Properties for the People

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University of Pennsylvania

February 2026

The talk in 20 seconds:

Recent progress in property-based testing

and

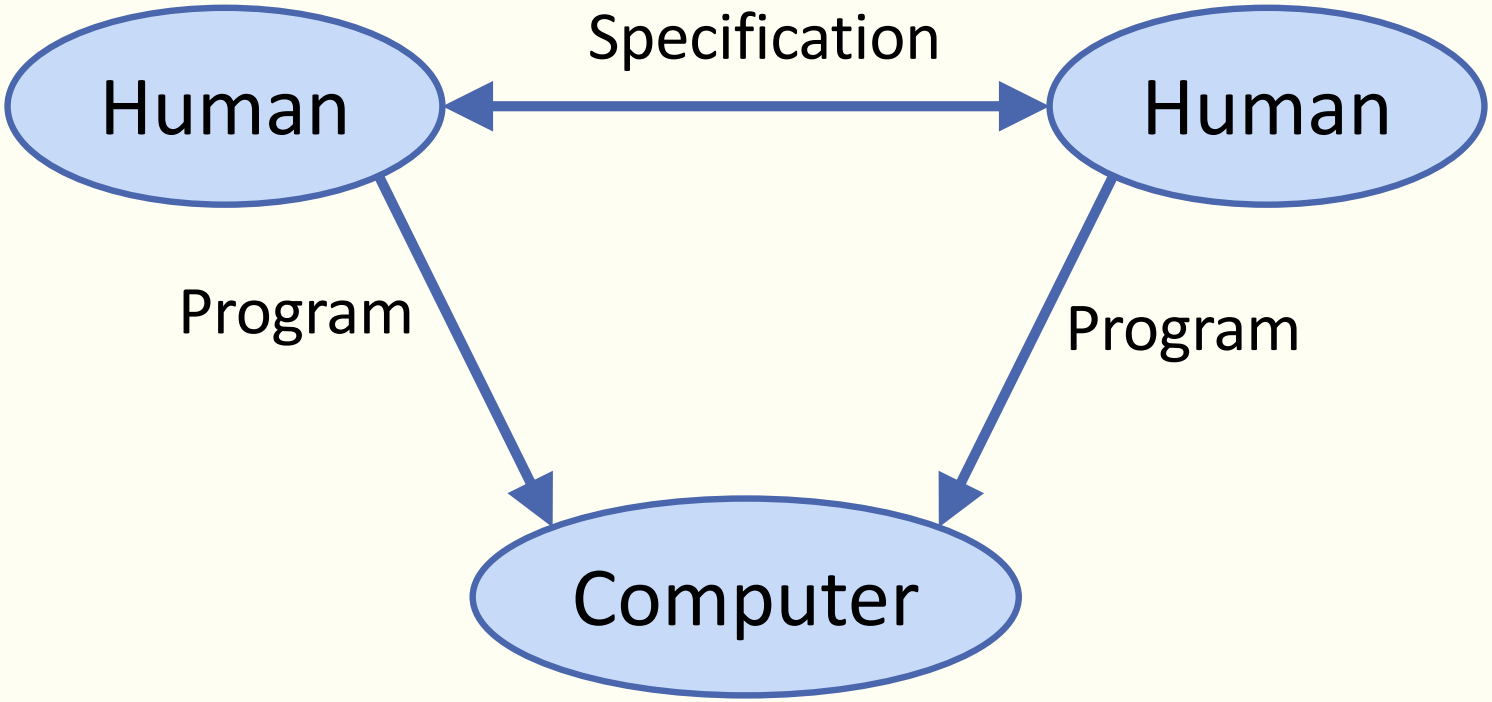
Why this is a good thing for communicating with AI agents

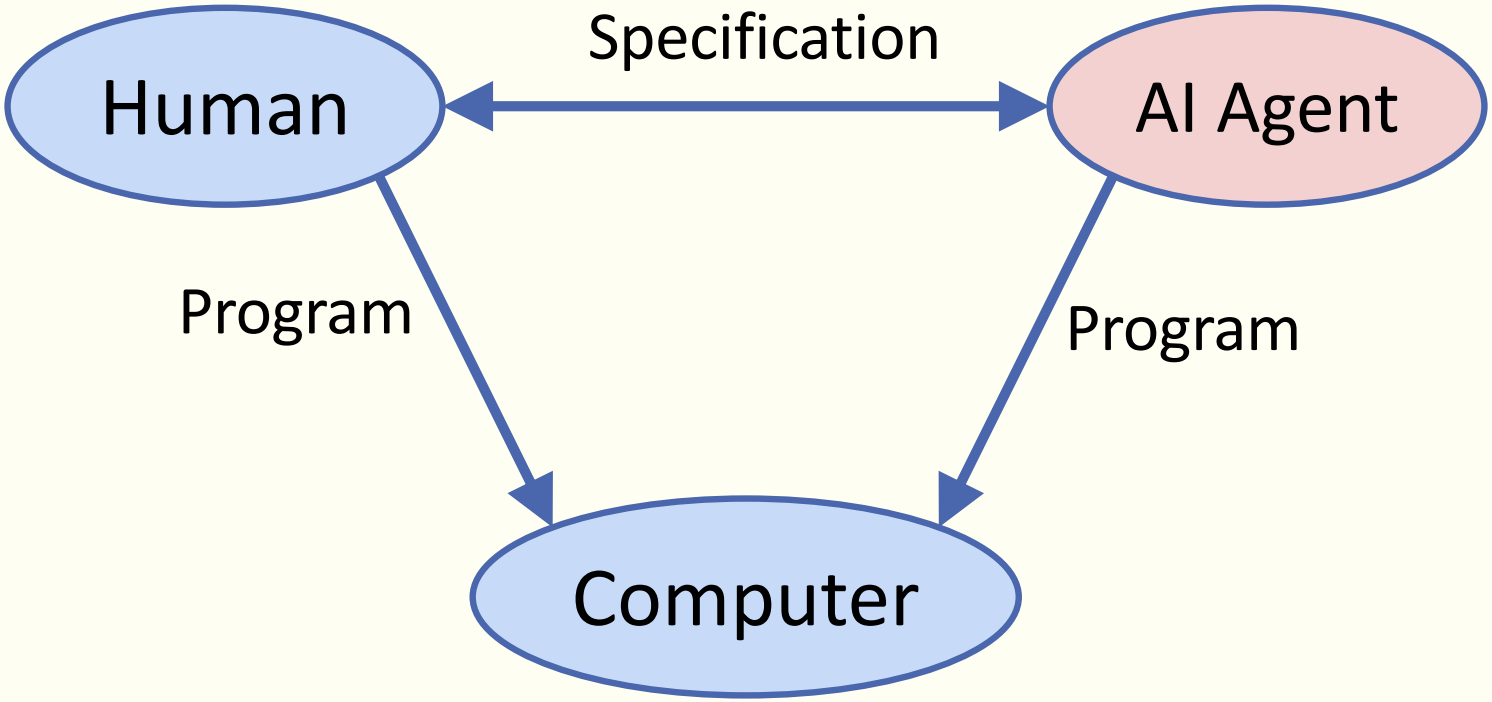
plus

Some challenges

Please interrupt!

