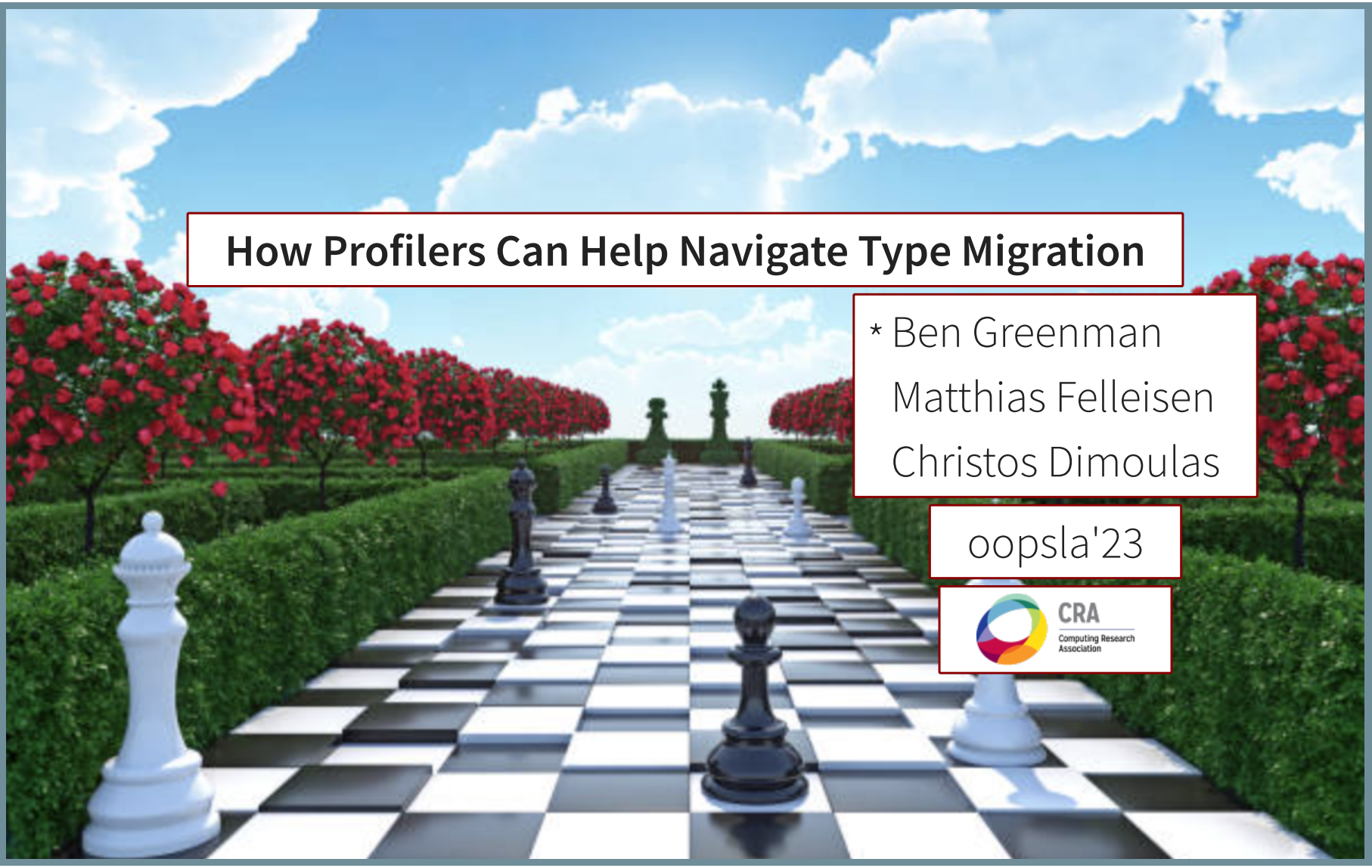

How Profilers Can Help Navigate Type Migration
* Ben Greenman
Matthias Felleisen
Christos Dimoulas
oopsla'23
CRA
Computing Research Association

How Profilers Can Help Navigate Type Migration

How Profilers Can Help Navigate Type Migration

How to avoid **runtime costs** using **off-the-shelf tools**?

How Profilers Can Help Navigate Type Migration

How to avoid **runtime costs** using **off-the-shelf tools**?

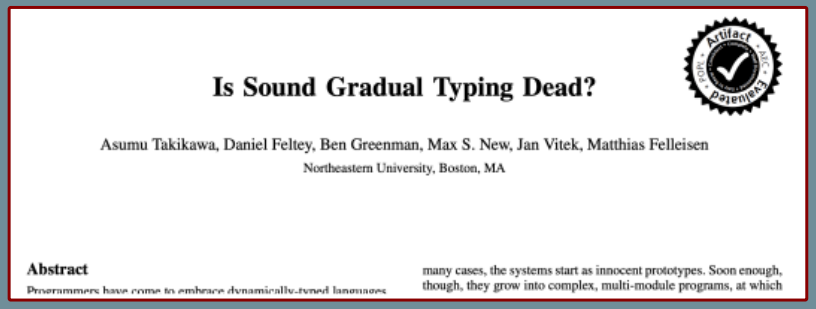
costs ~ gradual types

tools ~ statistical profilers

Old Problem, New Idea

Old Problem, New Idea

popl'16: 10x slowdowns are common,
but fast points exist!



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Northeastern University, Boston, MA

Abstract

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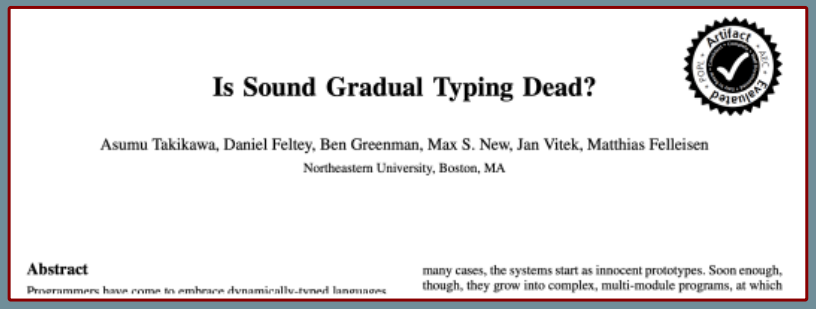

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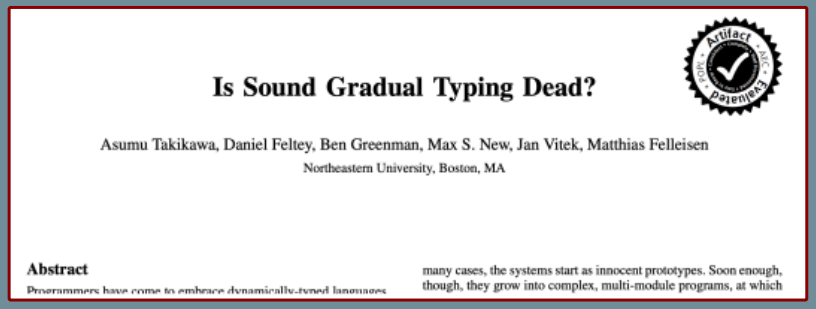

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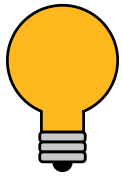

Rational Programmer
method (icfp'21)

Gradual Types + Costs

Gradual Types + Costs

```
def avg(g):
  return mean(get_column(g, "score"))
```

```
def mean(nums):
  ....
```

```
def get_column(table, col_name):
  ....
```

```
avg(quiz_1_grades)
avg(recipe_book)
avg(42)
```

Gradual Types + Costs

```
avg : Gradebook -> Num
def avg(g):
  return mean(get_column(g, "score"))
```

```
def mean(nums):
  ....
```

```
def get_column(table, col_name):
  ....
```

```
avg(quiz_1_grades)
avg(recipe_book)
avg(42)
```

Add types, code still runs

Gradual Types + Costs

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avg : Gradebook -> Num
def avg(g):
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```

```
avg(quiz_1_grades)
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Gradual Types + Costs

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Type soundness ◀ Runtime checks

Gradual Types + Costs

```
avg : Gradebook -> Num
def avg(g):
  return mean(get_column(g, "score"))
```

```
avg(quiz_1_grades)   ✓
avg(recipe_book)     ■
avg(42)              ■
```

Type soundness ➤ Runtime checks

Costs depend ...

Guarded semantics

(**deep** types)

Contract @ boundary

Transient semantics

(**shallow** types)

Asserts in typed code

Gradual Types + Costs

```
avg : Gradebook -> Num
def avg(g):
  return mean(get_column(g, "score"))
```

```
avg(quiz_1_grades)   ✓
avg(recipe_book)     ■
avg(42)              ■
```

Type soundness ◀ Runtime checks

Costs depend ...

deep

check full gradebook

9x

shallow

check book shape, numbers

~1x

```
avg : Gradebook -> Num
def avg(g):
  return mean(get_column(g, "score"))
```

```
avg(quiz_1_grades)
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```

```
avg : Gradebook -> Num
def avg(g):
  return mean(get_column(g, "score"))
```

```
avg(quiz_1_grades)
```

deep

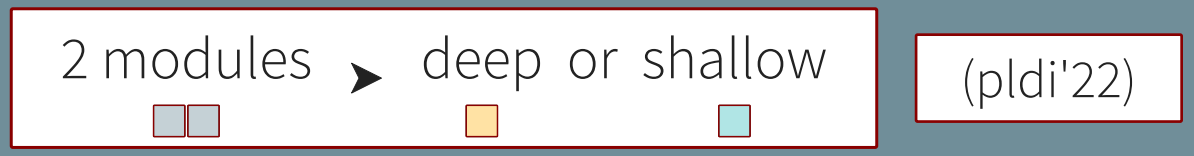
no boundaries!

