PERFORMANCE EVALUATION FOR GRADUAL TYPING

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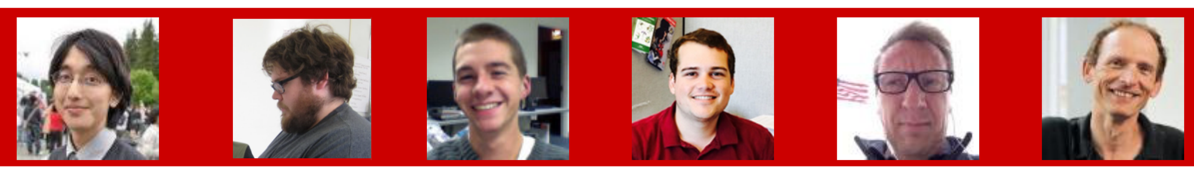


GRADUAL TYPING is for software maintenance

Fact 1: developers use untyped languages

Fact 2: type annotations enable safety checks and serve as documentation

Thesis: stable untyped code + type annotations = happy future maintainers

PROMISES

Freedom to add types **incrementally**

Soundness: type invariants are enforced at runtime . . . **What about performance?**

PERFORMANCE LATTICE

Visualizing all possible gradually-typed configurations

Example: FSM benchmark

4 modules, 16 configurations

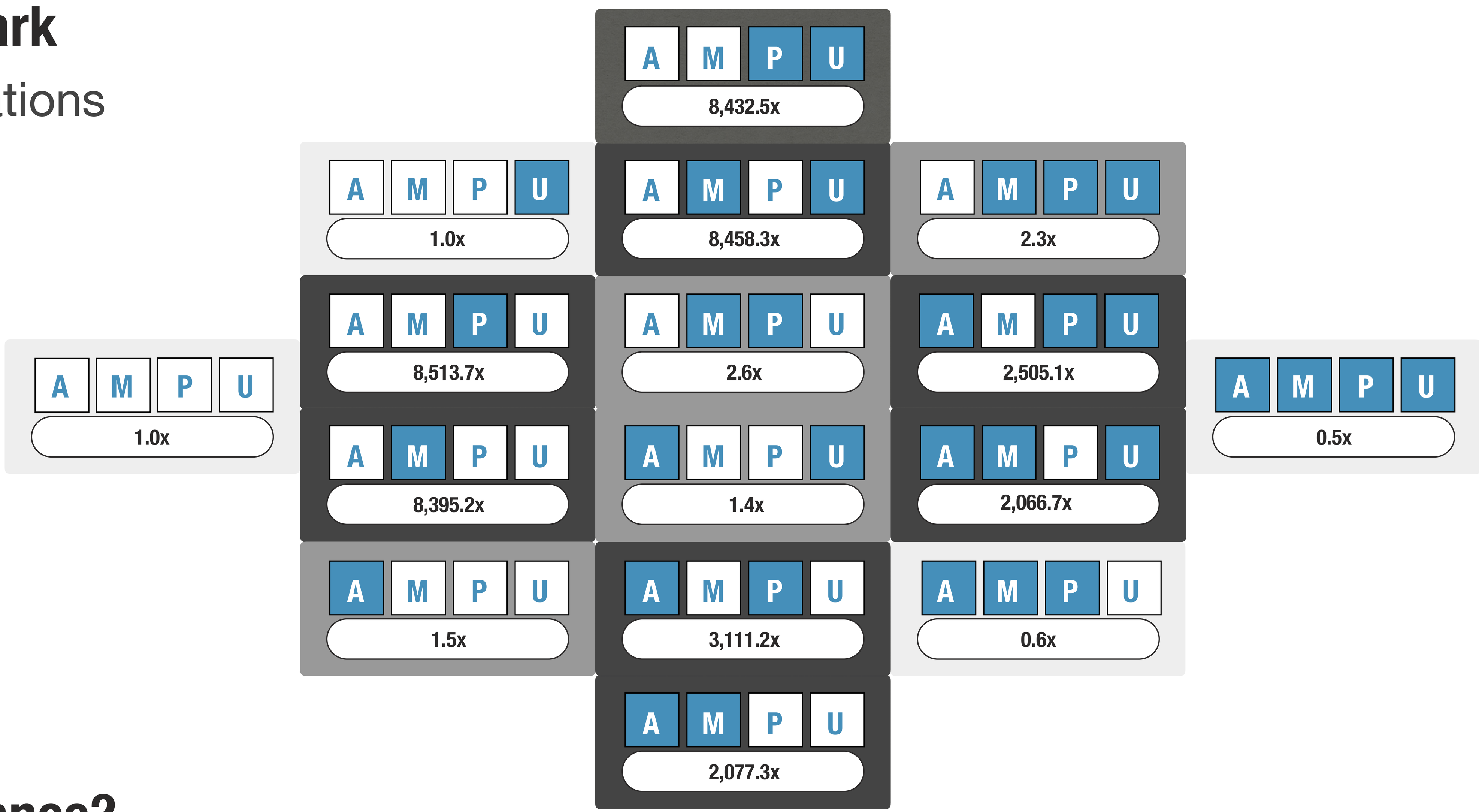
A. automata.rkt
Interface & basic strategies

