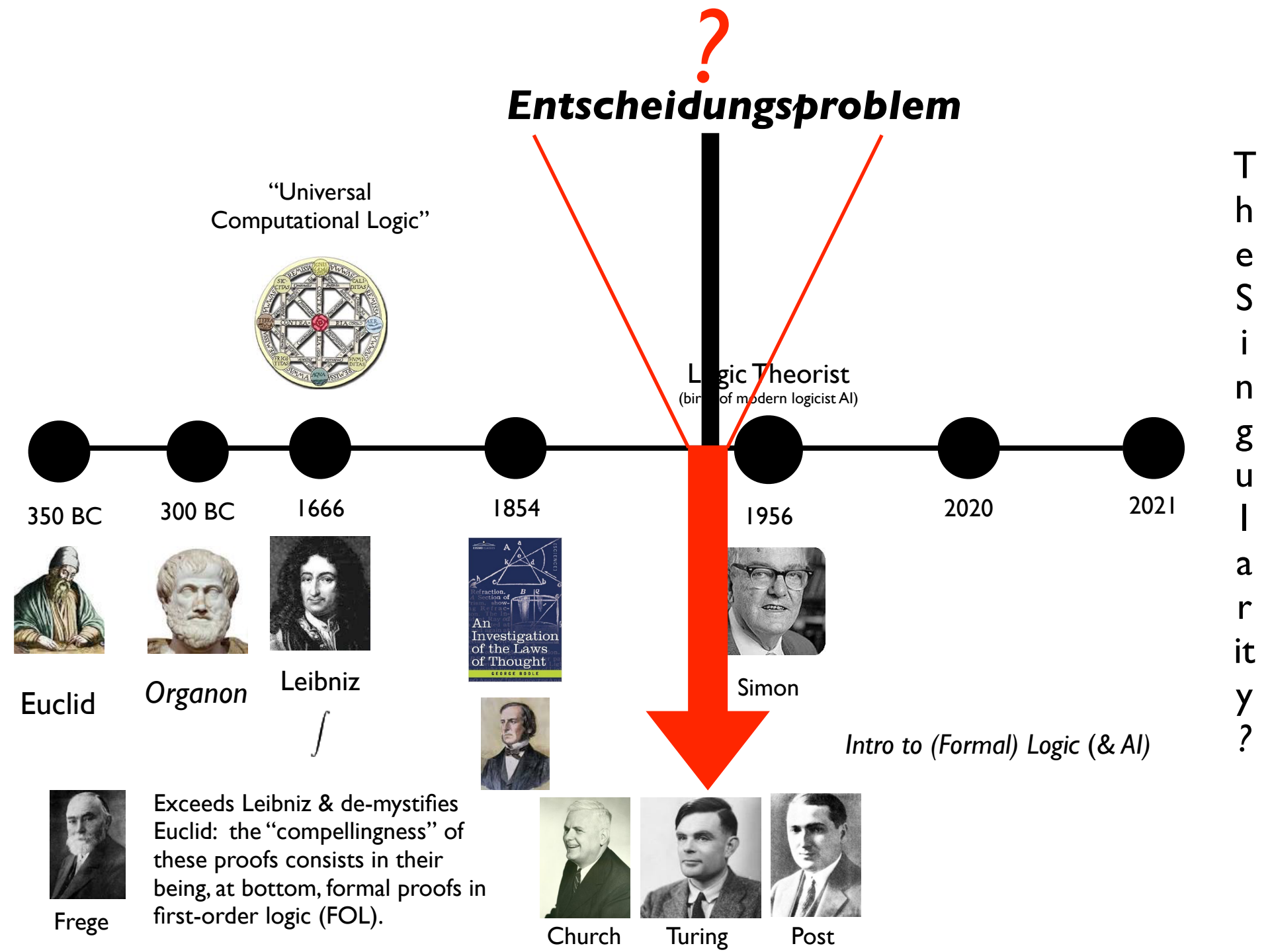
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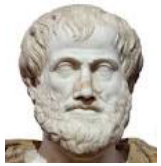

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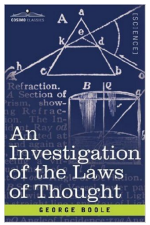

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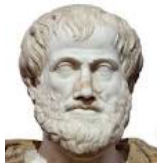

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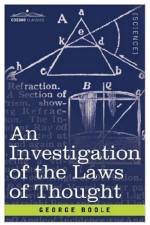

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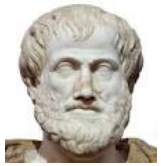

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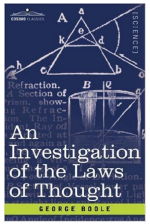

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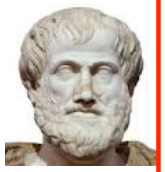

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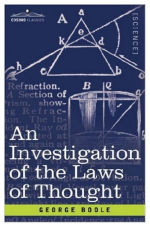

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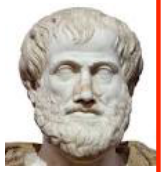

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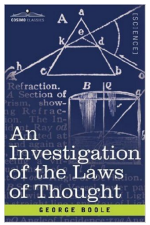

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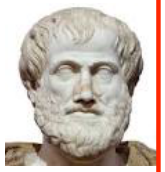

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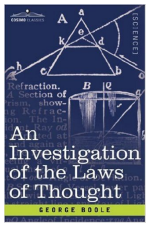

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Programming Languages

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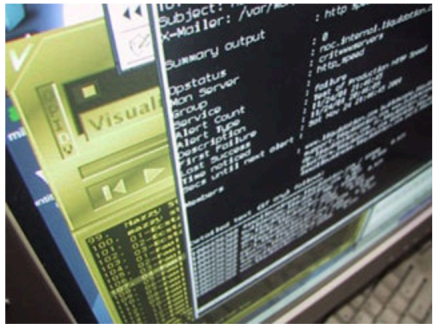

Programming computer screen. (Photo courtesy of openphoto.net.)

Instructor(s)
Prof. Michael Ernst

MIT Course Number
6.821

As Taught In
Fall 2002

Level
Graduate

CITE THIS COURSE

Course Features

› Assignments: programming (no examples) › Exams (no solutions)

Course Description

6.821 teaches the principles of functional, imperative, and logic programming languages. Topics covered include: meta-circular interpreters, semantics (operational and denotational), type systems (polymorphism, inference, and abstract types), object oriented programming, modules, and multiprocessing. The course involves substantial programming assignments and problem sets as well as a significant amount of reading. The course uses the Scheme+ programming language for all of its assignments.