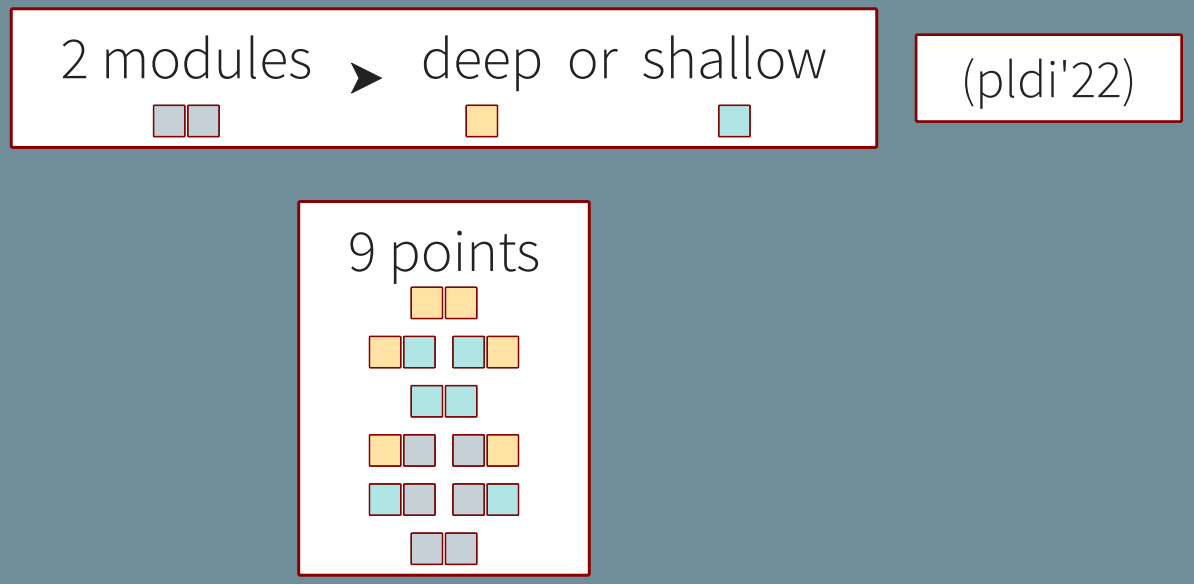
1x

shallow

more types, more checks

2x


2 modules
deep or shallow
(pldi'22)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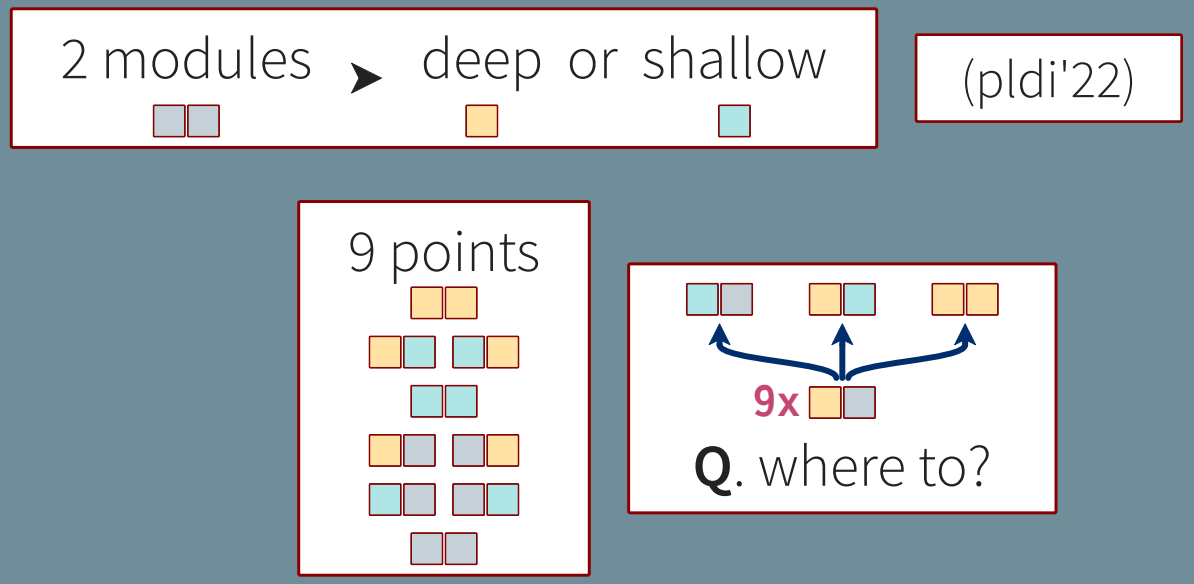
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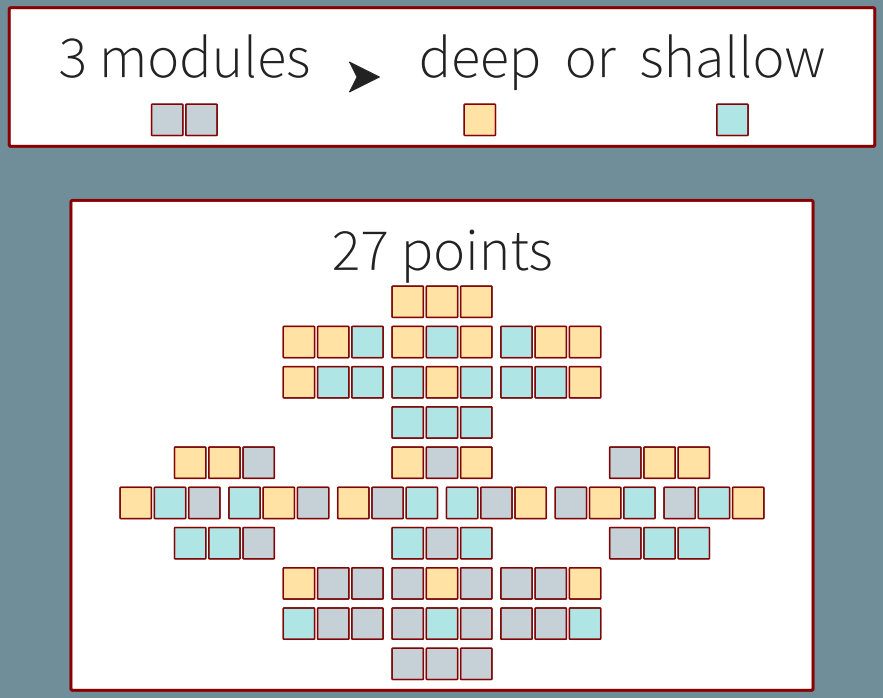
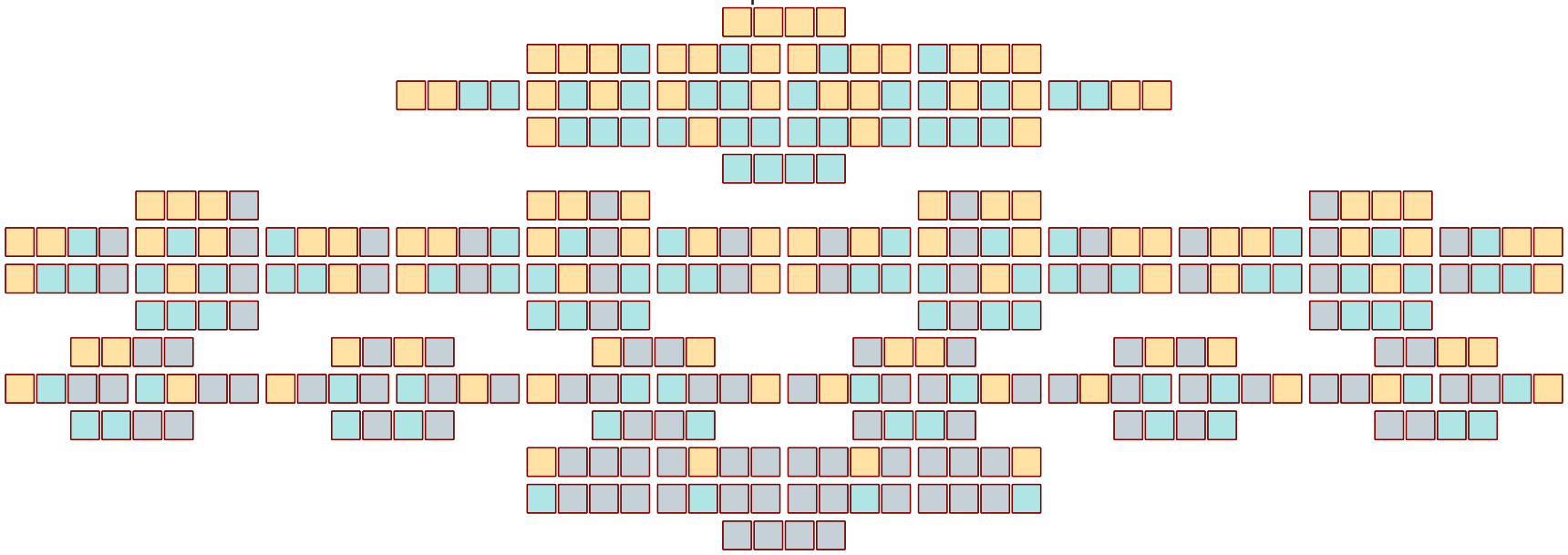
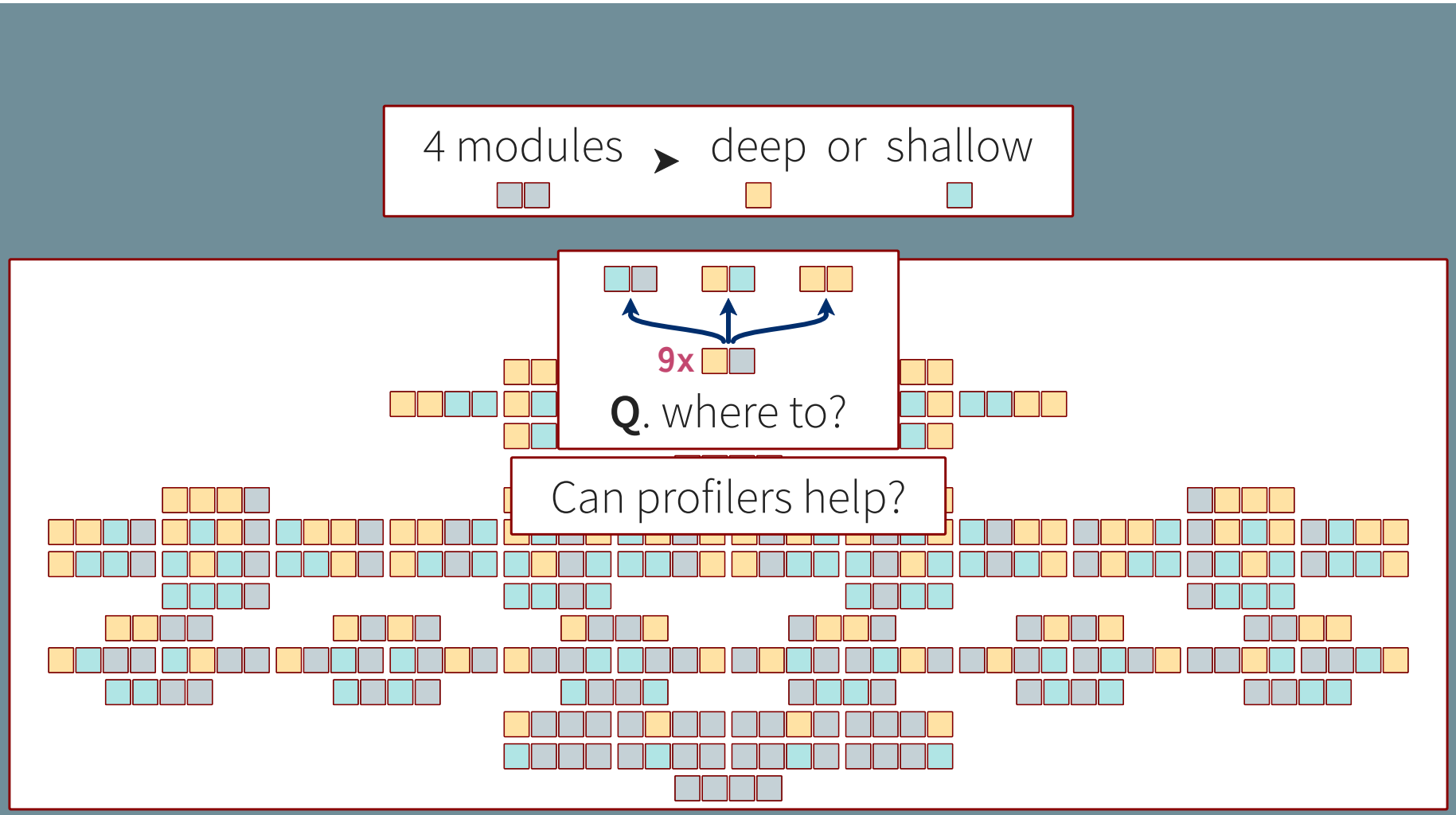
9 points
9x
Q. where to?


3 modules
deep or shallow
27 points

4 modules ➤ deep or shallow




4 modules
deep or shallow
9x
Q. where to?
Can profilers help?