Prologue


Human
Specification
Human
Program
Program
Computer


Human
Specification
AI Agent
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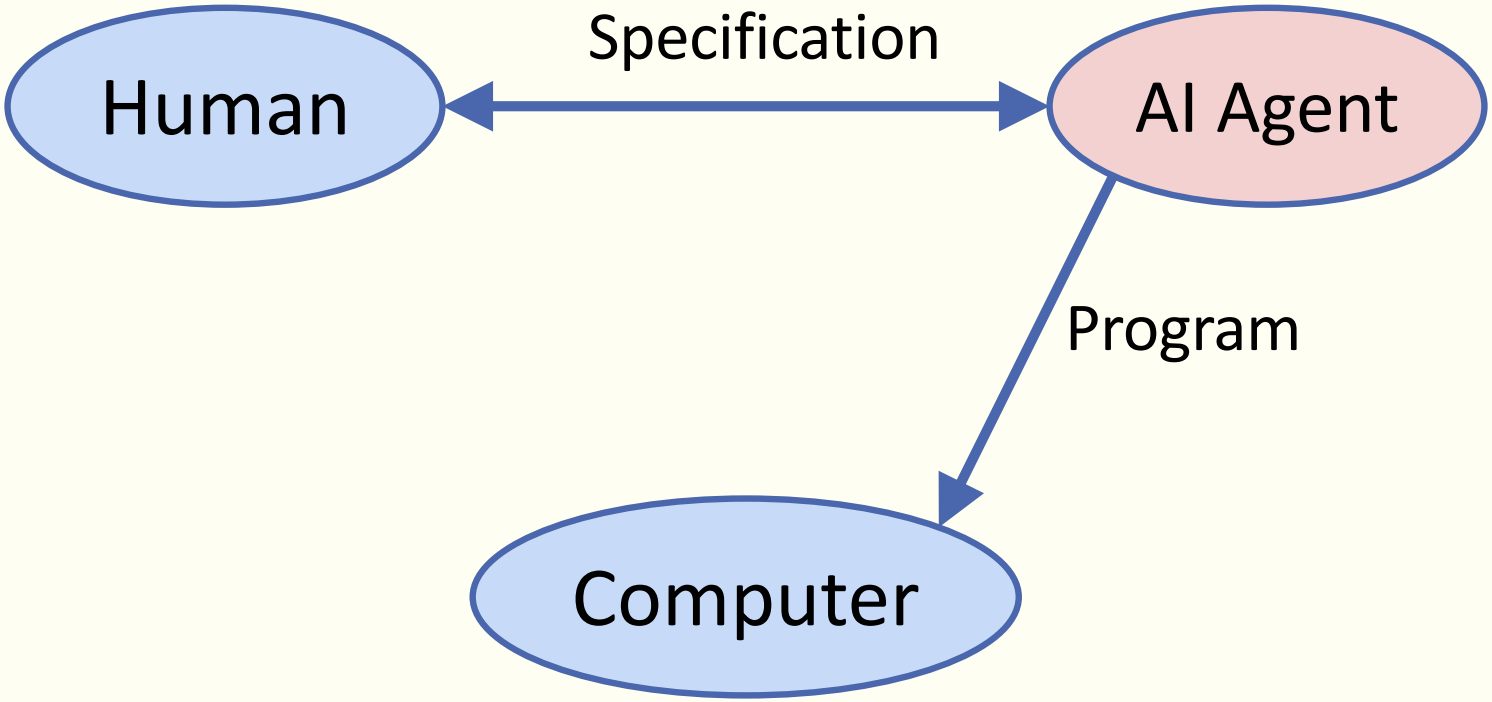
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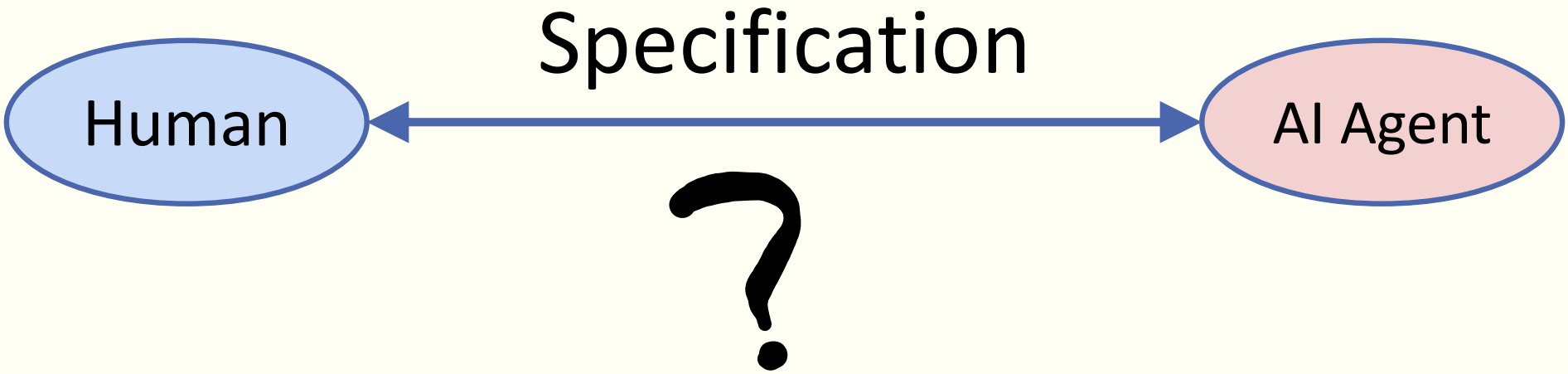
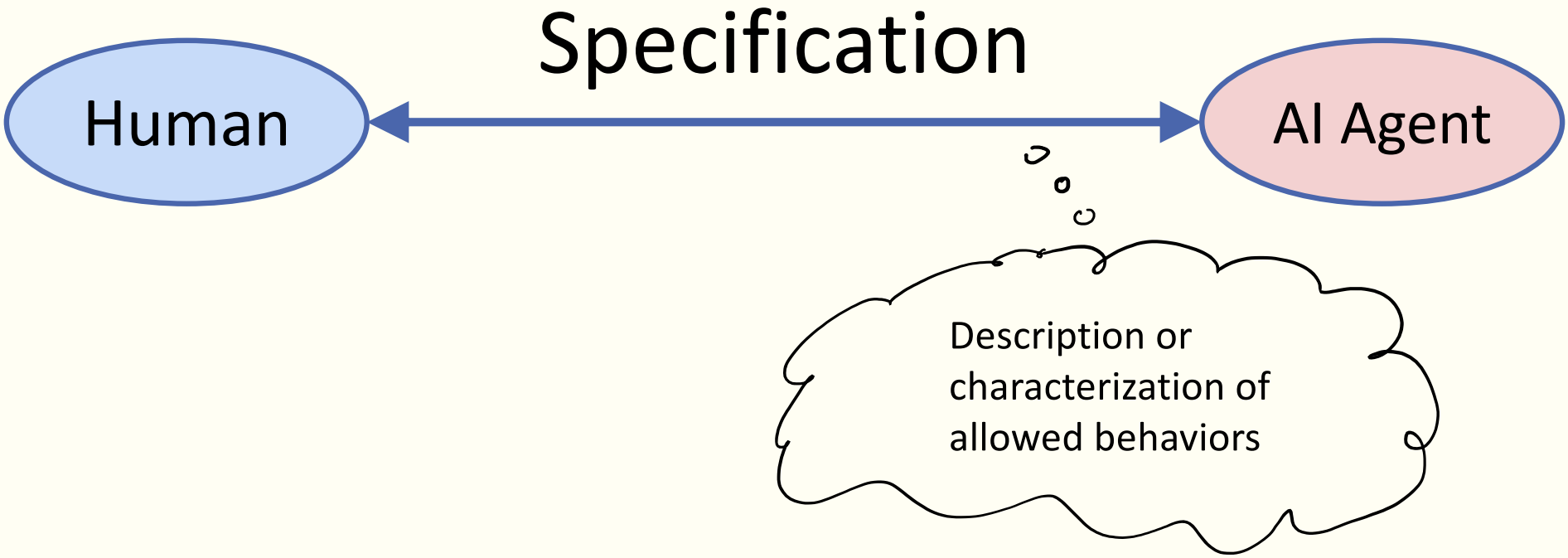

Specification
Human
AI Agent
?

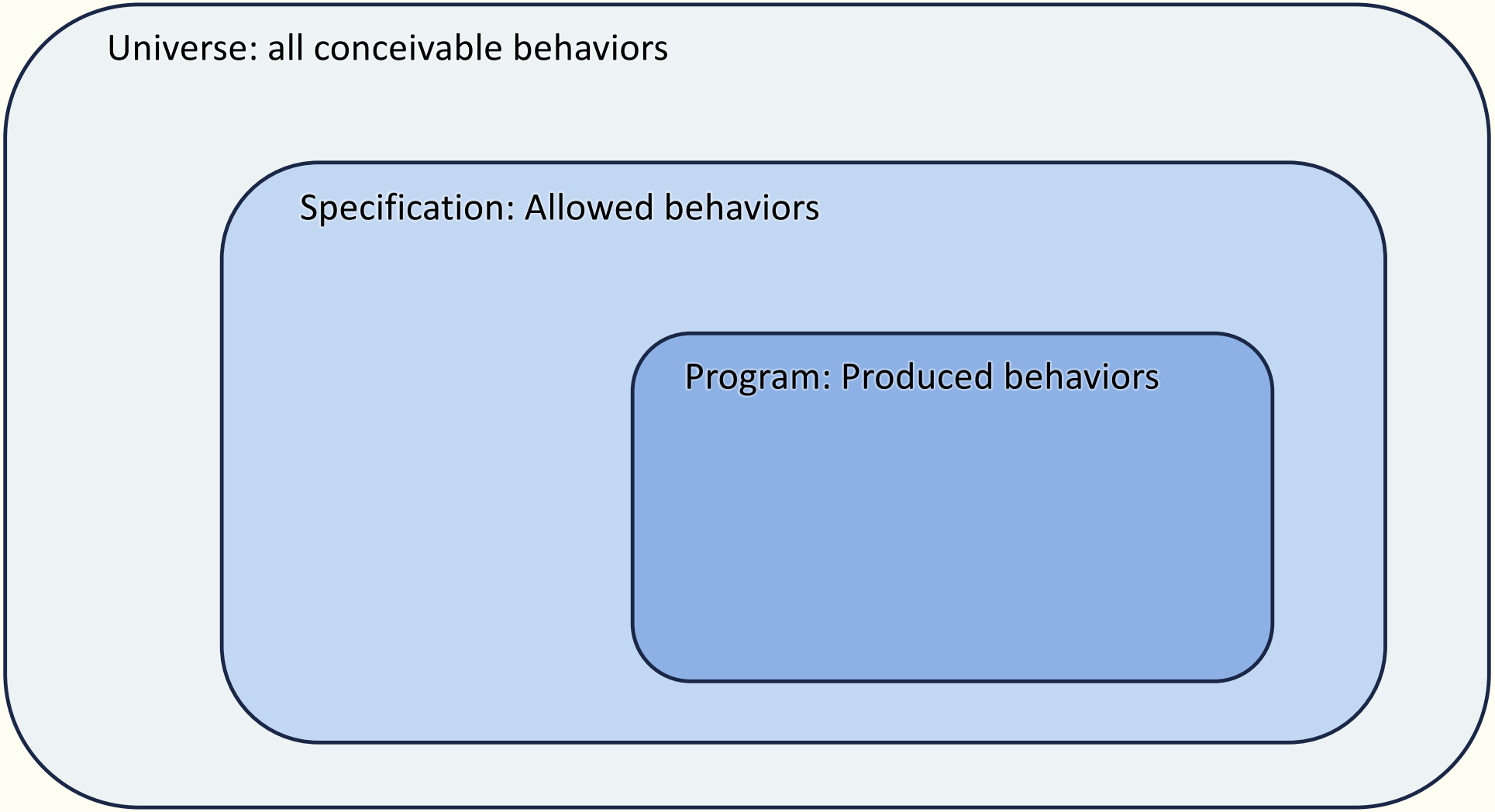

Specification
Human
AI Agent
Description or
characterization of
allowed behaviors