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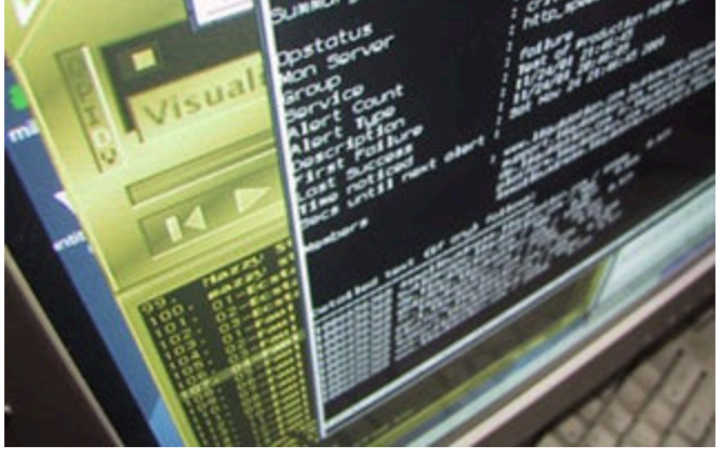

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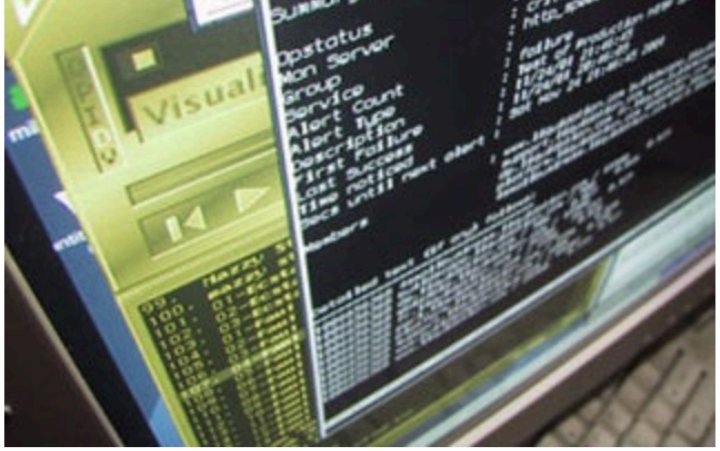

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Syllabus
Programming Languages CSCI-4430

Meetings: Webex, TF 2:30-4:20pm
Website: http://www.cs.rpi.edu/~milanova/csci4430

I. Brief Course Description

This course is a study of important concepts in programming languages. Topics include programming language syntax and semantics, types and parameter passing, and programming paradigms (logic-oriented, functional, von Neumann, object-oriented).

Prerequisite: Introduction to Algorithms (CSCI 2300) and Principles of Software (CSCI 2600)

Mailing list: proglang@cs.lists.rpi.edu. Email goes to Milanova, Kuzmin, and Hulbert. Use this list for administrative questions, including homework extension requests, quiz and exam makeup requests, extra time scheduling, and so on.

II. Learning Outcomes

The goal of this course is to teach students how to analyze programming languages. Students will become more productive programmers, will be able to learn new programming languages with ease, and will be able to choose the most suitable programming language for a given problem.

Concretely, students who successfully complete the course should be able to 1) explain programming language syntax and semantics, 2) implement a front-end for a programming language, 3) explain the concepts of scoping, data abstraction, types, control abstraction, and parameter passing, which are essential building blocks of programming languages, and 4) demonstrate competence across a spectrum of programming language paradigms by writing programs in Prolog, Scheme, and Haskell.

III. Required Textbook

Programming Language Pragmatics, Fourth Edition, by Michael Scott, Morgan Kaufmann, 2015.

IV. Class Work and Policies

Quizzes

There are 9 quizzes that should be completed and submitted individually. We will drop the lowest quiz grade and only 8 will count towards the final grade. Quizzes will be administered on Submitty at the beginning of our regularly scheduled class time. We will be offering alternative times for quizzes and exams. If you are unable to attend during regularly scheduled class hours, you must request an alternative time. Email course staff at proglang@cs.lists.rpi.edu by September 10 outlining the reasons why you will be attending at an alternative time (e.g., you reside in a different time zone). We will assign an alternative time and you will be taking the quizzes during this time slot on the date of the quiz. Note that once assigned, you cannot change the quiz time slot.

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Church, 1920's & 30's:
"Aha! The lambda calculus!

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Two Logicist Branches; B2:

The AI Branch: Automated Reasoning

Two Logicist Branches; B2:

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Leibniz

Two Logicist Branches; B2:

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Simon & Newell @
Dawn of Modern AI: LT & GPS

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Prolog?

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PGLP

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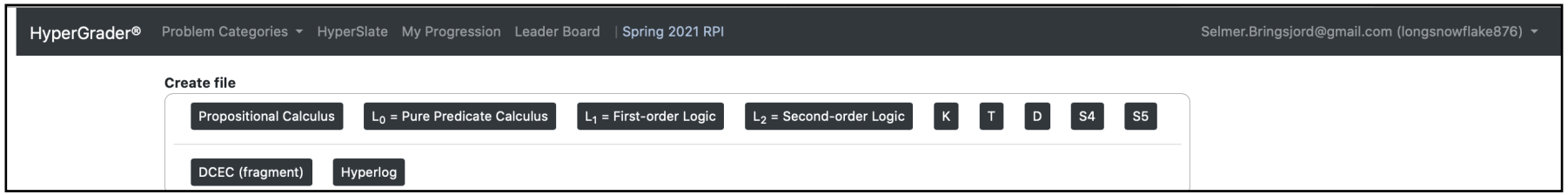

PGLP

HyperSlate® : HyperLog

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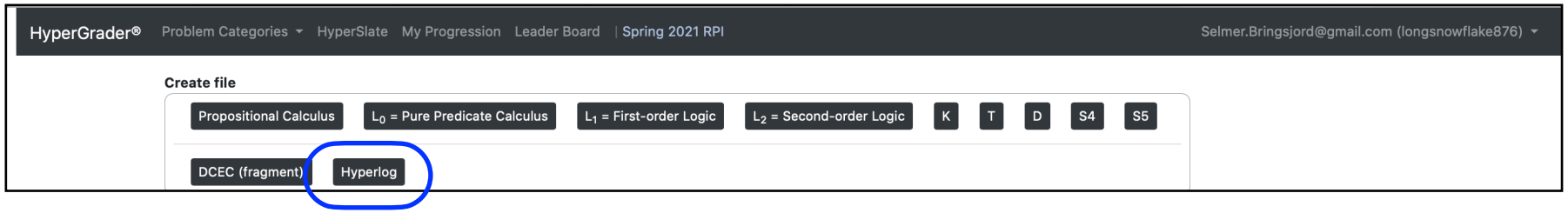
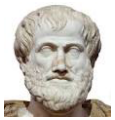


PGLP

HyperSlate® : HyperLog

HyperLog: Historico-logico-programming Landscape



First "logic programs"
300 BC

Liebniiz
Dies 1716

Frege
1893

Schöenfinkel
1893

Combinatory Logic

simple type theory

Church

λ-calculus

Logic Theorist
(birth of modern logicist AI)

Simon

1956

Turing

Lisp

Athena

ML

Scheme

CL

Lisp Family

Clojure

Prolog

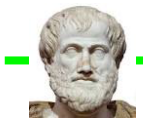
HyperLog

Fortran

Java

Smalltalk

HyperLog: Historico-logico-programming Landscape



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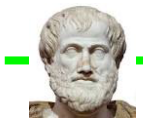