Profilers

Profilers

Statistical Profiler

Contract Profiler

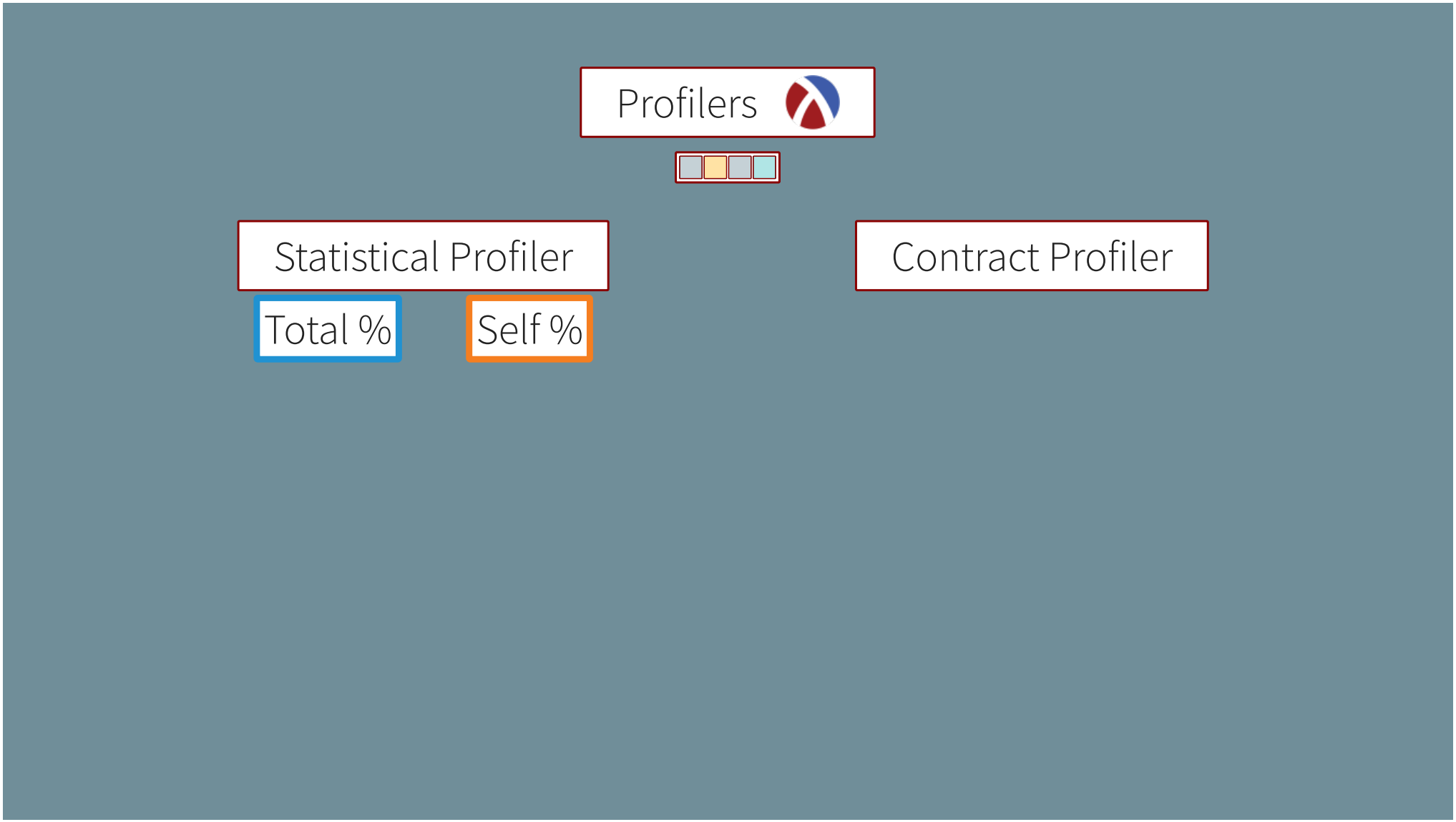
Profilers

Statistical Profiler

```
  Total cpu time observed: 1192ms (out of 1236ms)
  Number of samples taken: 23 (once every 52ms)

================================================
         ■          ■          Caller
 Idx    Total      Self       Name+src
        ms(pct)    ms(pct)    Callee
================================================
                              ??? [12]
                              evolve [17]
[17]  818(68.6%)    0(0.0%)   evolve main
                              evolve [17]
                              shuffle-vector [19]
                              death-birth [18]
                              ??? [20]
------------------------------------------------
                              match-up* [22]
                              shuffle-vector [19]
[24]  152(12.7%)  152(12.7%)  contract-wrapper
------------------------------------------------
```

Contract Profiler


Profilers
Statistical Profiler
Total %
Self %
Contract Profiler

Profilers

Statistical Profiler

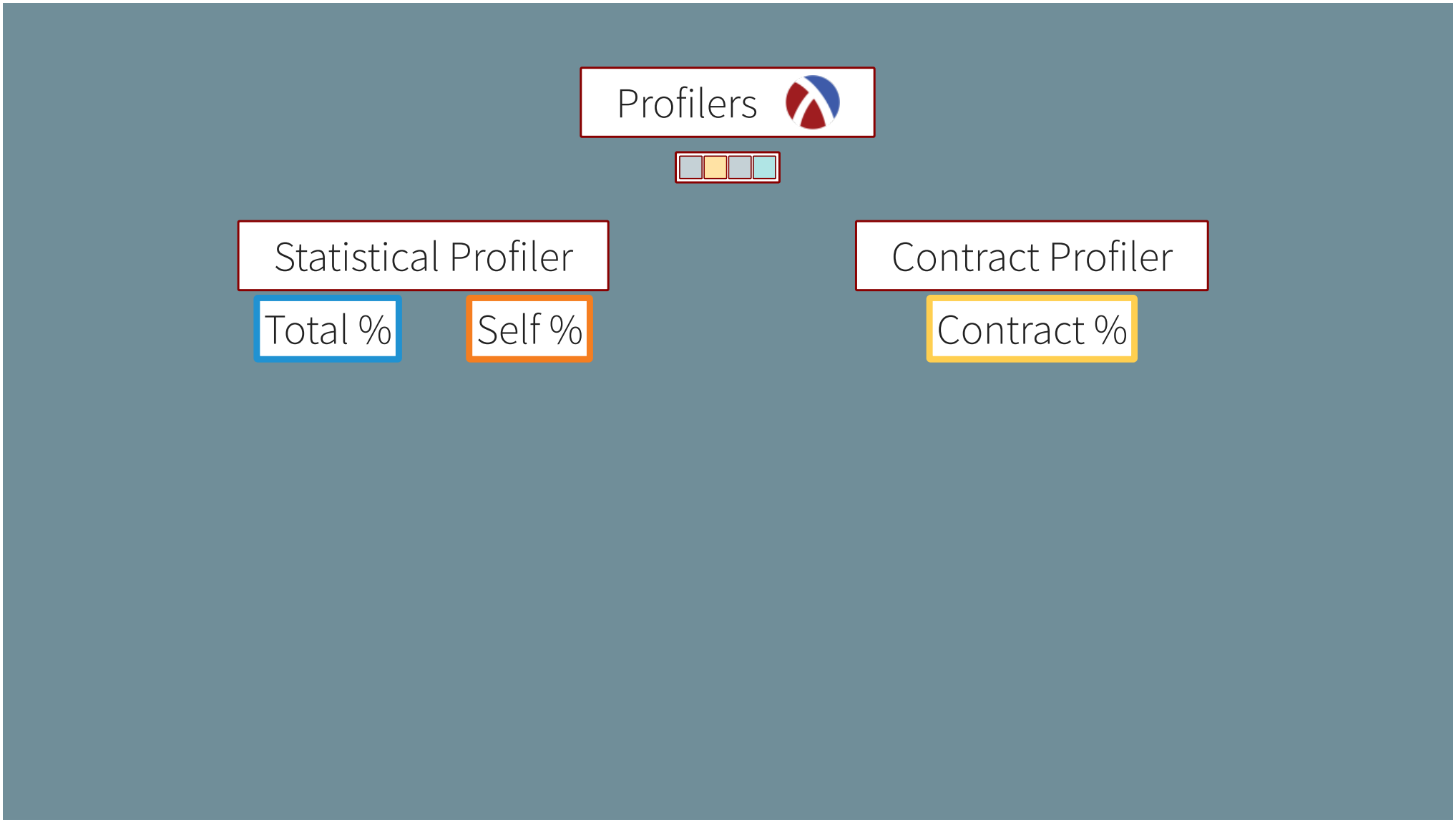
Total %

Self %

Contract Profiler

```
cpu time: 984 real time: 984 gc time: 155
Running time is 18.17% contracts
253/1390 ms

(interface:death-birth pop main)
  142 ms
  (->* ((cons/c (vectorof automaton?)
                (vectorof automaton?))
        any/c)
       (#:random any/c)
       (cons/c (vectorof automaton?)
               (vectorof automaton?)))
(interface:match-up* pop main)
  81.5 ms
  (-> ....)
(interface:population-payoffs pop main)
  29 ms
  (-> ....)
```


Profilers
Statistical Profiler
Total %
Self %
Contract Profiler
Contract %

Deep types
Contract @ boundary

Contract %

Total %

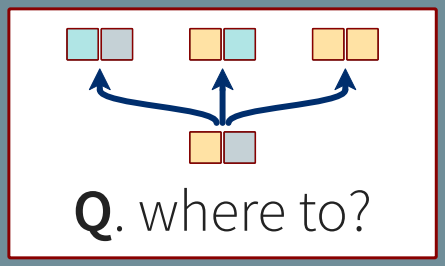
Self %

Shallow types
Asserts in typed code

Contract %

Total %

Self %



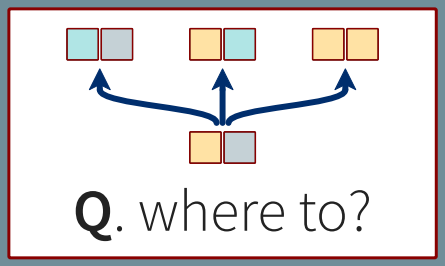
Q. where to?

Q. how to find a boundary?

Contract %

Total %

Self %



Q. where to?

A. Rational Programmer experiment

Q. how to find a boundary?

Contract %

Total %

Self %

Rational Programmer

Rational Programmer

Identify strategies, let them compete.

Rational Programmer

Identify strategies, let them compete.

Deep ()

Rational Programmer

Identify strategies, let them compete.

Deep ( )

Shallow

...

Rational Programmer

Identify strategies, let them compete.

Deep ( )

Shallow

Type-Aware Deep

1. 
2. 

Rational Programmer

Identify strategies, let them compete.

Deep ( )

Shallow

… 

Type-Aware Deep

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… 

Rational Programmer

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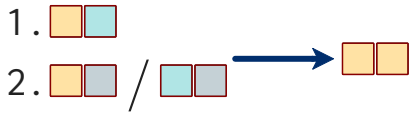


Type-Aware Shallow

Lattice[S; D] count #typed, choose Deep or Shallow

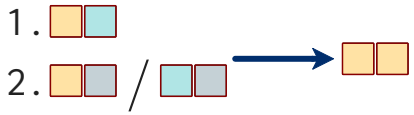
Rational Programmer

Identify strategies, let them compete.

Deep ( )

Shallow

Type-Aware Deep



Type-Aware Shallow

Lattice[S; D] count #typed, choose Deep or Shallow

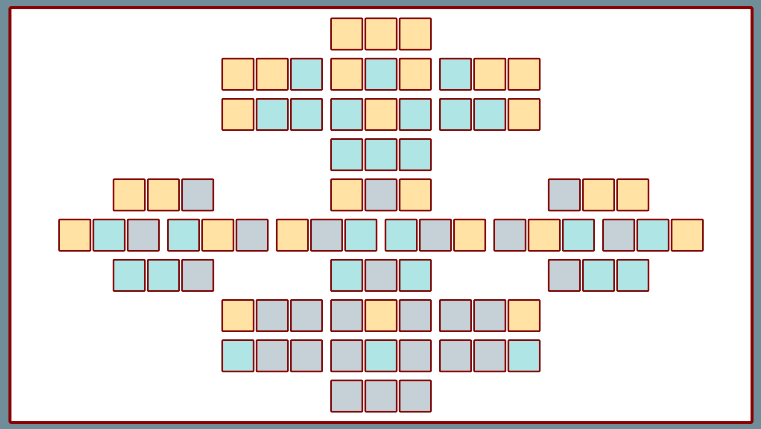
null, **pldi22** = baselines

Rational Programmer

Identify strategies, let them compete.