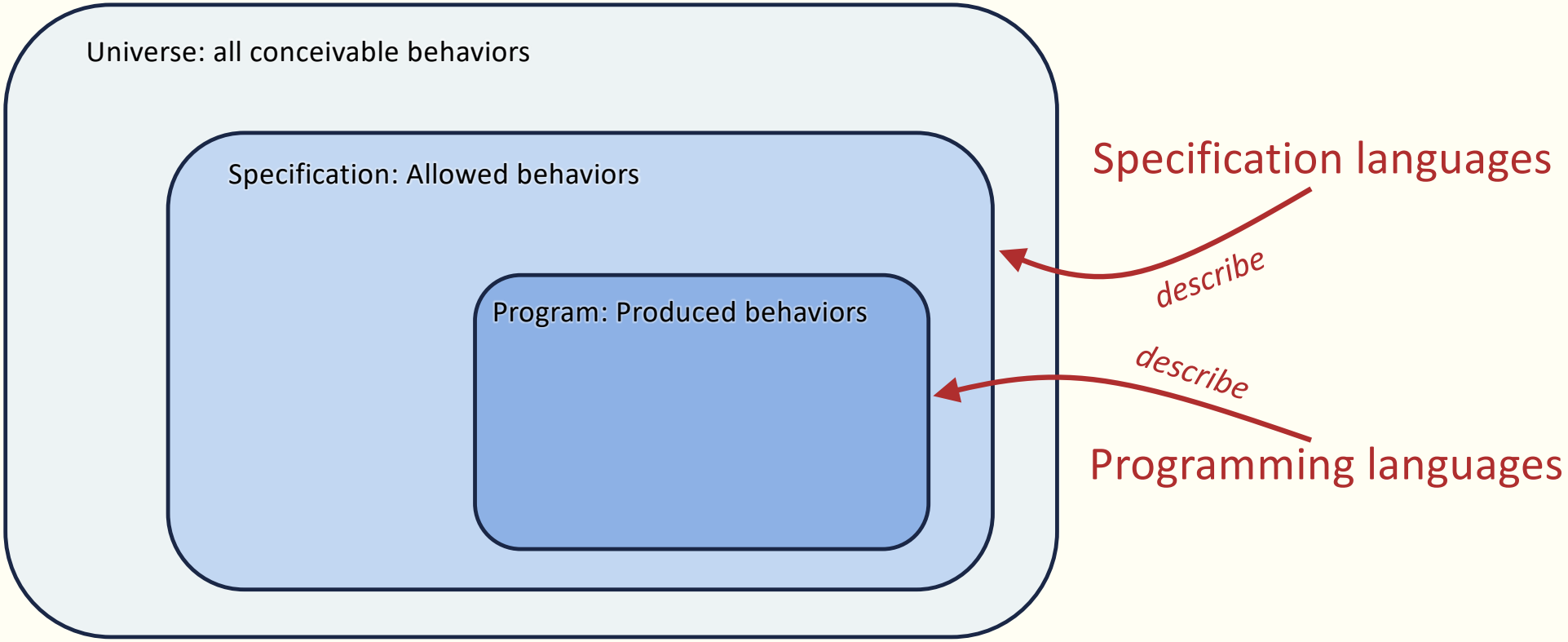
Universe: all conceivable behaviors

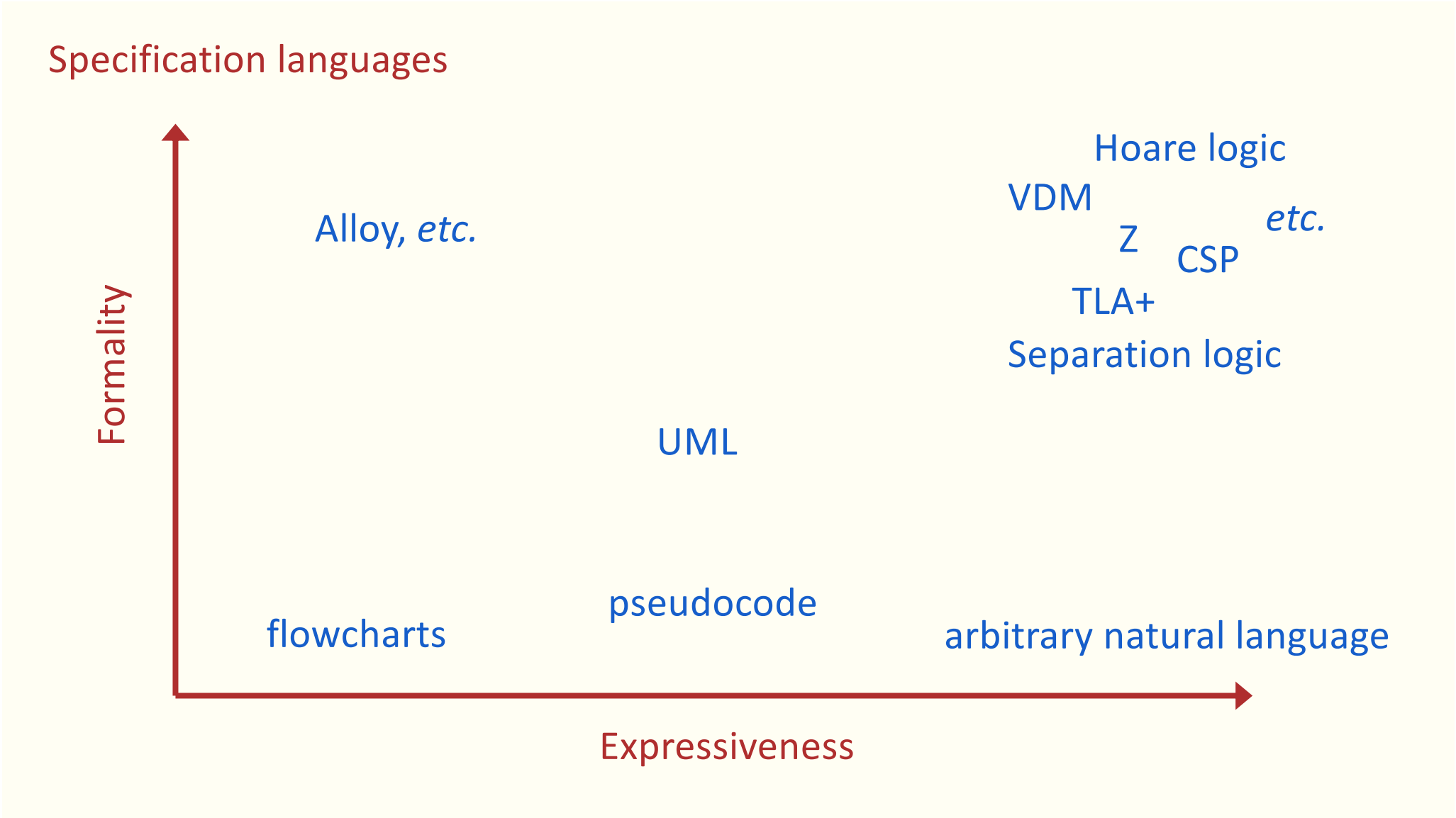
$$\mathcal{U} = \mathcal{P}(\mathrm{I} \times \mathrm{O})$$