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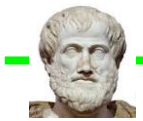

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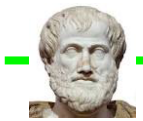

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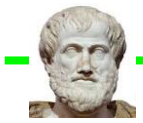

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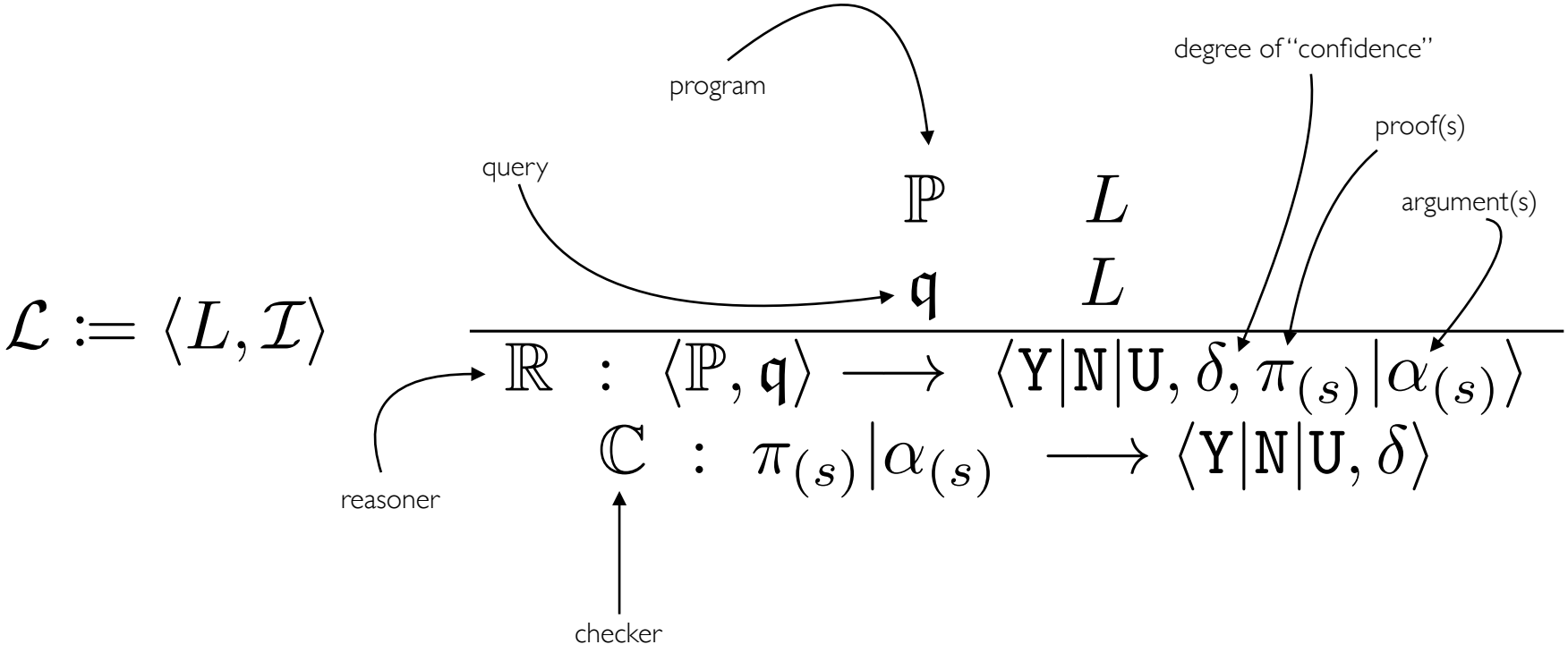
Single-Slide Encapsulation …

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

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


$\mathcal{L} := \langle L, \mathcal{I} \rangle$
program
query
degree of "confidence"
proof(s)
argument(s)
$\mathbb{P}$ L
$\mathfrak{q}$ 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

A Hard Question …

Easy Question

Easy Question

What is pure procedural programming?

Another Easy Question

Another Easy Question

What is pure functional programming?

A *Hard* Question

A *Hard* Question

What is pure *logic* programming?

A *Hard* Question

What is pure *logic* programming?

A *Hard* Question

What is pure *logic* programming?

A: …

B: …

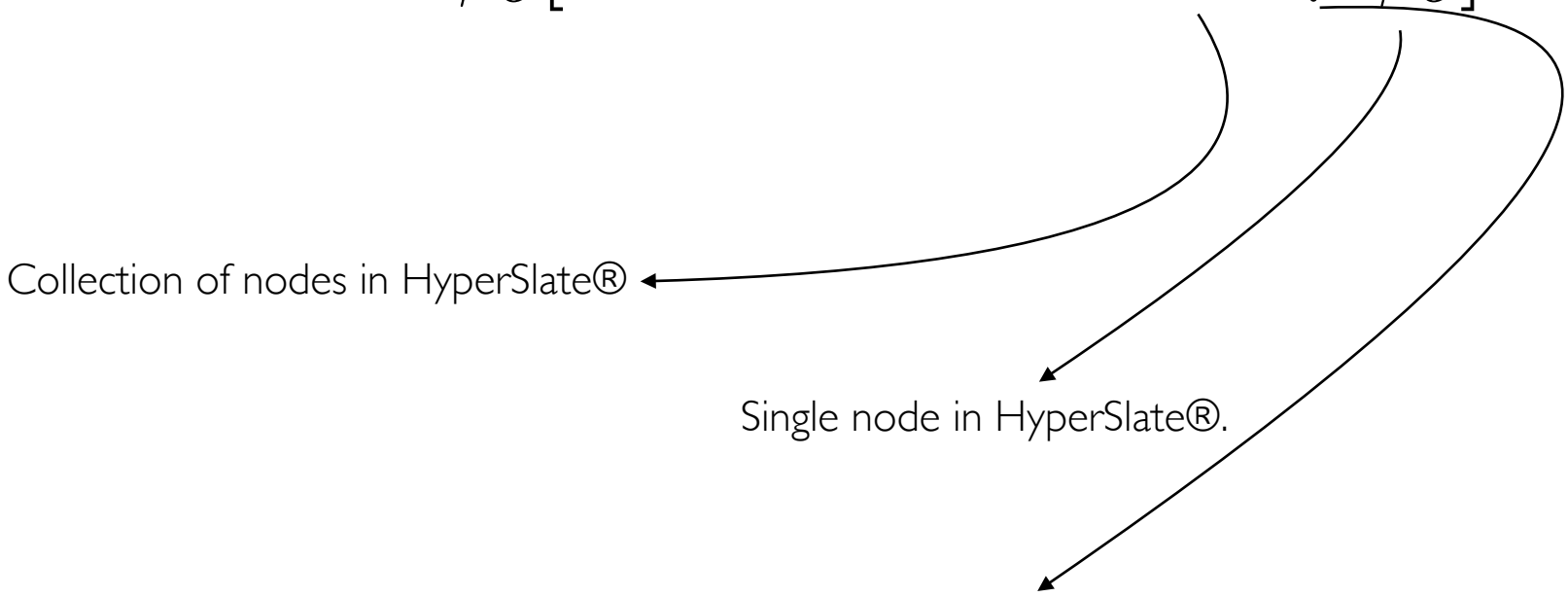
C: …

…

Naveen: "Using automated theorem provers; in fact, you can just use HyperSlate.®"