Rational Programmer

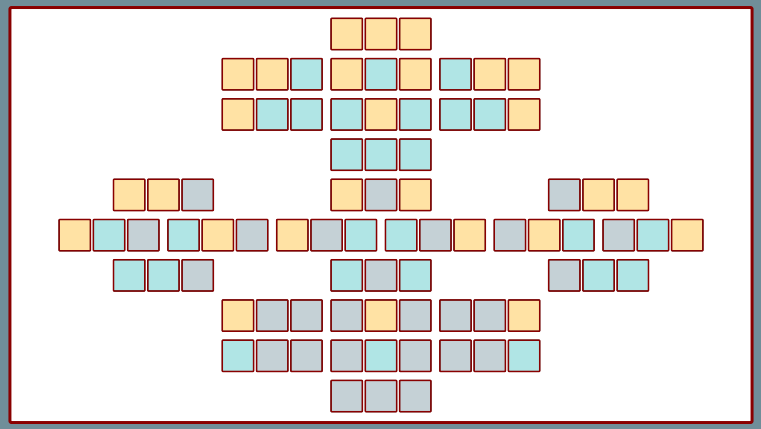
Identify strategies, let them compete.



For all starting points,
Goal = **path** to a fast config

Rational Programmer

Identify strategies, let them compete.



For all starting points,
Goal = **path** to a fast config

strict = faster each step

k **loose** = k slower steps

99x ➤ 99x ➤ 3x ➤ **1x**

3x ➤ **99x** ➤ **1x**

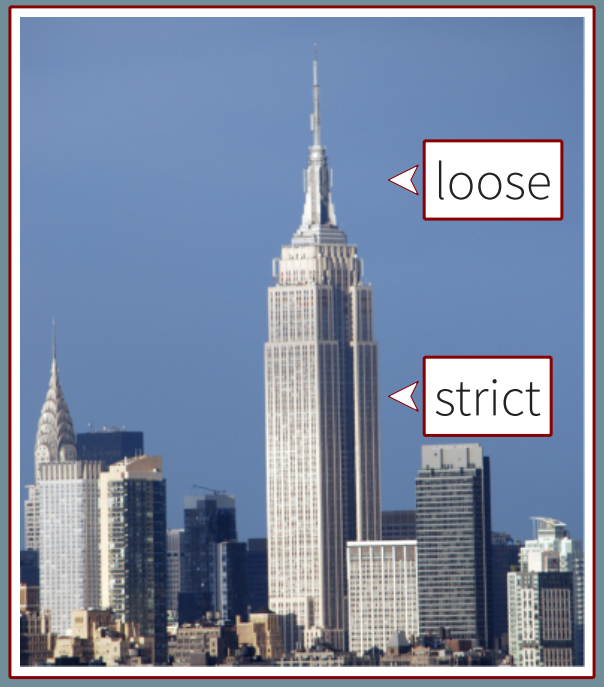
Dataset

16	GTP Benchmarks
116 K	starting points
1.2 M	measurements
5 GB	output
10	months on CloudLab

How often do the strategies succeed?

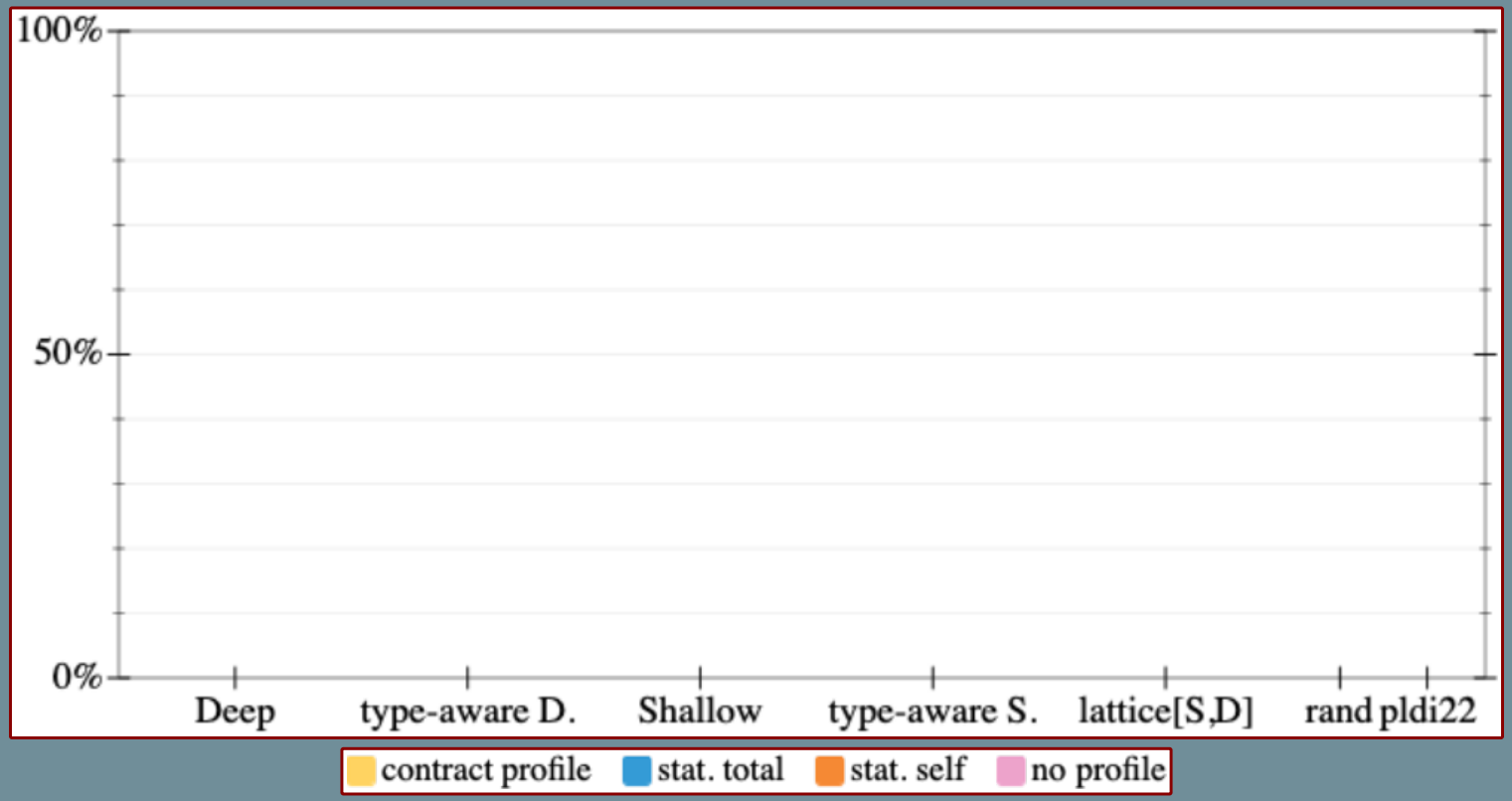
How often do the strategies succeed?

How often do the strategies succeed?



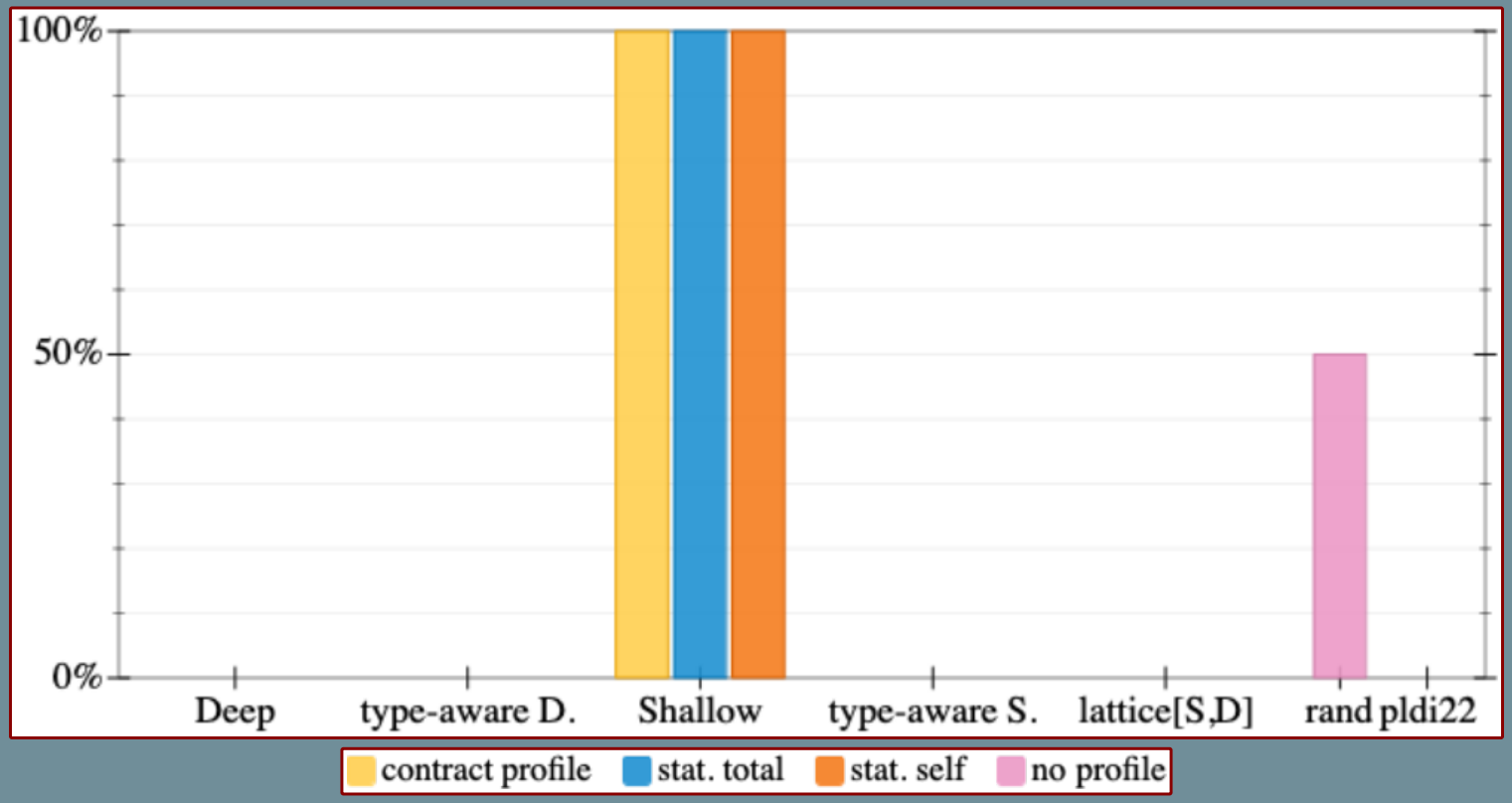
How often do the strategies succeed?