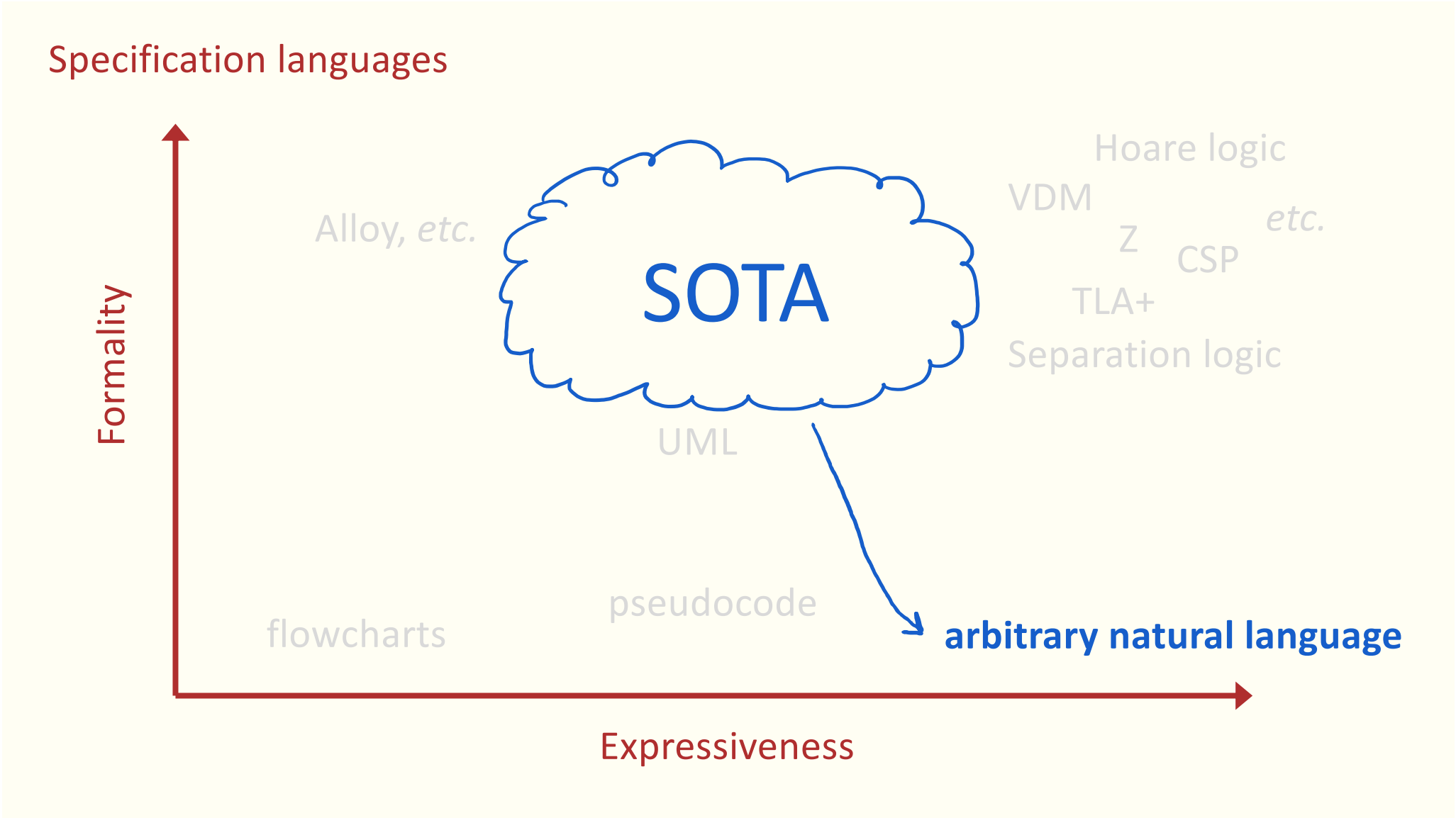
or

$$\mathcal{U} = \mathcal{P}(\mathrm{IO\ traces})$$


Universe: all conceivable behaviors
Specification: Allowed behaviors
Program: Produced behaviors


Universe: all conceivable behaviors
Specification: Allowed behaviors
Program: Produced behaviors
Specification languages
describe
describe
Programming languages


Specification languages
Formality
Expressiveness
Alloy, *etc.*
Hoare logic
VDM
Z
CSP
etc.
TLA+
Separation logic
UML
pseudocode
flowcharts
arbitrary natural language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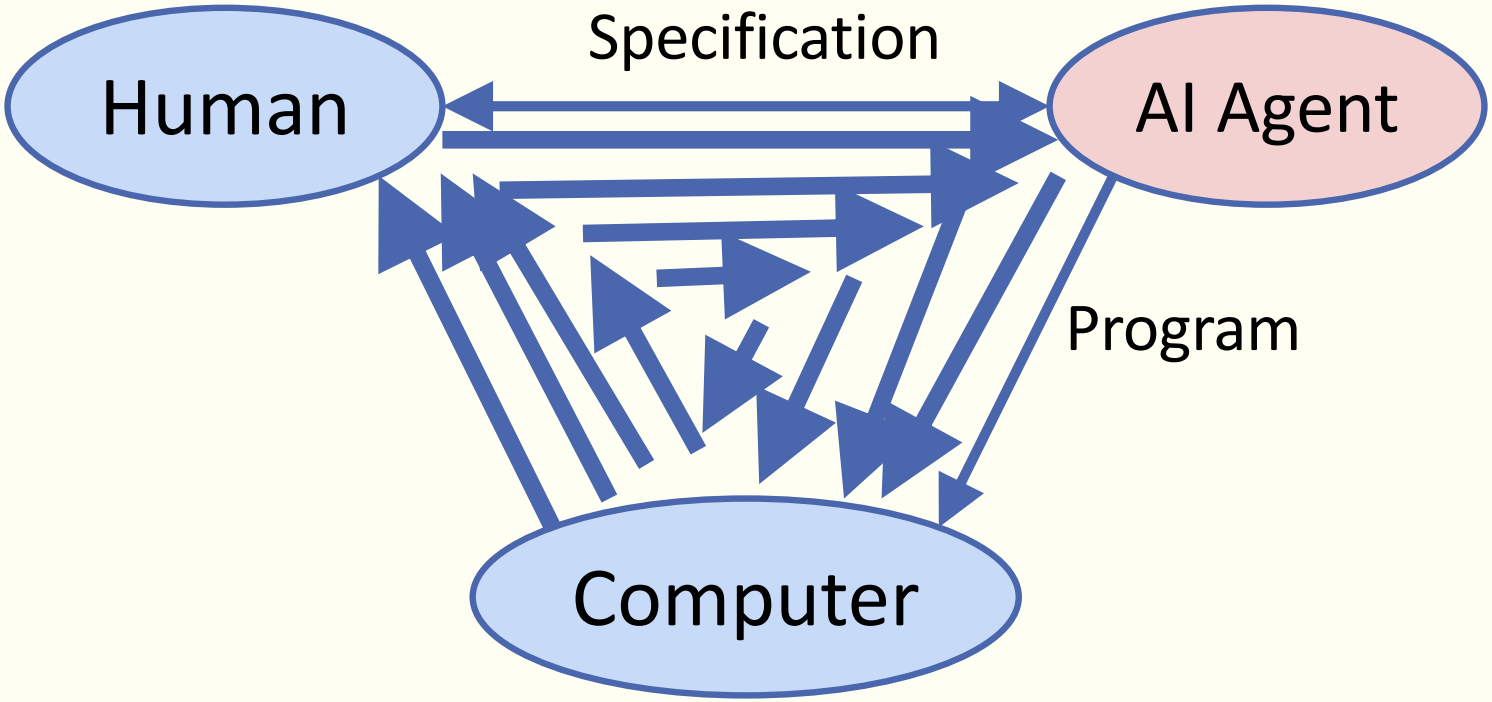
So… is this fine?

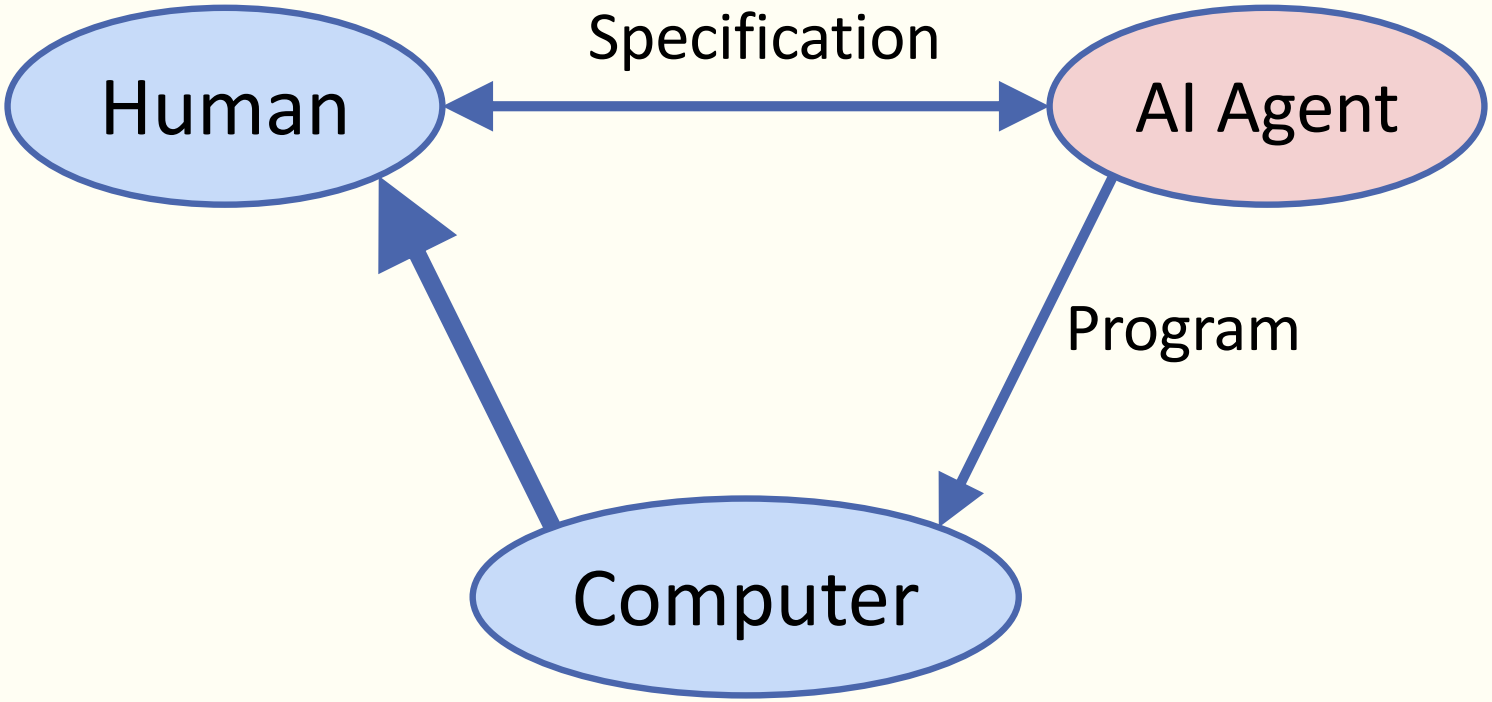
Is **natural language** the perfect specification language?