“Direct” Programming in HyperSlate®

$$\forall m \forall i \forall o \exists \Phi \exists \phi_o [m : i \longrightarrow o \Leftrightarrow \Phi \vdash_? \phi_o]$$



Ingredients for Making a PGLP Program …

On the Anatomy of a PGLP Program

On the Anatomy of a PGLP Program

Linguistics

$\vdots$ $\vdots$ $\vdots$

L_2^{μ} meta-level$_2$ language $(\{\phi\} \vdash \psi \wedge \{\psi\} \vdash \delta) \vdash_{\mu_2} \{\phi\} \vdash \delta$

L_1^{μ} meta-level$_1$ language $\exists x\ \mathrm{rank}(\phi) = x \quad \{\phi\} \vdash \psi \quad \mathfrak{U} \models \phi$

L object-level language $\phi \quad \psi \quad \delta$

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Inference

A collection of inference schemata. (For economy, see coming Example 1.)

On the Anatomy of a PGLP Program

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Reasoning-semantic; wholly inferentialist (after all, what's the semantics of deduction over meta-level$_1$ formulae??).

On the Anatomy of a PGLP Program

Linguistics

$$\begin{array}{lll} \vdots & \vdots & \vdots \\ L_2^{\mu} & \text{meta-level}_2 \text{ language} & (\{\phi\} \vdash \psi \wedge \{\psi\} \vdash \delta) \vdash_{\mu_2} \{\phi\} \vdash \delta \\ L_1^{\mu} & \text{meta-level}_1 \text{ language} & \exists x \; \mathbf{rank}(\phi) = x \quad \{\phi\} \vdash \psi \quad \mathfrak{U} \models \phi \\ L & \text{object-level language} & \phi \quad \psi \quad \delta \end{array}$$

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Selection of language, inference schemata, plus formulae/meta-formulae $= \mathbb{P}_{\mathscr{L}}$

On the Anatomy of a PGLP Program

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$\mathscr{L}$

Selection of language, inference schemata, plus formulae/meta-formulae $= \mathbb{P}_{\mathscr{L}}$ + ShadowReasoner

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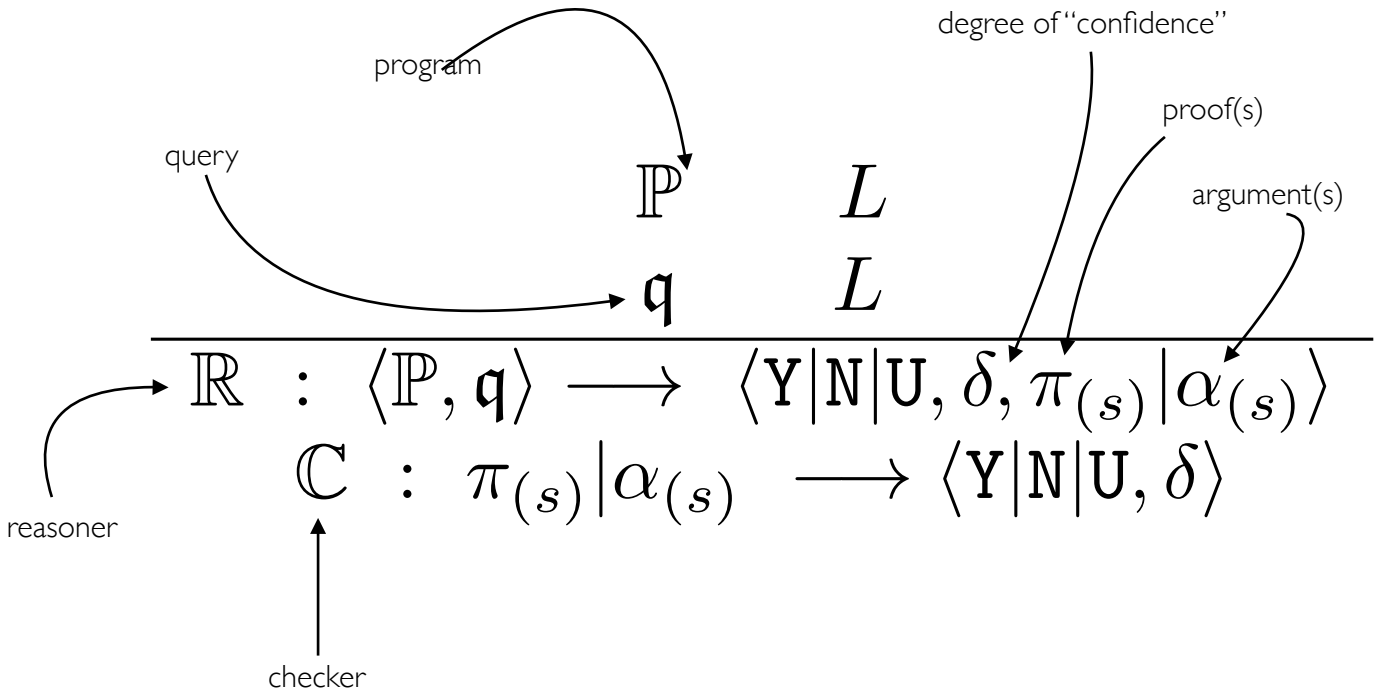

AI today …

AI today:

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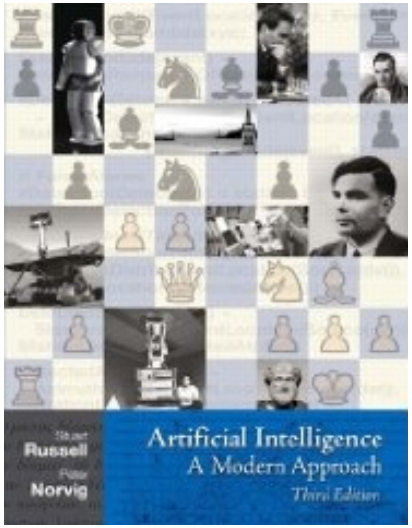
Russell
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A Modern Approach
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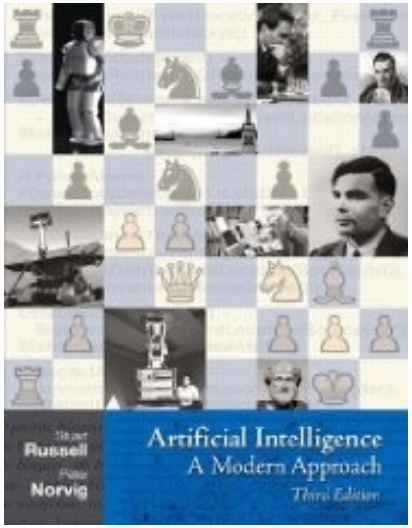