X = strategies, Y = % scenarios



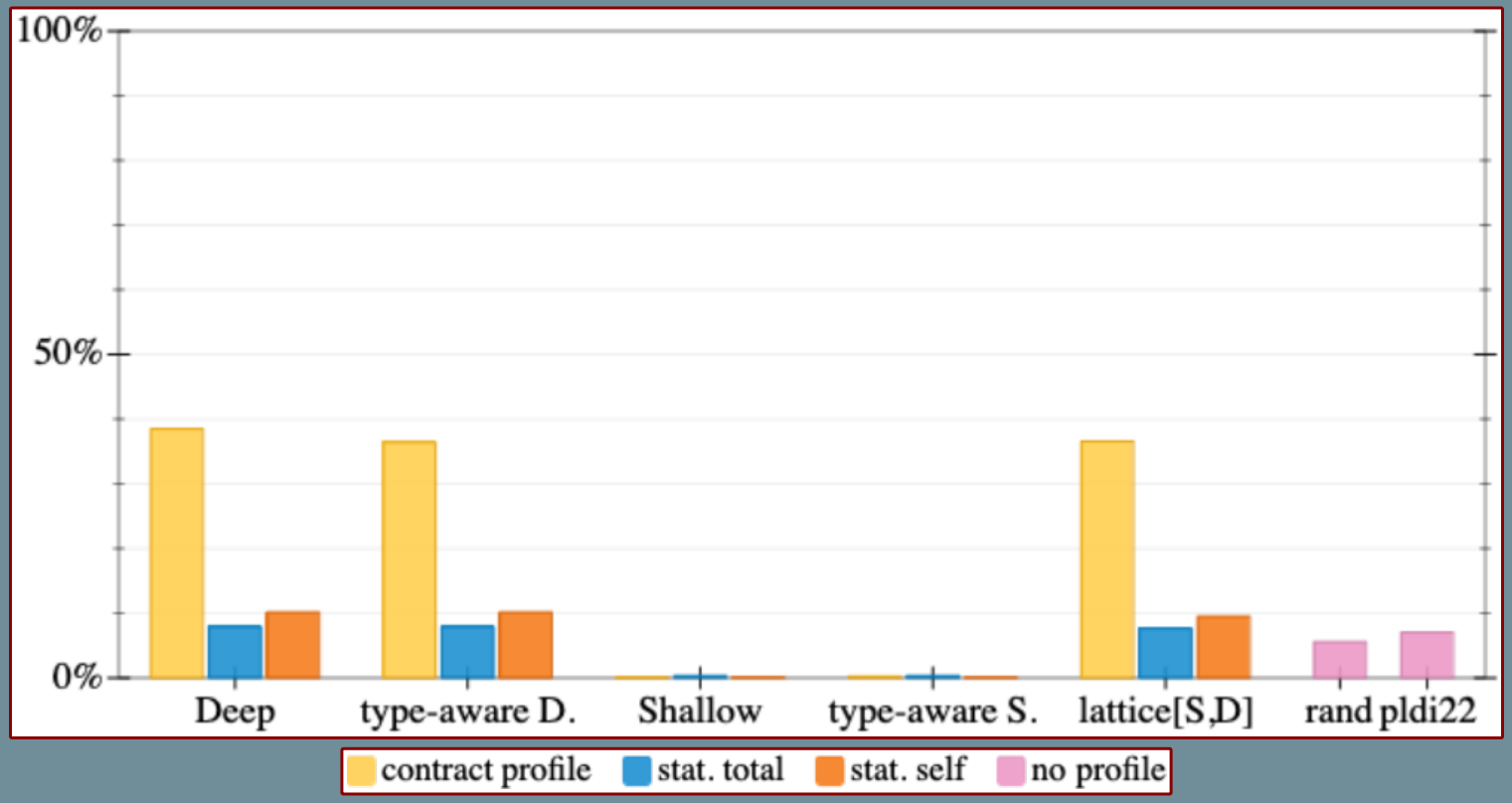
How often do the strategies succeed?

example data



How often do the strategies succeed?

strict success



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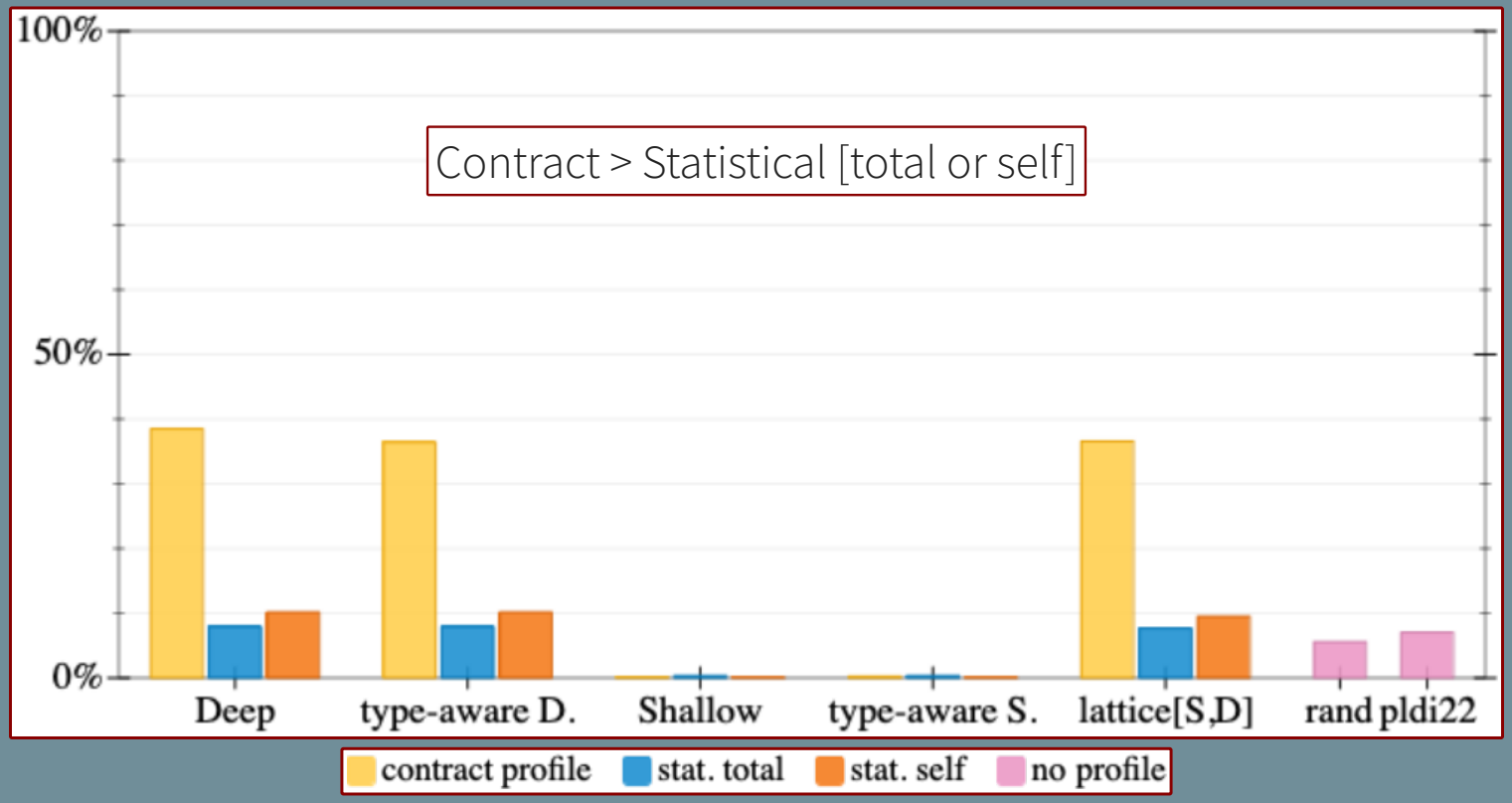

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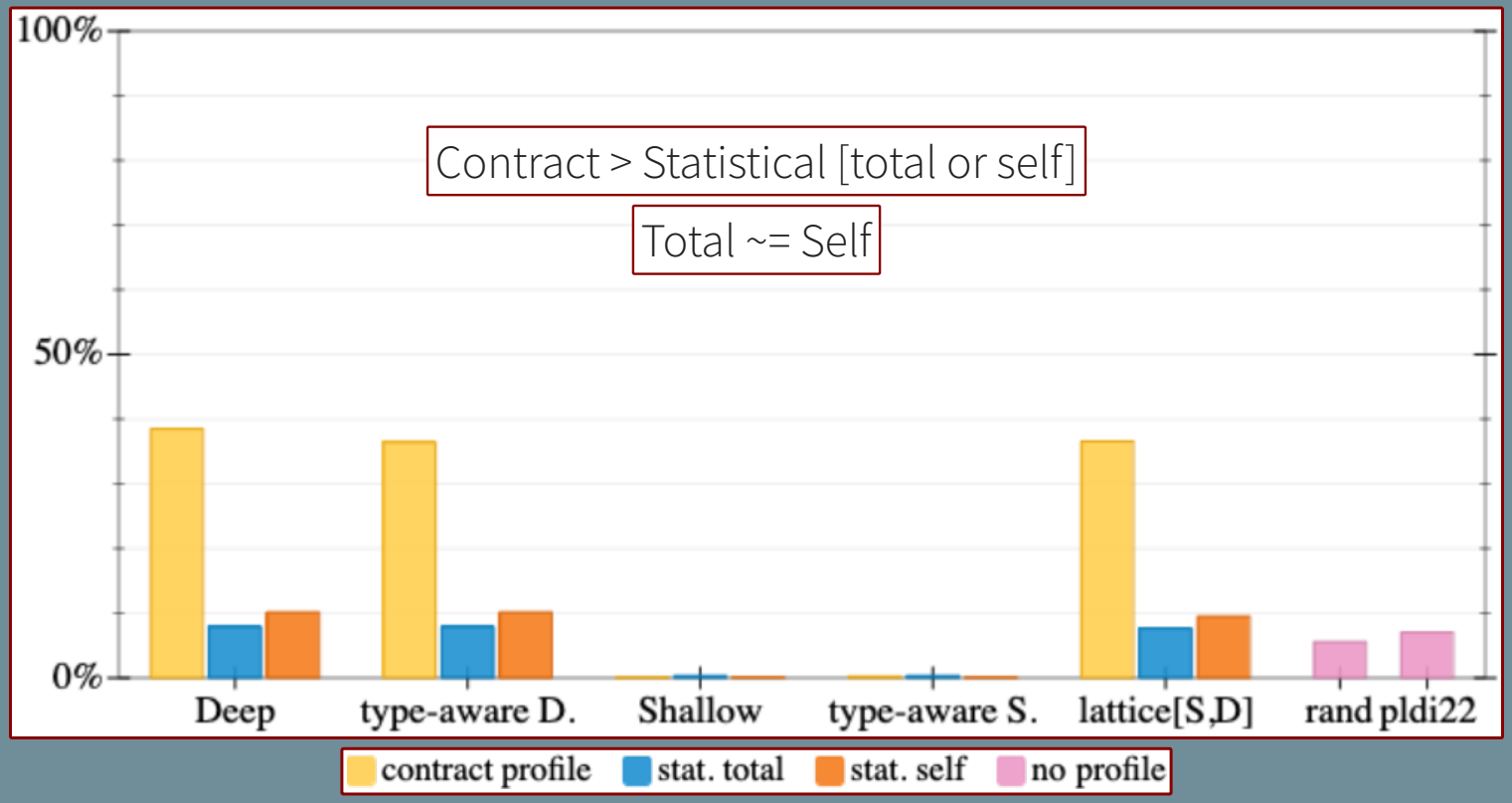