Nope…

1) Imprecision limits expressiveness

2) Imprecision inhibits iteration


Human
Specification
AI Agent
Program
Computer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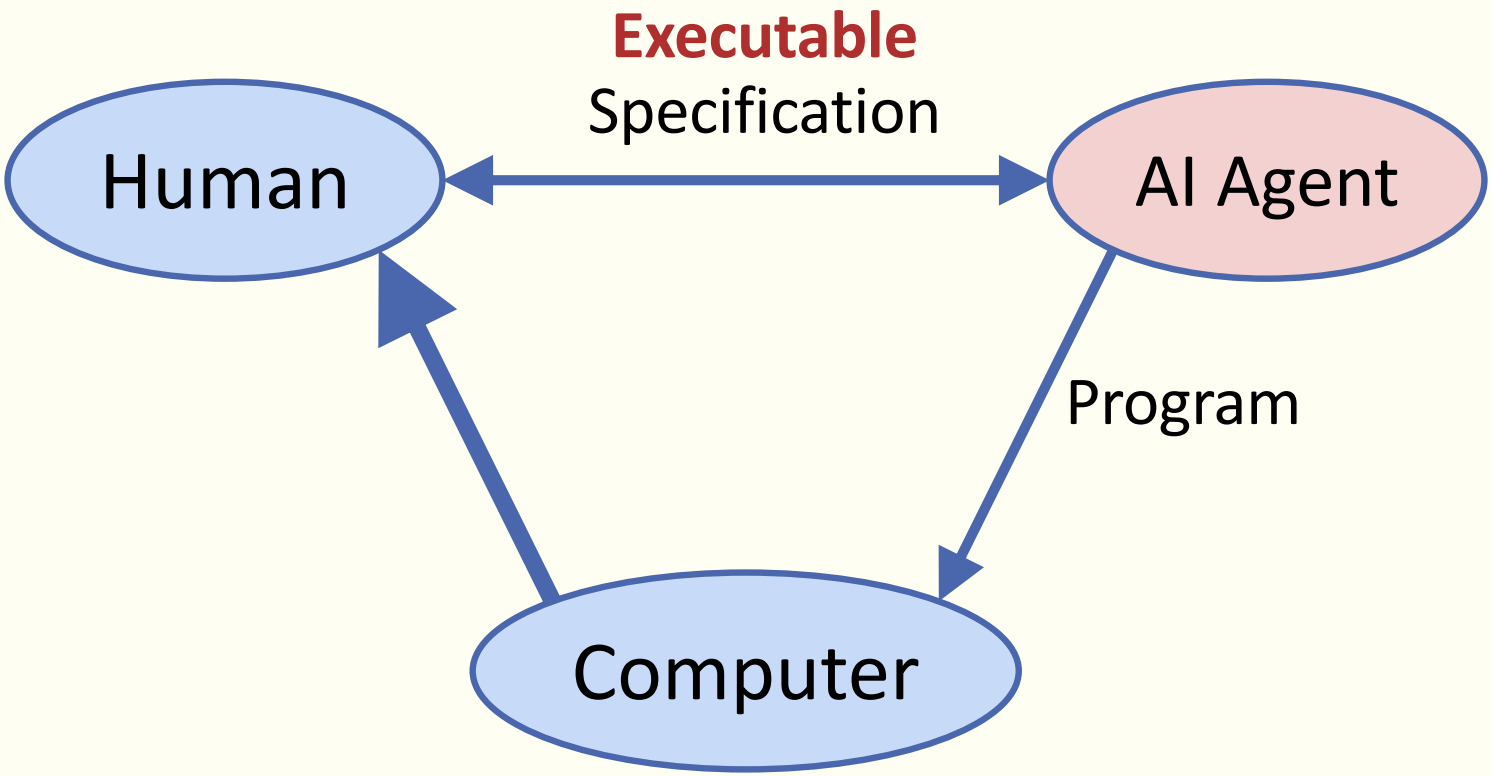
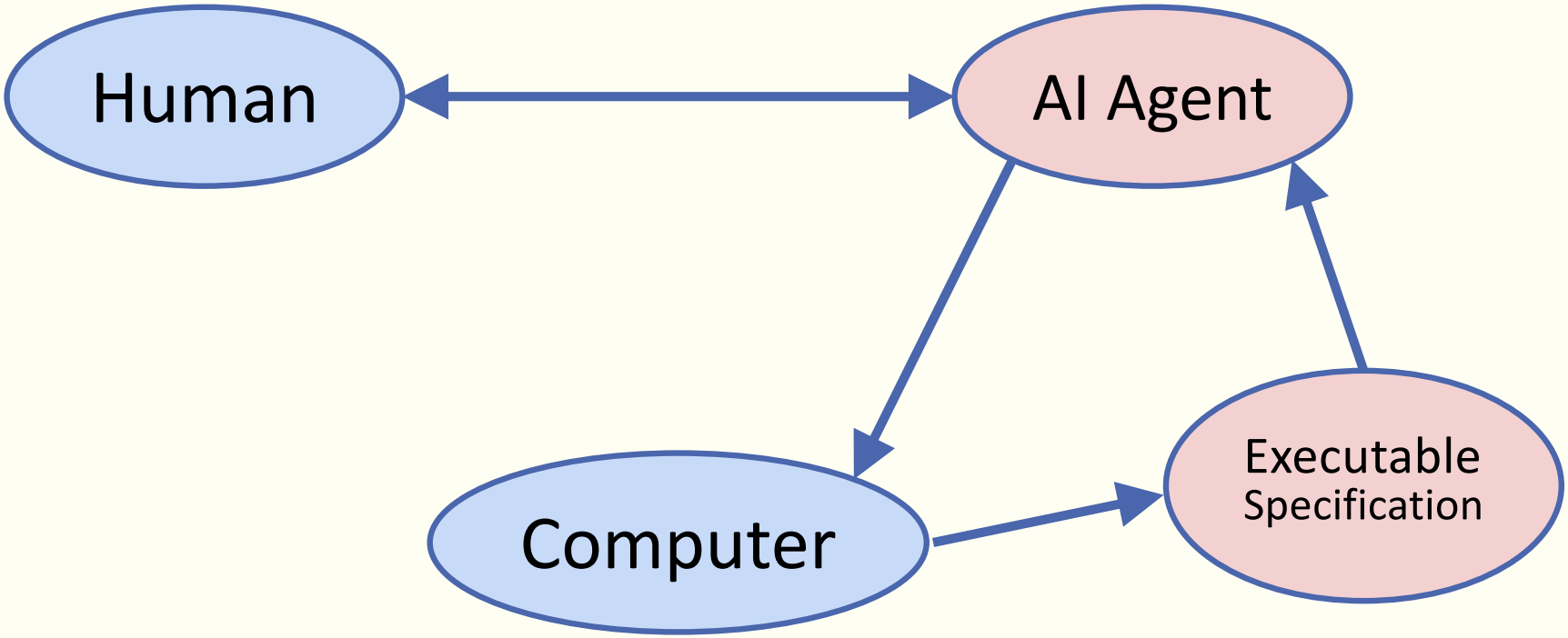
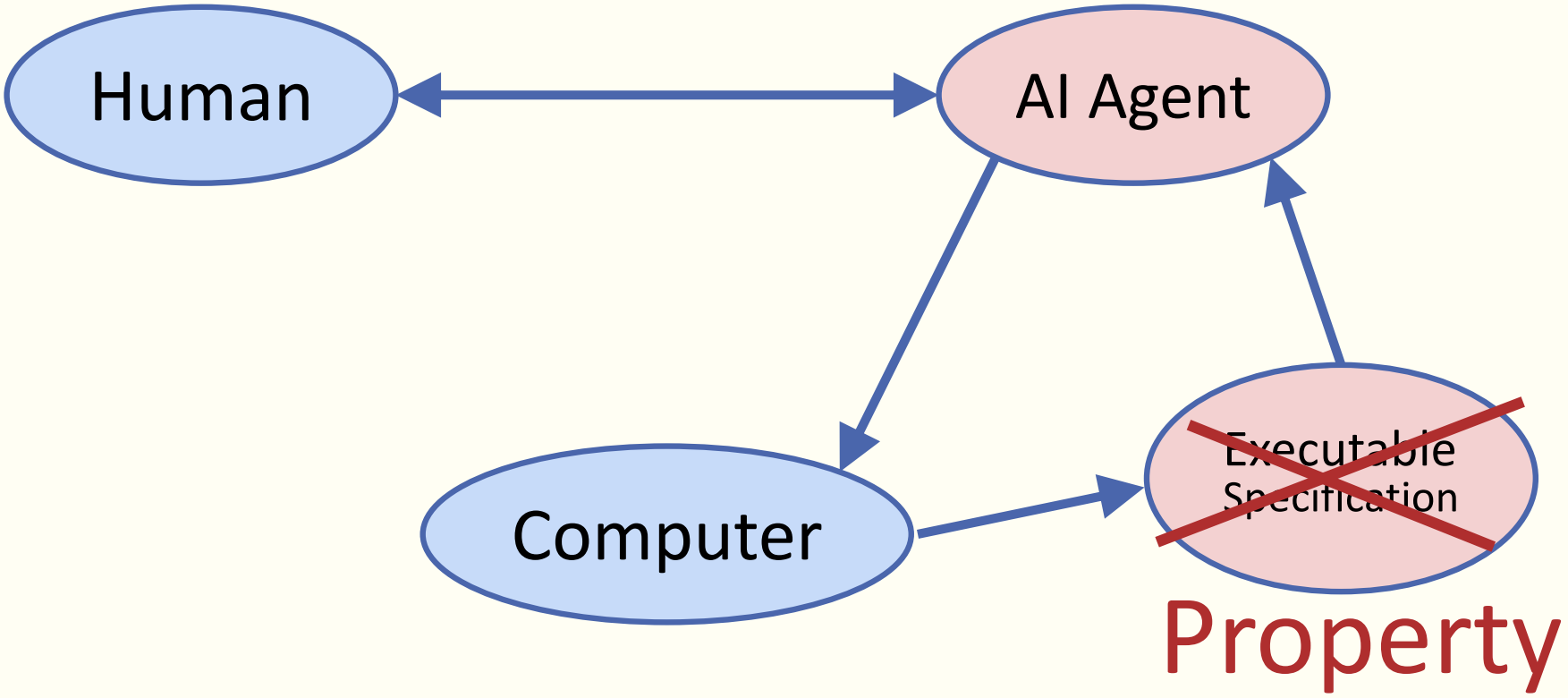
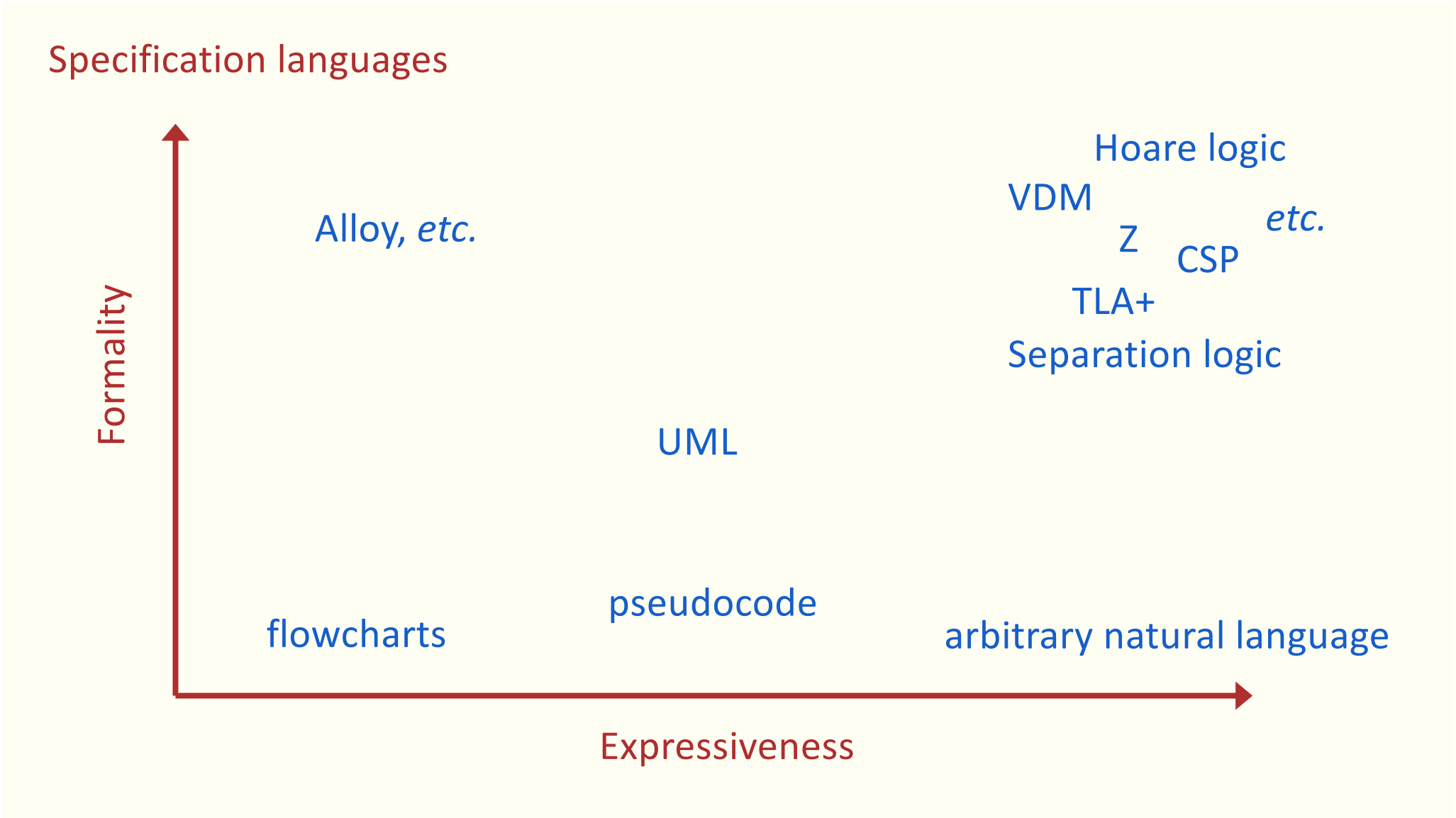