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Artificial Intelligence

First published Thu Jul 12, 2018

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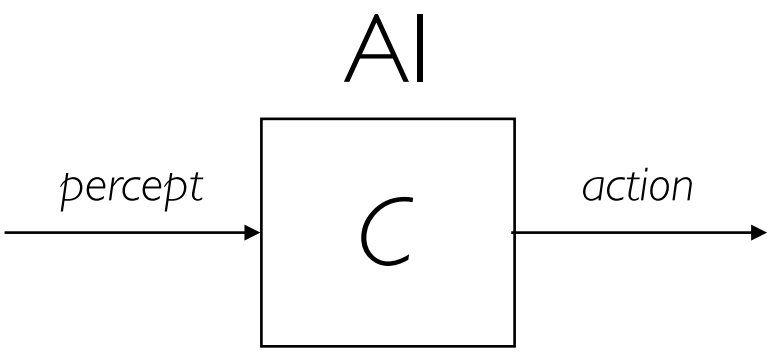
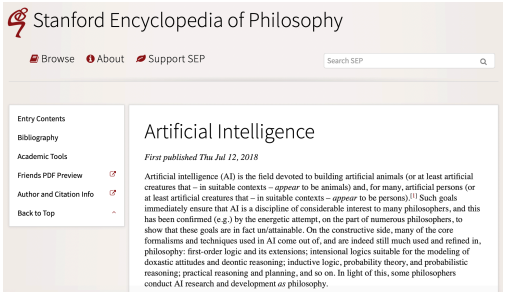
AI:


AI
percept
C
action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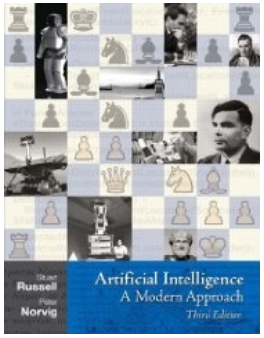
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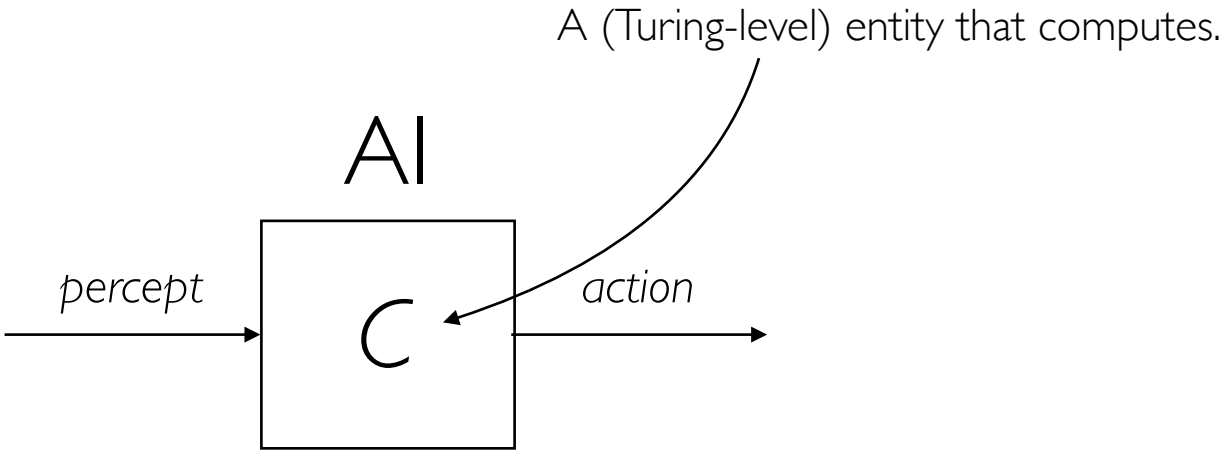

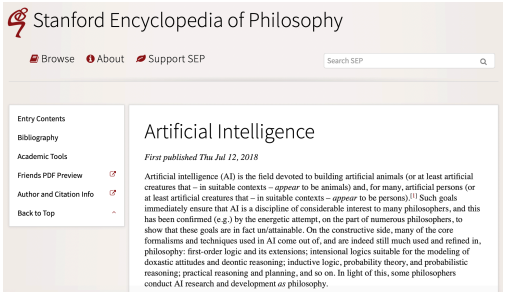
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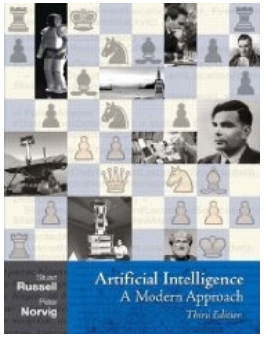
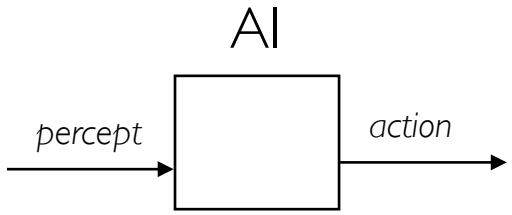


Resurrection of The Triad

The Triad Resurrected & Rebuilt, & Better

Logic

$\mathcal{L}$



$\mathcal{L} \coloneqq \langle L, \mathcal{I} \rangle$

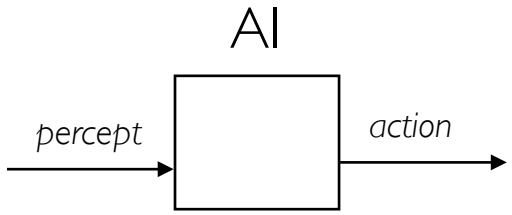
$$\frac{\begin{array}{cc} \mathbb{P} & L \\ \mathfrak{q} & L \end{array}}{\begin{array}{c} \mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle \\ \mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow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

Pure General Logic Programming

The Triad Resurrected & Rebuilt, & Better

Logic

$\mathcal{L}$



$\mathcal{L} \coloneqq \langle L, \mathcal{I} \rangle$

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

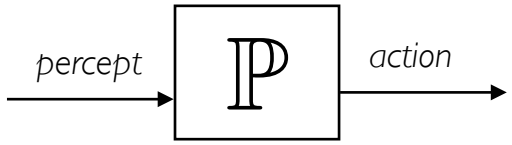
Pure General Logic Programming

The Triad Resurrected & Rebuilt, & Better

Logic

$\mathcal{L}$

AI



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Pure General Logic Programming

What's Part 2 about ? …

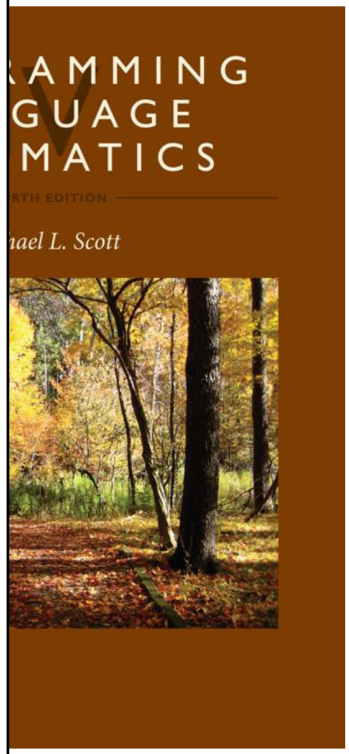
PROGRAMMING LANGUAGE PRAGMATICS

FOURTH EDITION

Michael L. Scott

MK
MORGAN KAUFMANN

Alternative Programming Models



As we noted in Chapter 1, programming languages are traditionally though imperfectly classified into various imperative and declarative families. We have had occasion in Parts I and II to mention issues of particular importance to each of the major families. Moreover much of what we have covered—syntax, semantics, naming, types, abstraction—applies uniformly to all. Still, our attention has focused mostly on mainstream imperative languages. In Part III we shift this focus.