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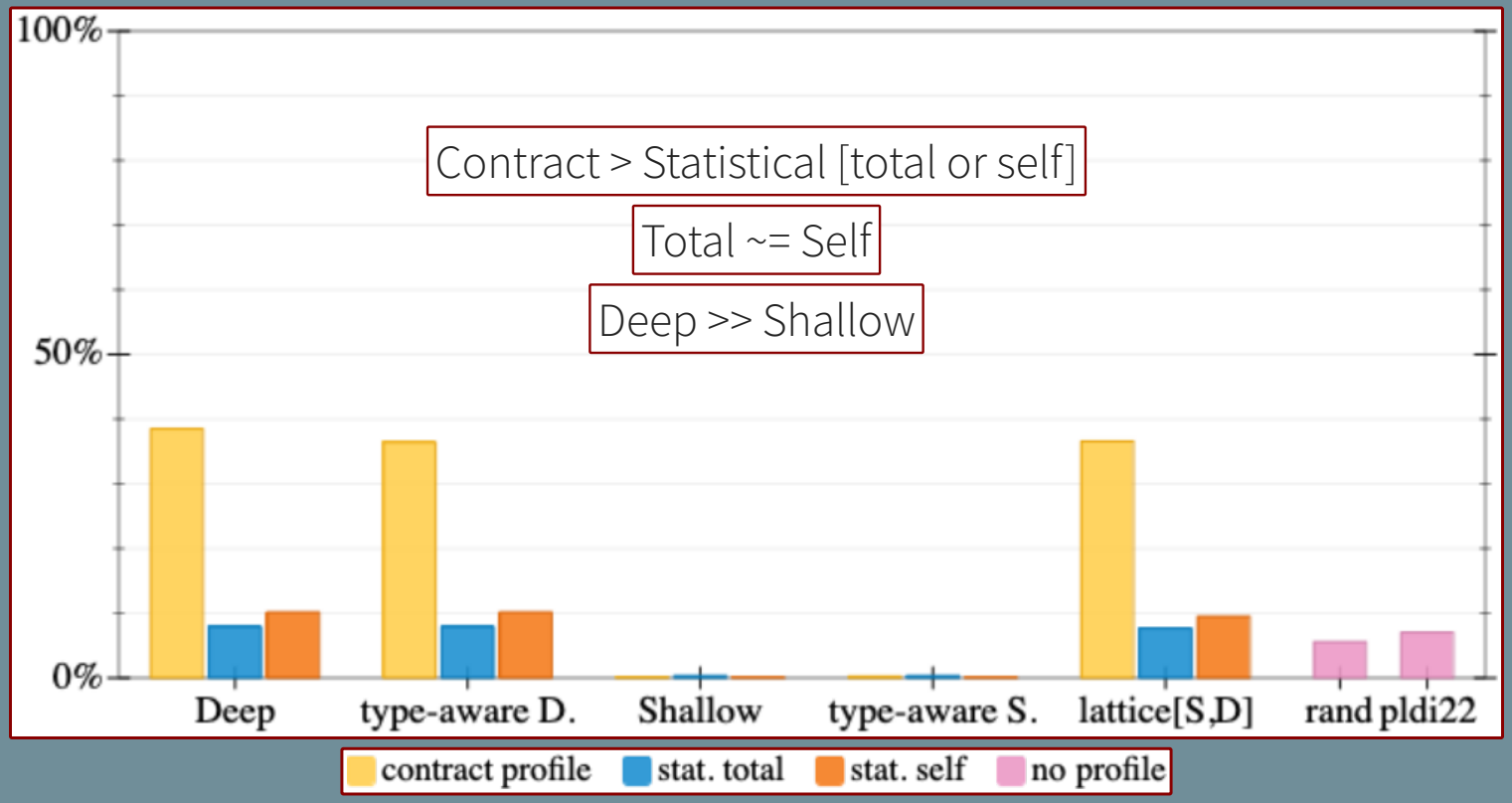

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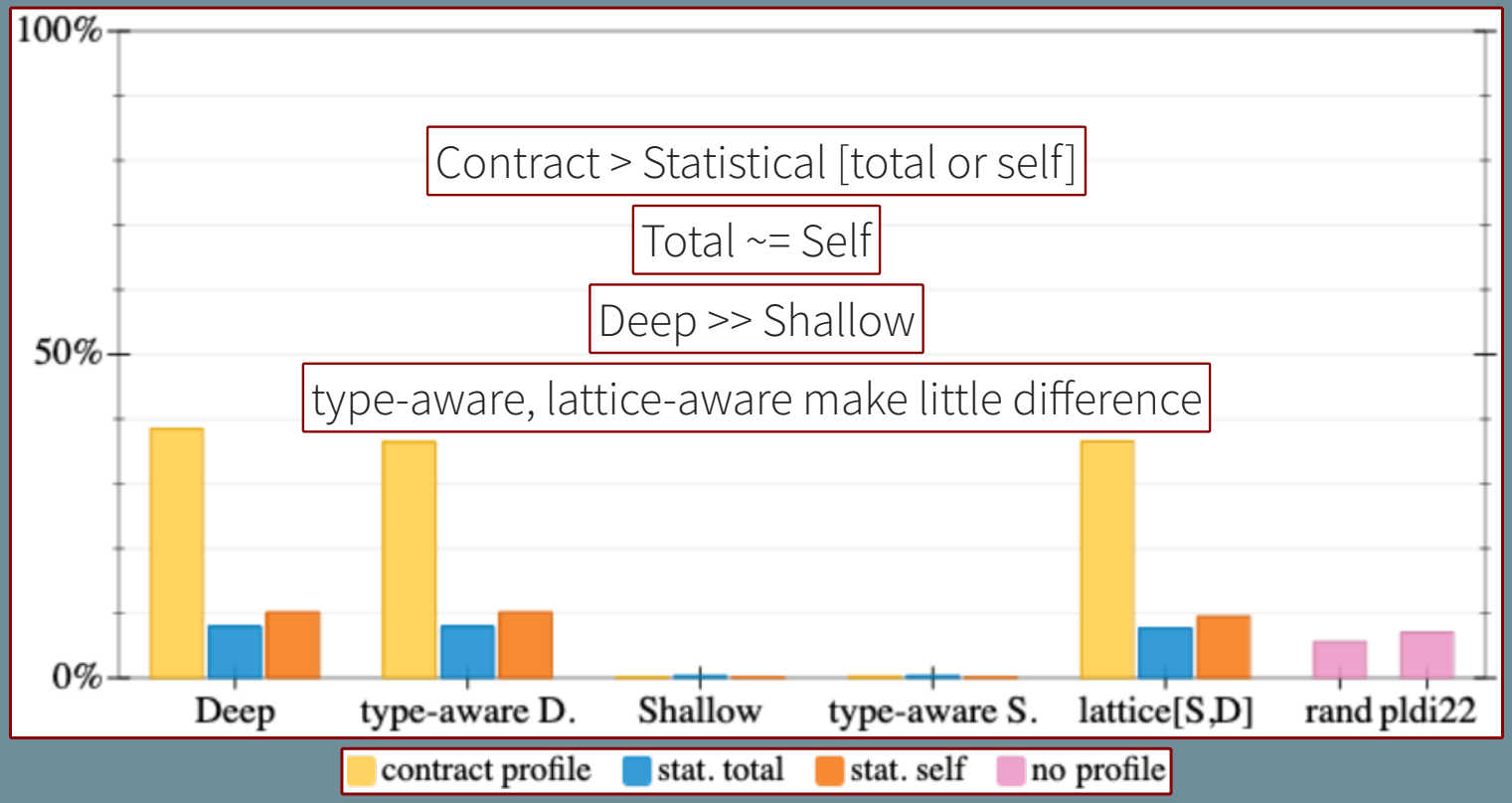
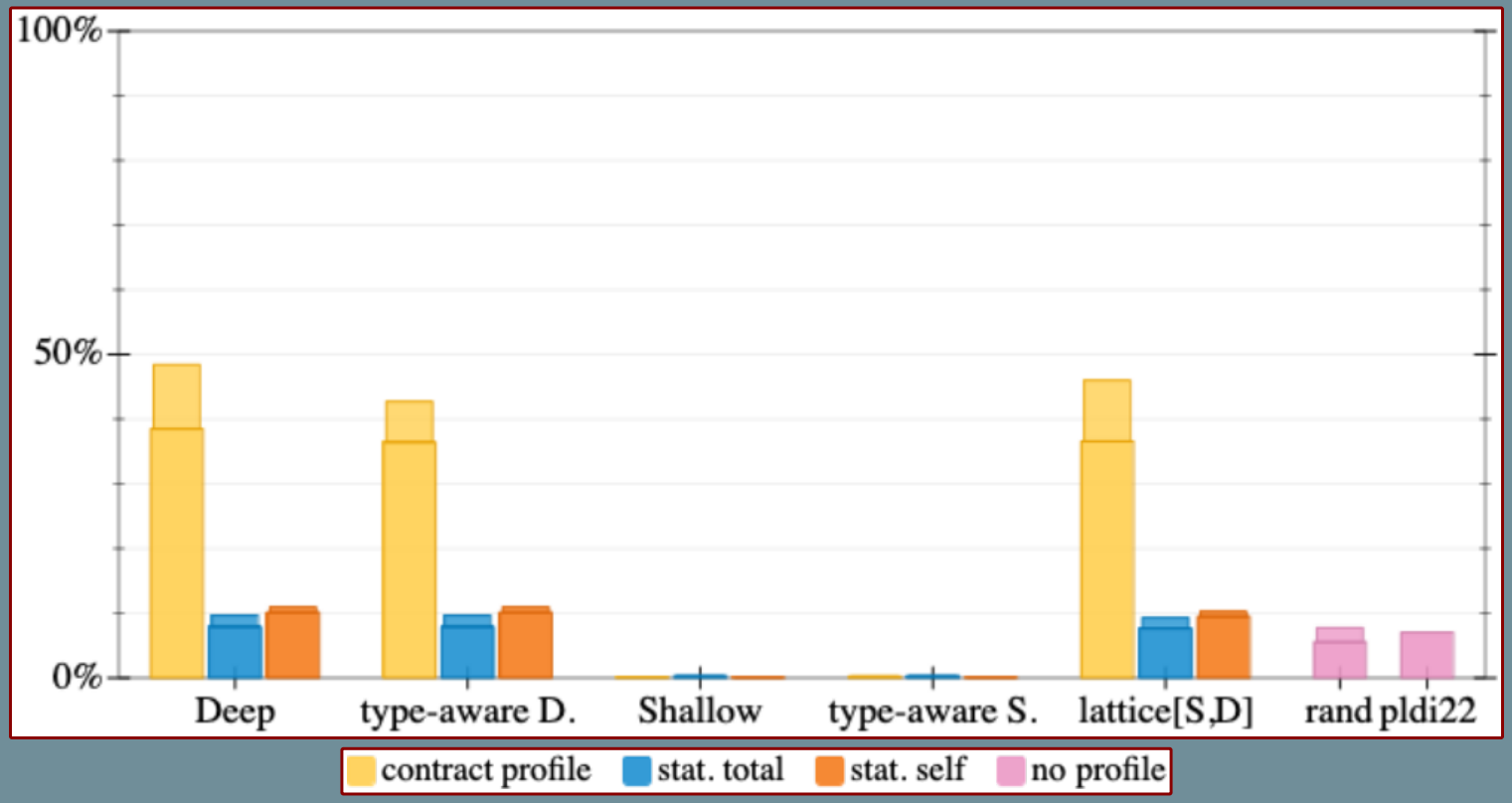