Executable
Specification
Human
AI Agent
Program
Computer


Human
AI Agent
Computer
Executable
Specification


Human
AI Agent
Computer
Executable Specification
Property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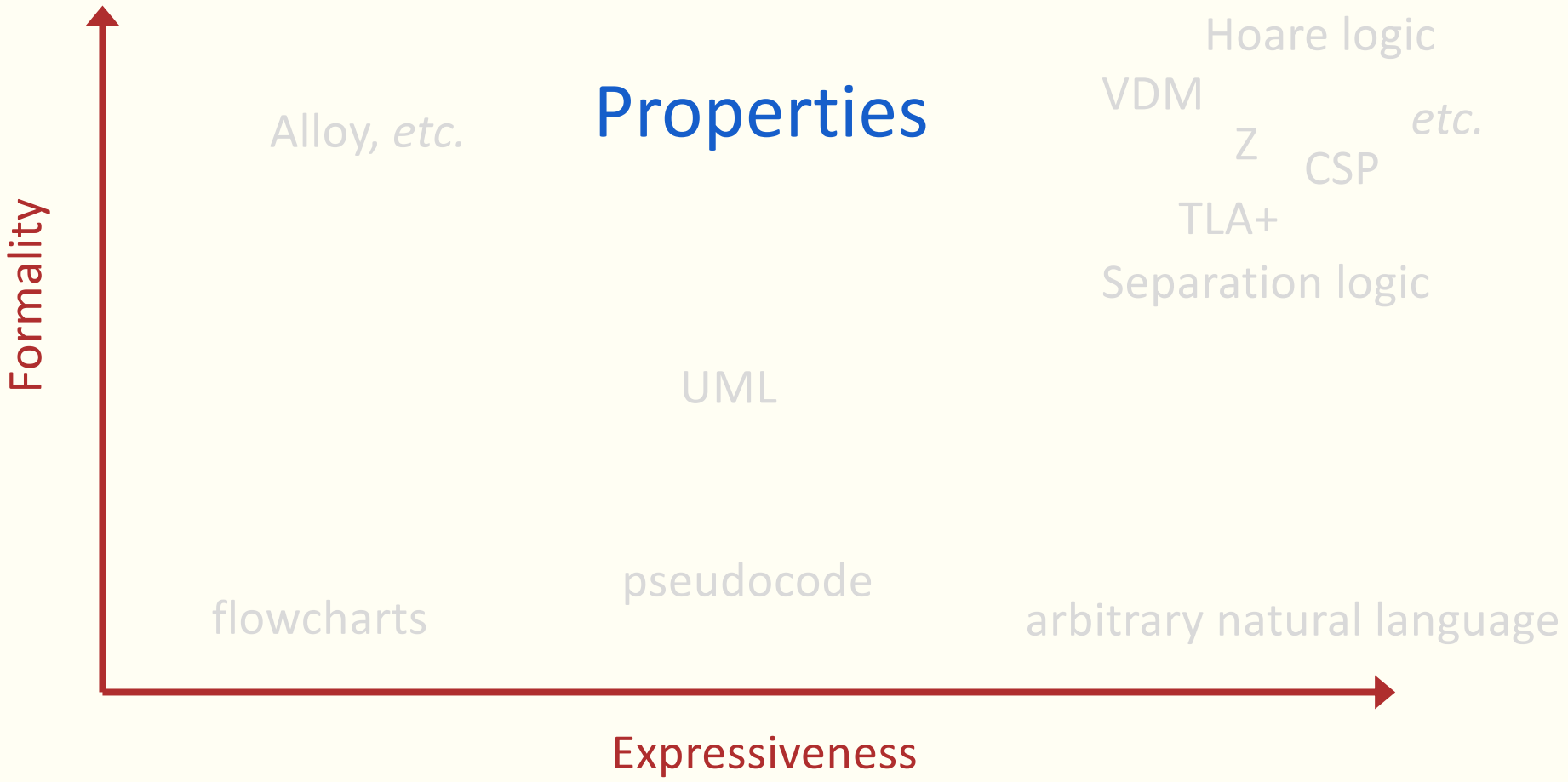
Specification languages



Properties

A property is an ordinary function from test inputs to booleans

```
def test_reverse_reverse(lst):
    assert  reverse(reverse(lst)) == lst
```

Goal of testing: Find a concrete argument lst that makes the assert fail (i.e., a counter-example to the property)

QuickCheck: A Lightweight Tool for Random Testing of Haskell Programs

Koen Claessen
Chalmers University of Technology
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John Hughes
Chalmers University of Technology
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1. INTRODUCTION

Testing is by far the most commonly used approach to

QuickCheck Family

C (theft)	C++ (CppQuickCheck)	Clojure (test.check)	Coq (QuickChick)	F# (FsCheck)
Go (gopter)	Haskell (QuickCheck or Hedgehog)	Java (QuickTheories)	JavaScript (jsverify)	PHP (Eris)
Python (Hypothesis)	Ruby (Rantly)	Rust (Quickcheck)	Scala (ScalaCheck)	Swift (Swiftcheck)

And more!