Functional and logic languages are the principal nonimperative options. We consider them in Chapters 11 and 12, respectively. In each case we structure our discussion around representative languages: Scheme and OCaml for functional programming, Prolog for logic programming. In Chapter 11 we also cover eager and lazy evaluation, and first-class and higher-order functions. In Chapter 12 we cover issues that make fully automatic, general purpose logic programming difficult, and describe restrictions used in practice to keep the model tractable. Optional sections in both chapters consider mathe-

Models

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The remaining two chapters consider concurrent and scripting models, both of which are increasingly popular, and cut across the imperative/declarative divide. Concurrency is driven by the hardware parallelism of internetworked computers and by the coming explosion in multithreaded processors and chip-level multiprocessors. Scripting is driven by the growth of the World Wide Web and by an increasing emphasis on programmer productivity, which places rapid development and reusability above sheer run-time performance.

Chapter 13 begins with the fundamentals of concurrency, including communication and synchronization, thread creation syntax, and the implementation of threads. The remainder of the chapter is divided between *shared-memory* models, in which threads use explicit or implicit synchronization mechanisms to manage a common set of variables, and (on the companion site) *message-passing* models, in which threads interact only through explicit communication.

The first half of Chapter 14 surveys problem domains in which scripting plays a major role: shell (command) languages, text processing and report generation, mathematics and statistics, the "gluing" together of program components, extension mechanisms for complex applications, and client and server-side Web scripting. The second half considers some of the more important language innovations championed by scripting languages: flexible scoping and naming conventions, string and pattern manipulation (extended regular expressions), and high level data types.

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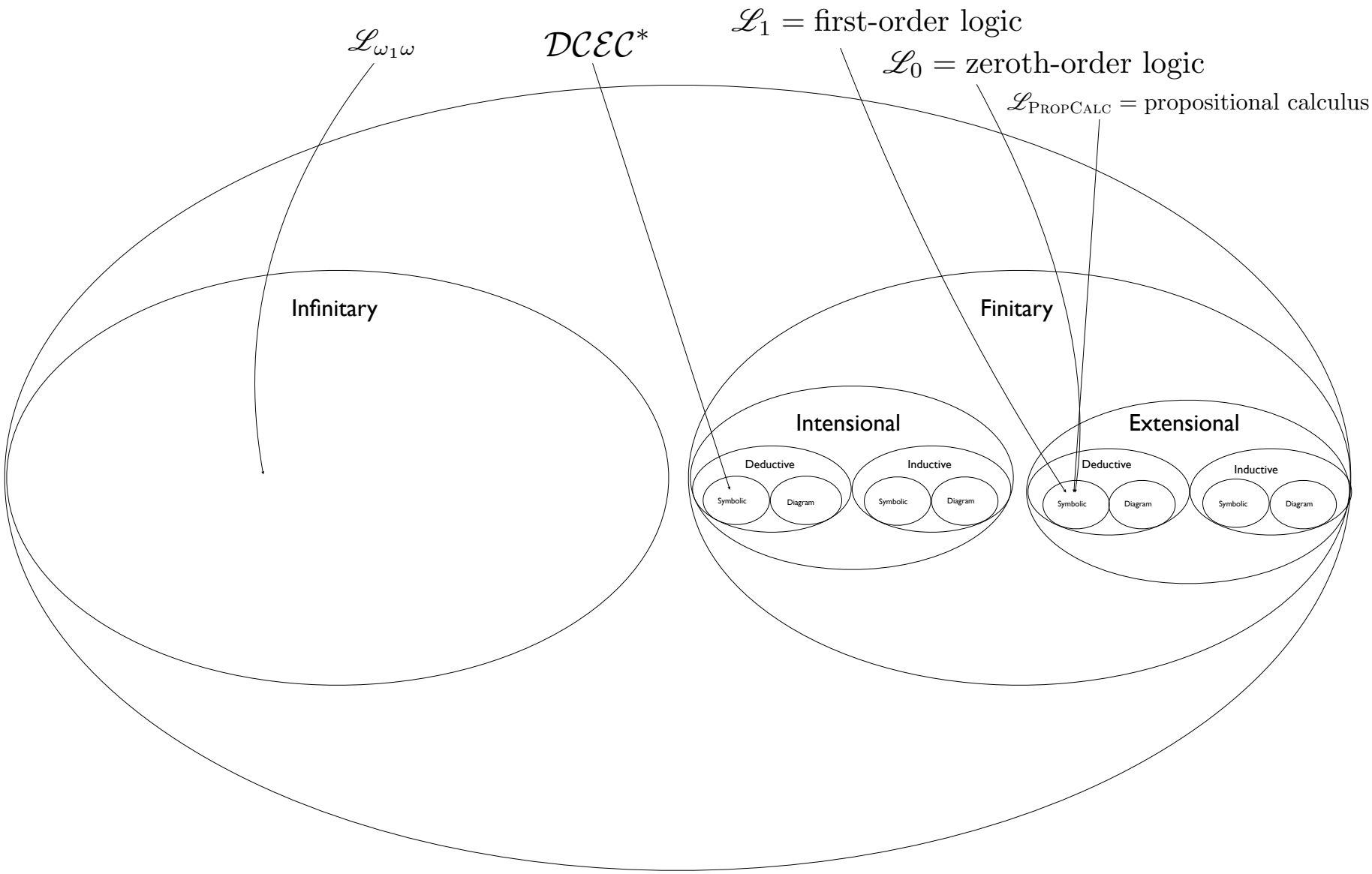
The Universe of Logics