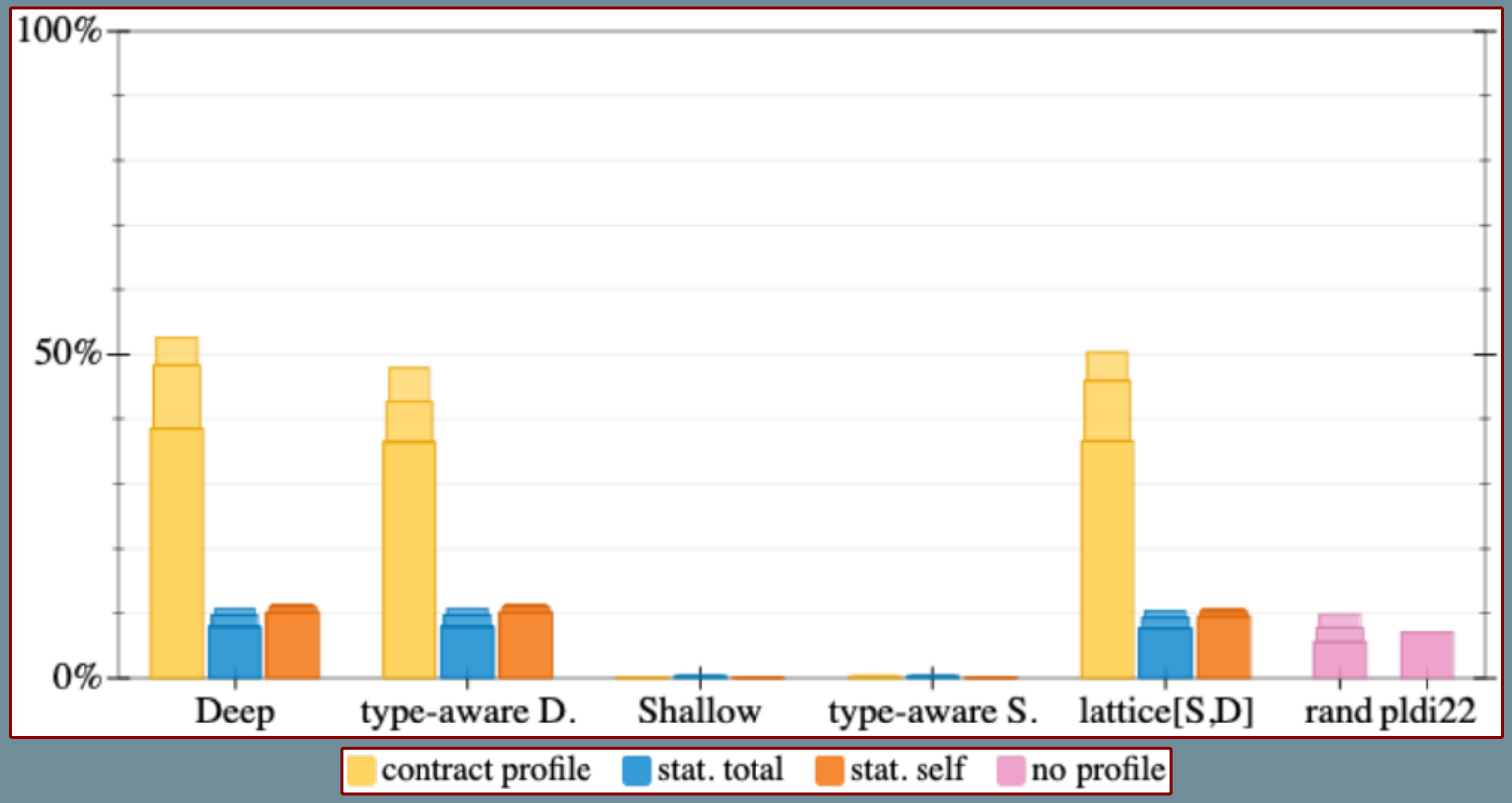
How often do the strategies succeed?

strict success | 1 loose



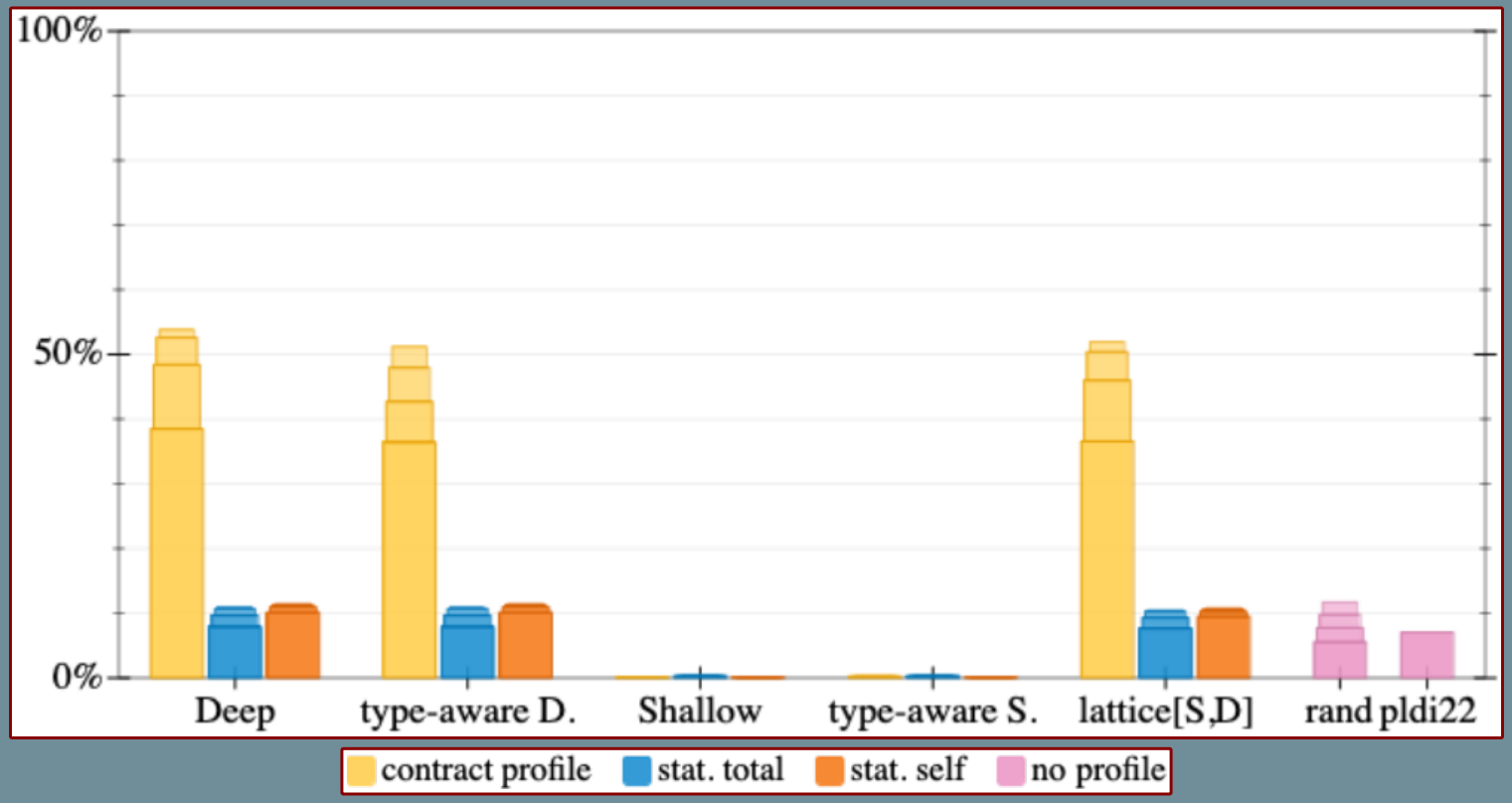
How often do the strategies succeed?

strict success | 1 loose | 2 loose



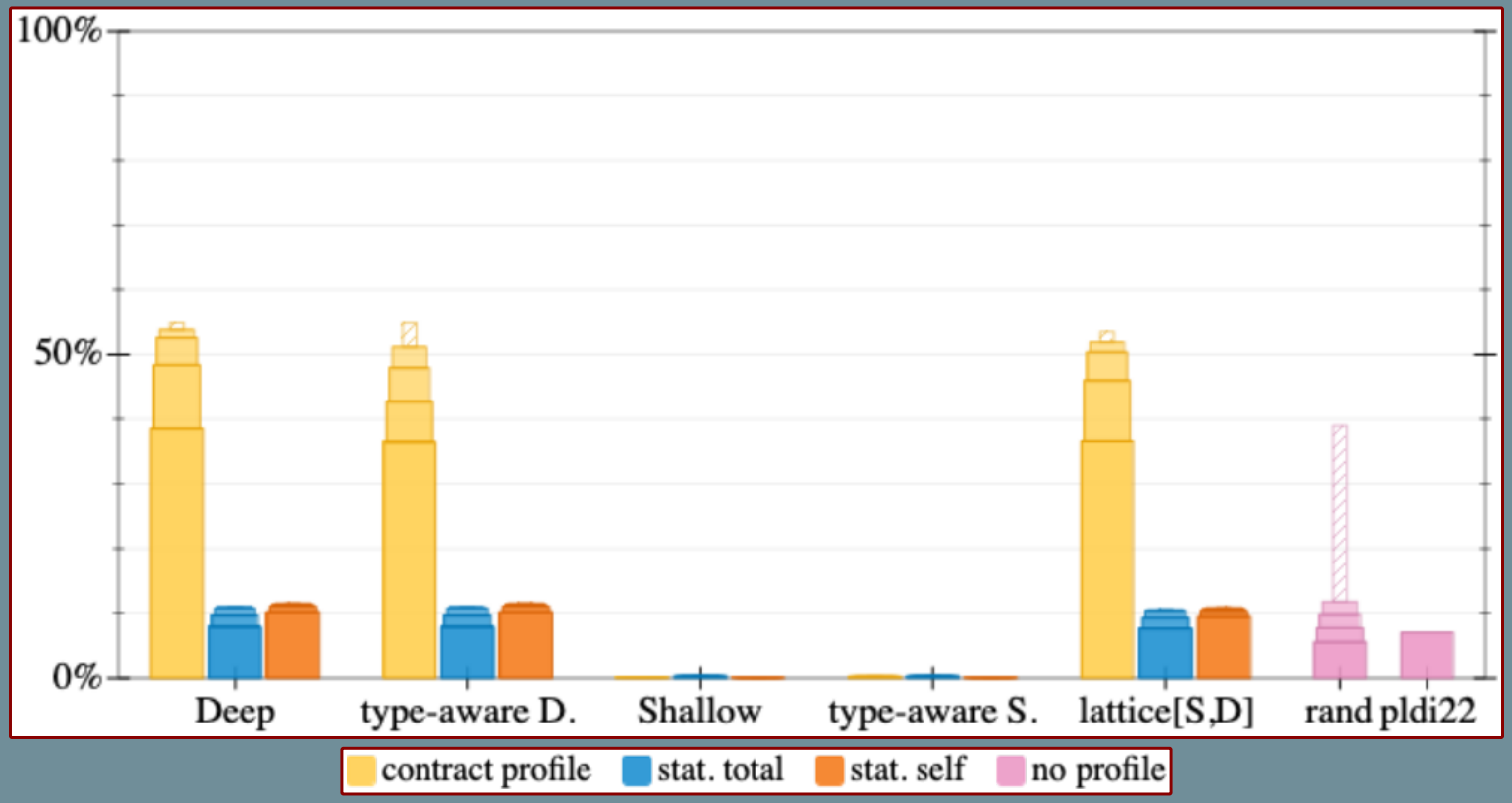
How often do the strategies succeed?

strict success | 1 loose | 2 loose | 3 loose



How often do the strategies succeed?