The Hypothesis PBT library in Python is downloaded over 4 million times each week, and was used by more than 5% of Python users surveyed by the PSF in 2023.

Engineers at Quviq built an executable specification based on the 3000-page AutoSAR standard for automotive software components

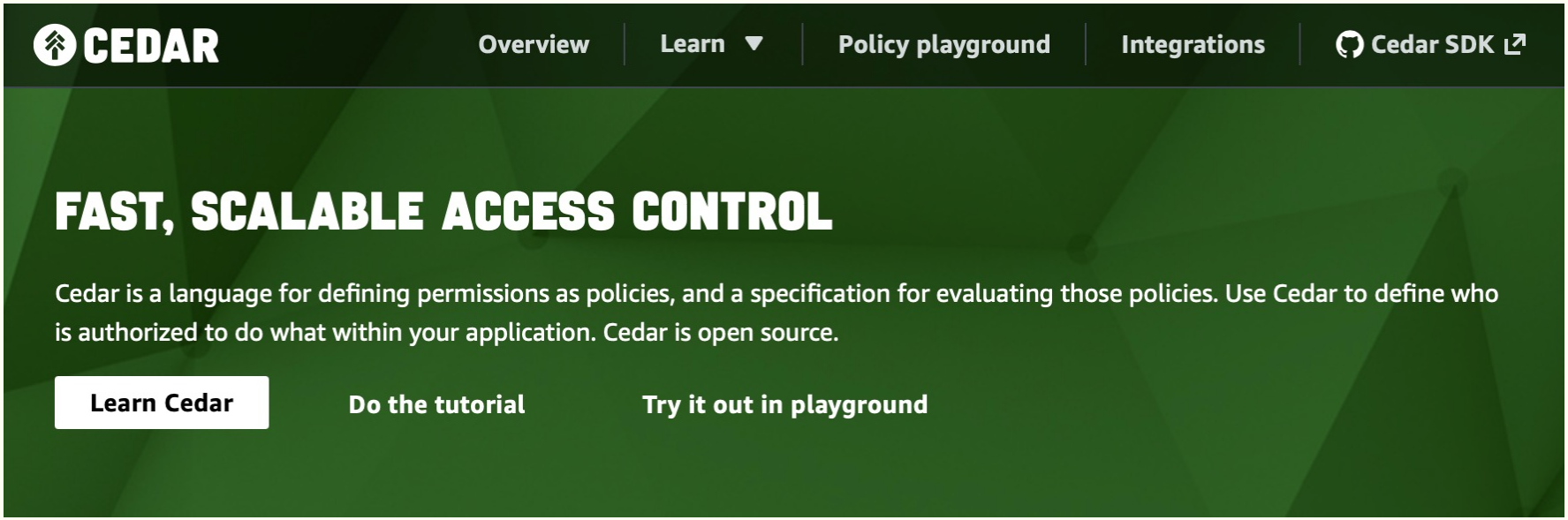
QuickCheck-based testing found >200 faults in AutoSAR Basic Software, including >100 inconsistencies in the standard

Dropbox

A QuickCheck specification of DropBox
found several new bugs in its behavior

Rust's PropTest tool was used to test that a new key-value store node implementation for S3 matches a reference implementation.

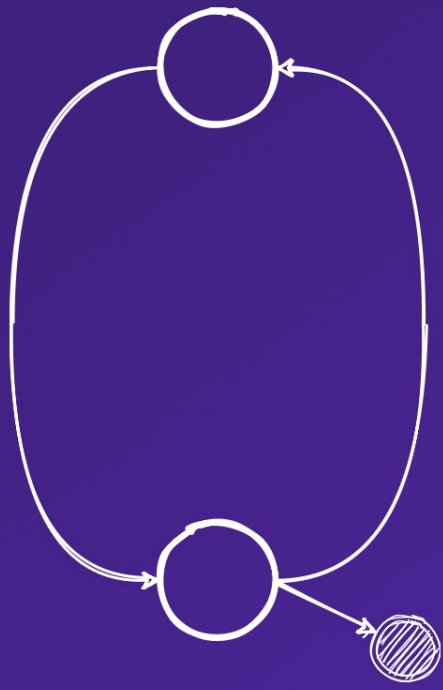
PBT is used in tandem with other lightweight formal methods like model checking.



AWS's Cedar implementation was validated against a formal model using PBT

Quickstrom

Quickstrom autonomously checks any type of web application. Focus on understanding and specifying, and let Quickstrom do the testing.



The Antithesis end-to-end automated testing platform integrates PBT, fuzzing, and deterministic simulation into a single testing tool

What does all this add up to?

Property-Based Testing

Specification-Driven Development

AI Coding Agents

Property-Based Testing

Autonomous

Specification-Driven Development

Autonomous Specification-Driven Development

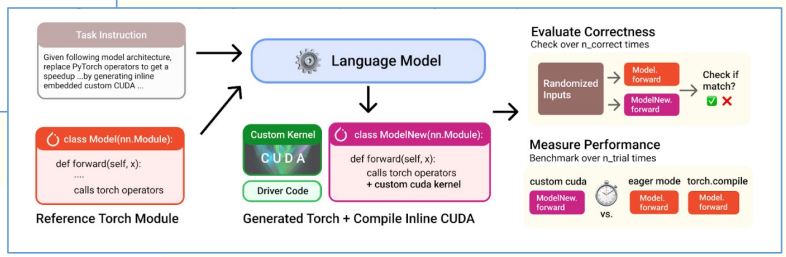
Scaling Intelligence Lab

Surprisingly Fast AI-Generated Kernels We Didn't Mean to Publish (Yet)