M. main.rkt
Runs a simulation

P. population.rkt
Models groups of automata

U. utilities.rkt
Helper functions

Untyped runtime: **182ms**



Is this "good" performance?

Yes

+ Fully typed is **2x** faster
+ **50%** of all configurations have **< 3x** overhead
+ Can avoid **> 2,000x** overhead by typing both **main.rkt** and **population.rkt**

No

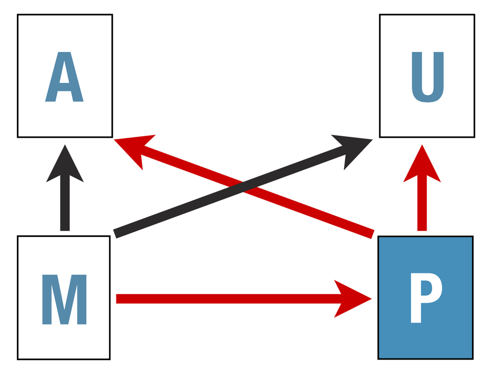
- Maximum overhead: **8,500x** (*26 minutes to run*)
- Average overhead: **2,700x**
- Median overhead: **470x**
- No smooth migration paths: Impossible to convert module-by-module and avoid **2,000x** overhead

Open Question

How to help developers avoid performance valleys (without exploring the whole lattice)?

Configuration A M P U in depth

- Type **boundaries** are checked at runtime
- Key boundary: **main.rkt** and **population.rkt**



main.rkt

```
require "automata.rkt"
require "population.rkt"
require "utilities.rkt"

define (evolve pop count)
  if (zero? count)
    null
    evolve (step pop)
           (count - 1)

evolve (create 100) 5
```

population.rkt

```
require/typed "automata.rkt"
  [#:opaque Automaton automaton?]
  ....
require/typed "utilities.rkt"

define-type Population
  (Vectorof (Vectorof Automaton))

provide:
  step   (-> Population Population)
  create (-> Natural Population)
```

Each call to **step** wraps **pop** with a higher-order contract

After **N** calls, each vector operation suffers **N** indirections

EVALUATION METHOD

Report the relative performance of the **untyped** and **fully-typed** configurations

Report the **proportion** of typed/untyped configurations:

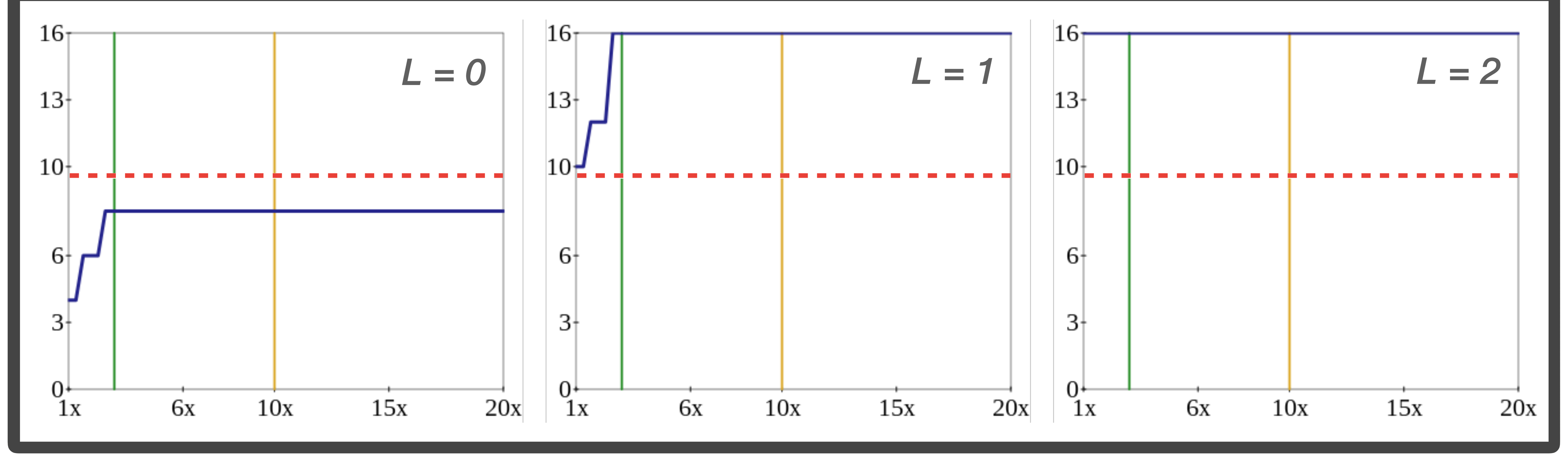
- with "**deliverable**" overhead (at most **N**x slowdown)
- with "**usable**" overhead (at most **M**x slowdown)
- within **L** conversion steps from an **N**x or **M**x configuration

L-N/M FIGURES

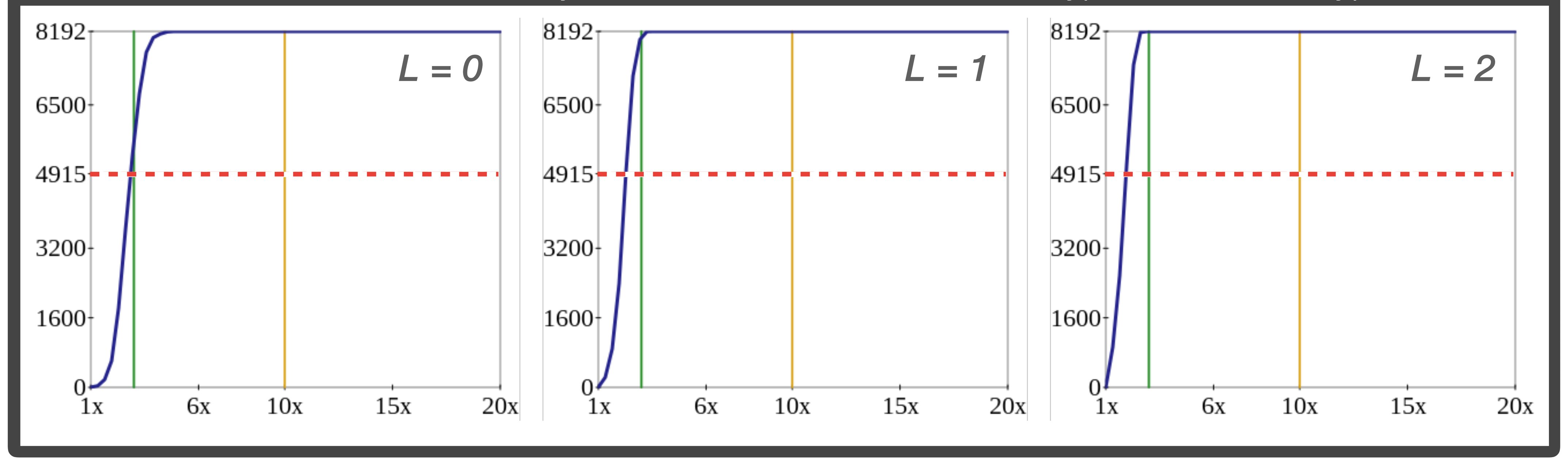
Summarizing performance lattices

Legend: #Configs < Overhead — 60% of Configs — N = 3 — M = 10

FSM economy simulator 4 modules **182ms** untyped **85ms** untyped



GREGOR time & date library 13 modules **666ms** untyped **815ms** typed



SYNTH music maker 10 modules **263ms** untyped **272ms** typed