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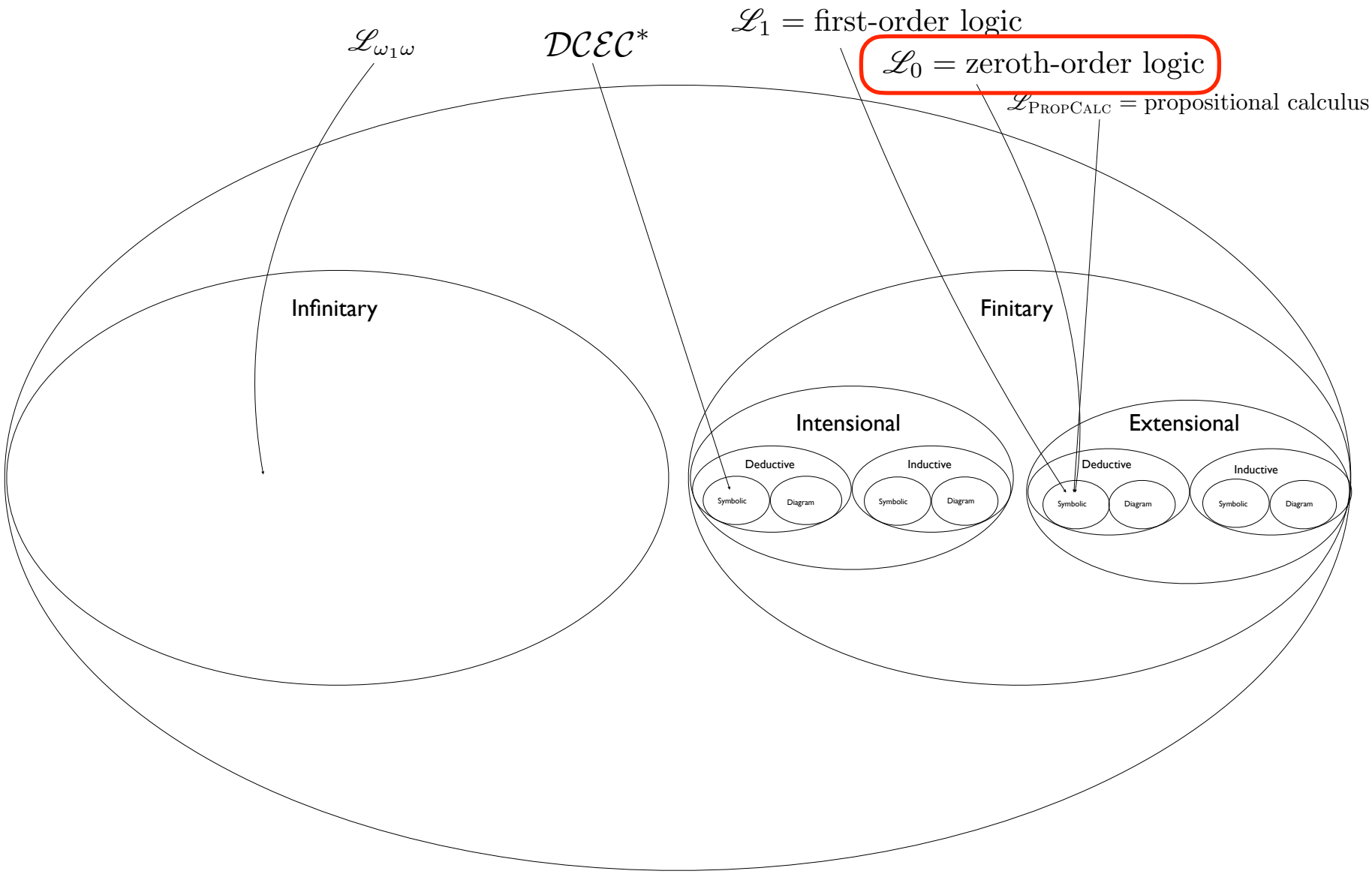

Starter Hyperlog®: Datalog

$\mathscr{L}_0 =$ zeroth-order logic

Datalog Syntax

(*program*) P	$:=$	$\phi_1 \wedge \phi_2 \wedge \ldots \wedge \phi_n$
(*horn-clause formula*) ϕ_i	$:=$	$\alpha_1 \wedge \ldots \wedge \alpha_m \rightarrow \alpha_j$
(*atomic formula*) α_i	$:=$	$R(t_1, t_2, \ldots t_o)$
(*terms*) t	$:=$	$x \mid c$

where x is a variable and c a constant

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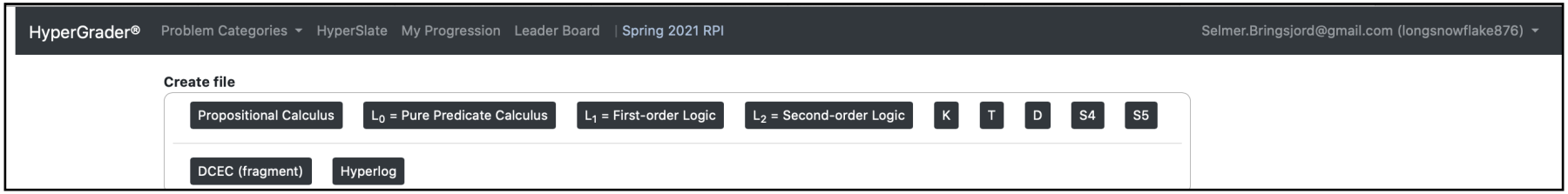

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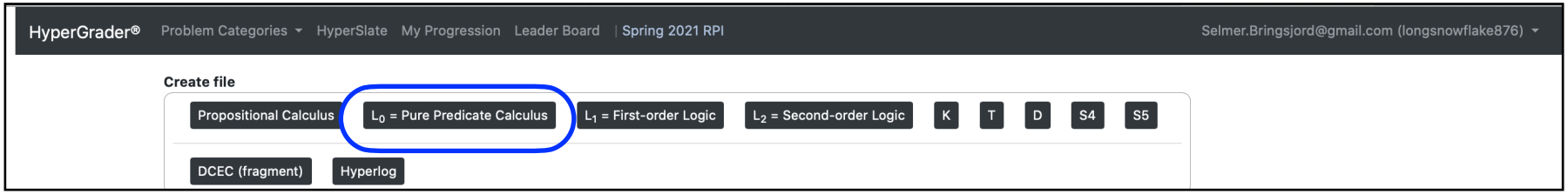

Starter HyperLog®: Datalog

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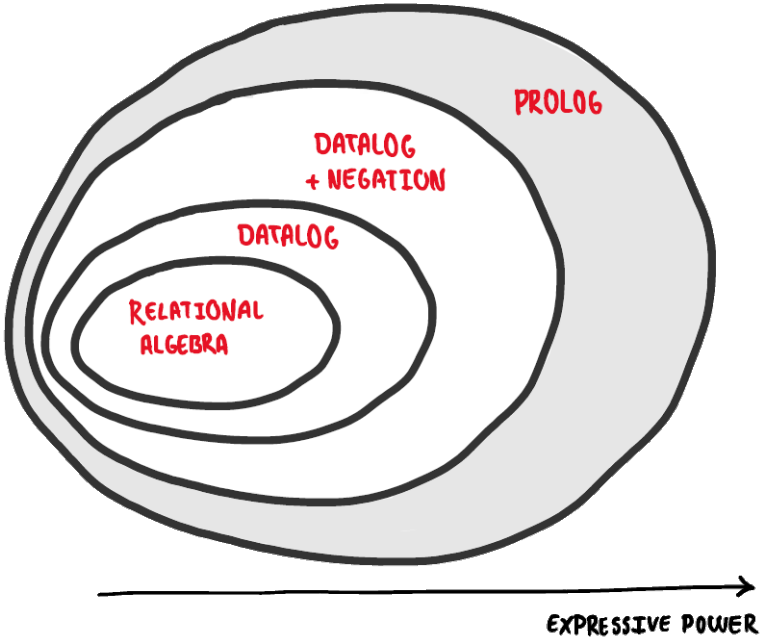