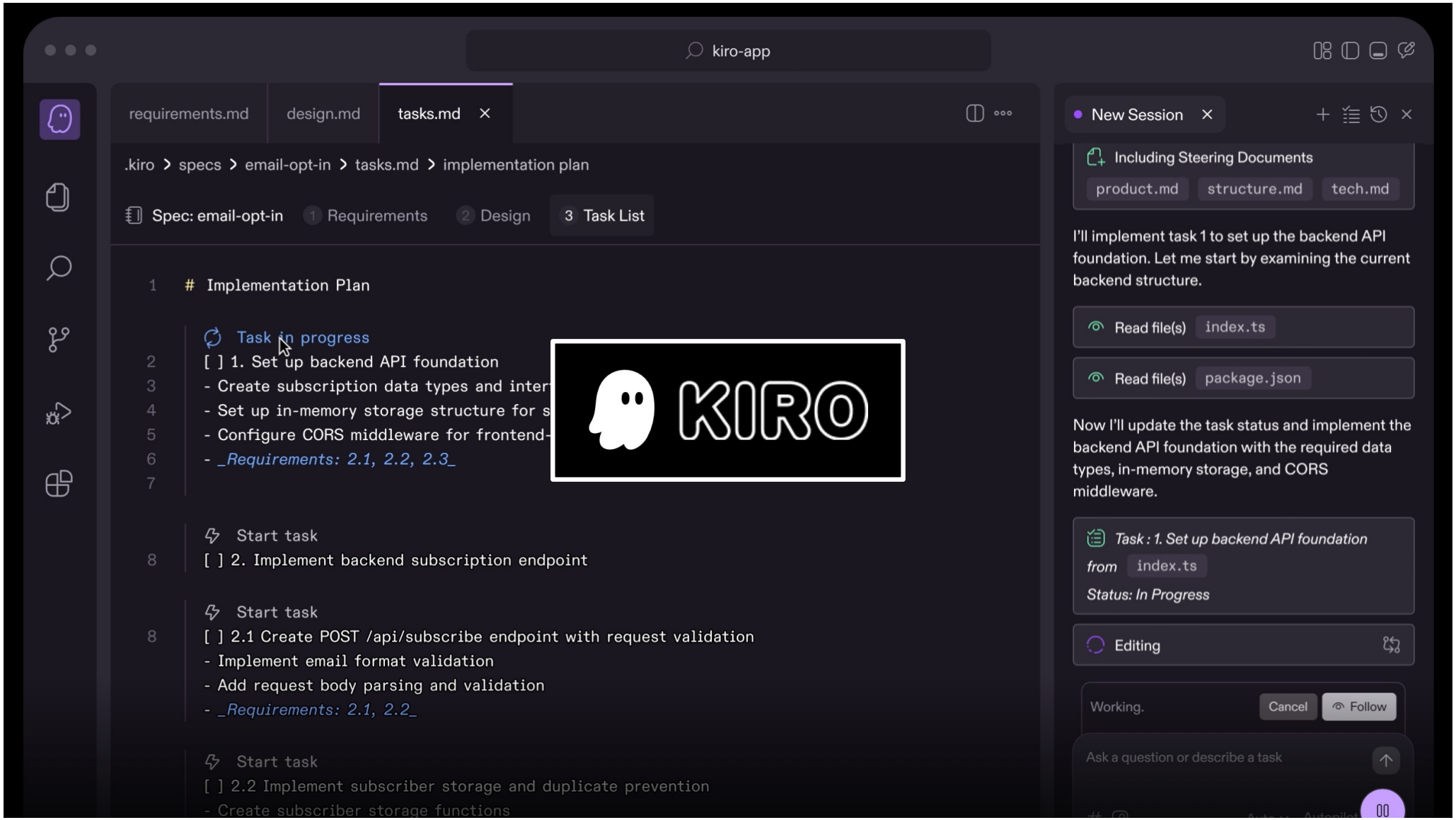
Anne Ouyang
Stanford

Percy Liang
Stanford

Azalia Mirhoseini
Stanford



- **Matmul (FP32): 101.3%** performance of FP32 torch.matmul; problem size: 4096x4096 square matrices
- **Conv2D: 179.9%** performance of FP32 torch.nn.Conv2D; problem size: (100, 3, 224, 224) input tensor, conv(in_channels=3, out_channels=96, kernel_size=11, stride=4, padding=2)
- **Softmax: 111.8%** performance of FP32 torch.softmax; problem size: (4096, 65536) input tensor
- **LayerNorm: 484.4%** performance of FP32 torch.nn.LayerNorm; problem size: (16, 64, 256, 256) input tensor
- **Conv2D + ReLU + MaxPool: 290.1%** performance of FP32 torch reference, 189.0% performance of FP32 torch.compile() reference; problem size: (100, 3, 224, 224) input tensor, conv(in_channels=3, out_channels=96, kernel_size=11, stride=4, padding=2), maxpool(kernel_size=3, stride=2)


kiro-app
requirements.md
design.md
tasks.md
.kiro > specs > email-opt-in > tasks.md > implementation plan
Spec: email-opt-in
1 Requirements
2 Design
3 Task List
1 # Implementation Plan
Task in progress
2 [ ] 1. Set up backend API foundation
3 - Create subscription data types and inter
4 - Set up in-memory storage structure for s
5 - Configure CORS middleware for frontend-
6 - _Requirements: 2.1, 2.2, 2.3_
7
Start task
8 [ ] 2. Implement backend subscription endpoint
Start task
8 [ ] 2.1 Create POST /api/subscribe endpoint with request validation
- Implement email format validation
- Add request body parsing and validation
- _Requirements: 2.1, 2.2_
Start task
[ ] 2.2 Implement subscriber storage and duplicate prevention
- Create subscriber storage functions
KIRO
New Session
Including Steering Documents
product.md
structure.md
tech.md
I'll implement task 1 to set up the backend API foundation. Let me start by examining the current backend structure.
Read file(s) index.ts
Read file(s) package.json
Now I'll update the task status and implement the backend API foundation with the required data types, in-memory storage, and CORS middleware.
Task : 1. Set up backend API foundation
from index.ts
Status: In Progress
Editing
Working.
Cancel
Follow
Ask a question or describe a task

Taking stock…

Preview

Recent progress in property-based testing

and

Why this is a good thing for communicating with AI agents

plus

Some challenges

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Recent progress in property-based testing

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plus

Some challenges

Main challenge:

Writing properties can be hard

Properties for the People!

Why is writing properties hard?

1. Requires abstract reasoning
2. Not a natural fit for every situation

How do we Teach People to Write Properties?

- Thinking explicitly at the level of specifications is unfamiliar to many programmers
- At what level should PBT be taught?
  - What would a software engineering course focused on PBT look like?
  - Can it be taught in an intro programming course?

Using Relational Problems to Teach Property-Based Testing

John Wrenn[a], Tim Nelson[a], and Shriram Krishnamurthi[a]

a Brown University, USA

Current experiment:
PBT in CIS 1200 at Penn

Xiaorui Liu

Andrew Head

How do we Teach People to Find Properties?

Harrison Goldstein

Andrew Head

How do we Teach People to Find Properties?

Observation study of PBT use at Jane Street

Key finding: Developers gravitate toward just a few PBT idioms most of the time:

- Differential tests
- Validity / invariants
- Round tripping
- Simple commuting diagrams

Andrew Head

Harrison Goldstein

Can AI Tools Help?

Some examples…

- Kiro uses a language model to translate informal requirements into executable tests
- Saketh Kasibatla (UCSD) is building an interactive environment for collaboratively developing executable specifications

Can AI Tools Help? Yes, but…

We do not want AI tools writing specifications all by themselves!

Second challenge:

Good generators are required

Or…

Generators

```
def test_reverse_reverse(lst):
    assert  reverse(reverse(lst)) == lst
```

```
def test_reverse_reverse(lst):
    assert  reverse(reverse(lst)) == lst
```

```
$ pytest
============================= test session starts ==============================
collected 1 item

test_reverse.py .                                                      [100%]

============================== 1 passed in 0.12s ===============================
```

```
def test_reverse_reverse(lst):
    assert  reverse(reverse(lst)) == lst
```

Or perhaps…

```
Falsifying example: test_reverse_reverse(lst=[1, 2])
AssertionError: assert [1] == [1, 2]
```

These test inputs come from generators…

QuickCheck

Type-based generators

No control over distribution

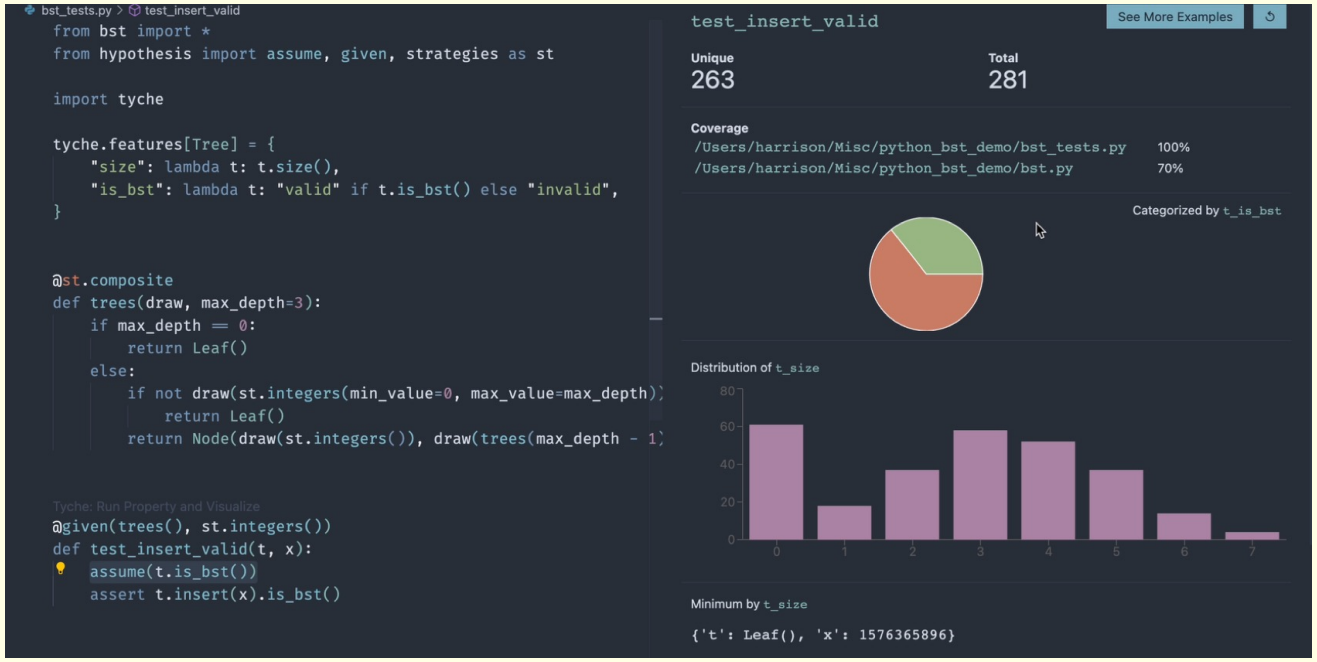
Hand-rolled generators

Distracting

But we can do better…

Tyche

VSCode-based tool for **visualizing generator distributions**



Harrison Goldstein

Palamedes

Synthesizing generators from logical specifications…

The Search for Constrained Random Generators

HARRISON GOLDSTEIN, University at Buffalo, SUNY, USA
HILA PELEG, Technion, Israel
CASSIA TORCZON, University of Pennsylvania, USA
DANIEL SAINATI, University of Pennsylvania, USA
LEONIDAS LAMPROPOULOS, University of Maryland, USA
BENJAMIN C. PIERCE, University of Pennsylvania, USA

Thank you!!

Questions, discussion, …?