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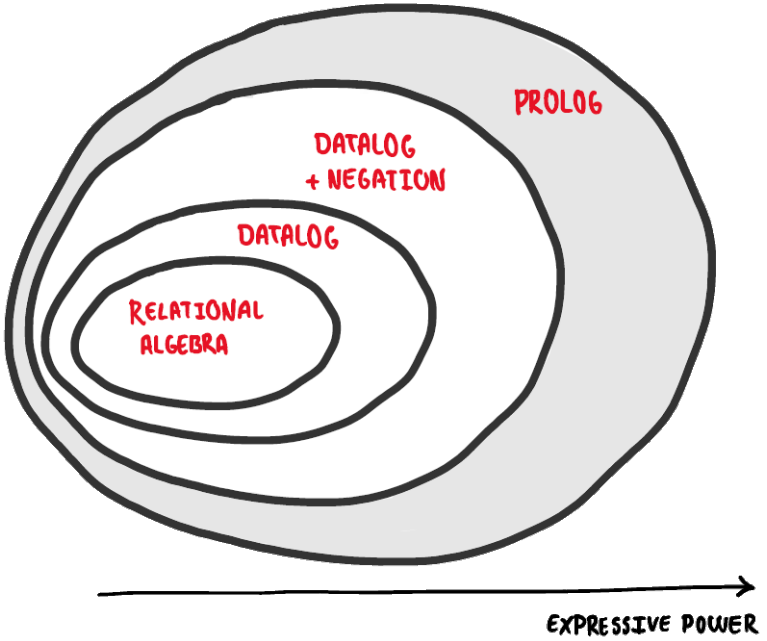

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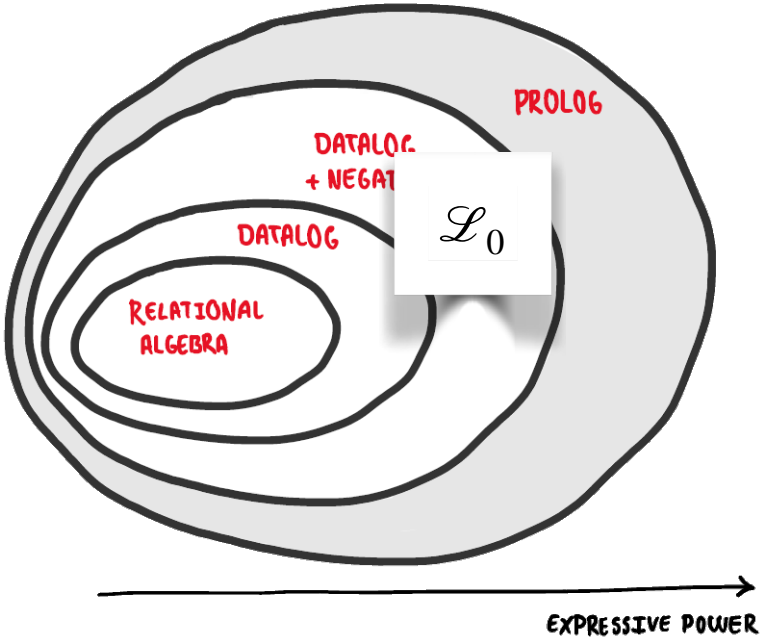

Starter HyperLog®: Datalog

$\mathscr{L}_1$

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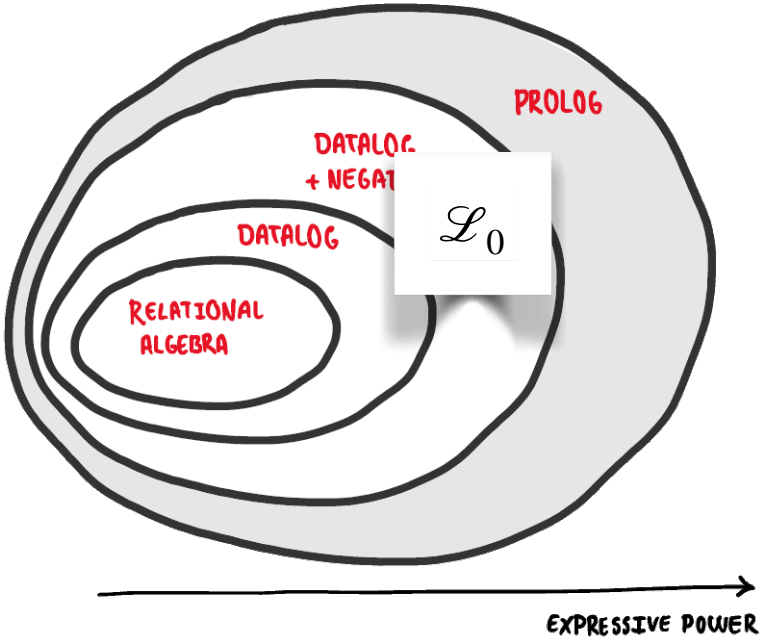

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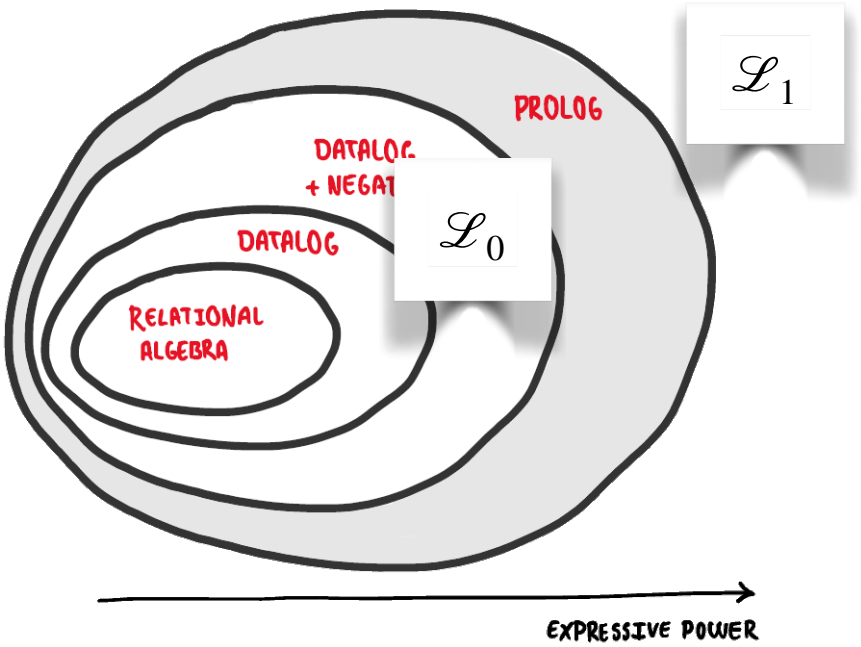

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