strict success | 1 loose | 2 loose | 3 loose | N loose



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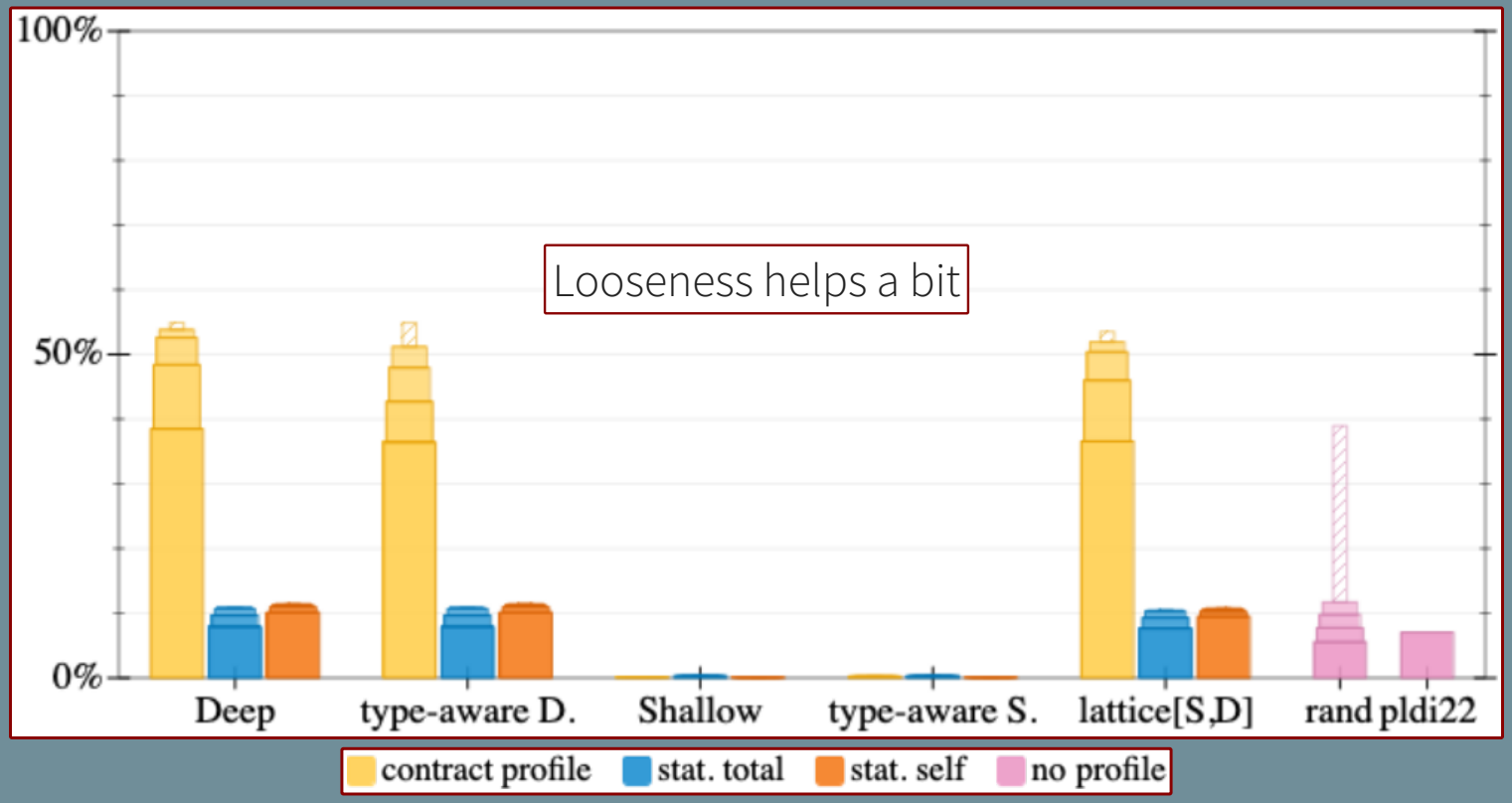
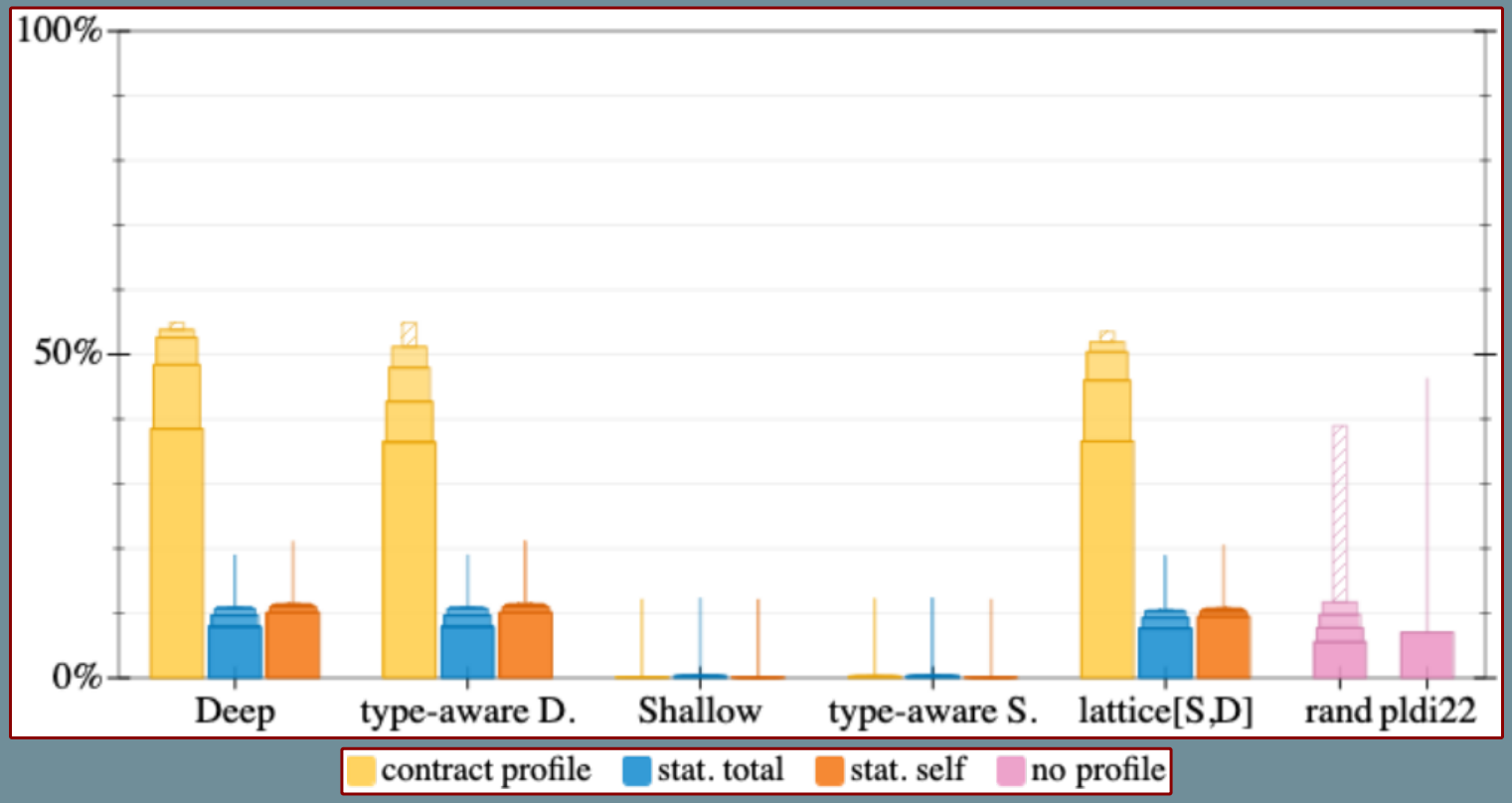


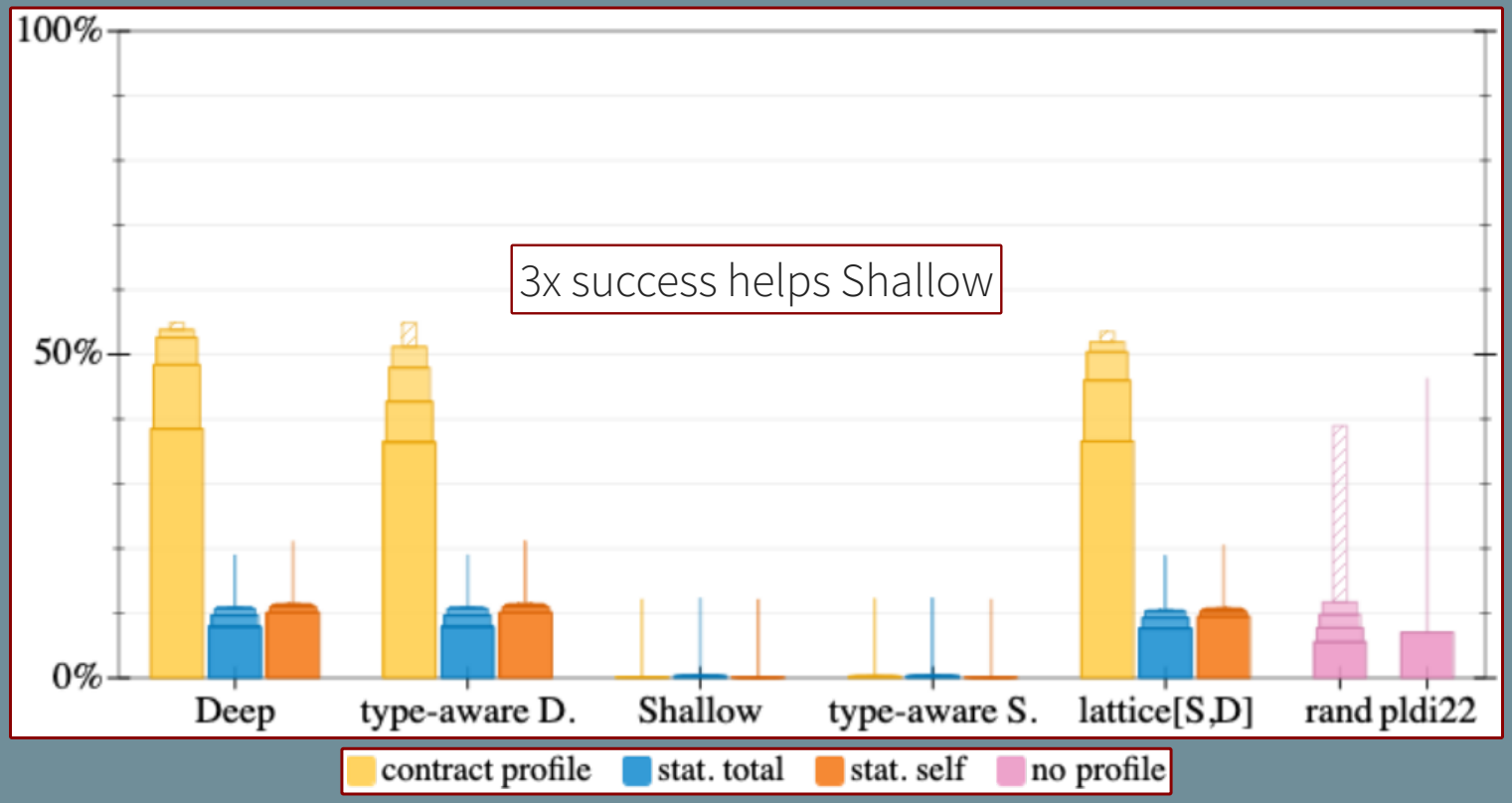
How often do the strategies succeed?

strict success | 1 loose | 2 loose | 3 loose | N loose | strict 3x



How often do the strategies succeed?

strict success | 1 loose | 2 loose | 3 loose | N loose | strict 3x



Takeaways

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* **contract** profiling + **deep** types
  = **best** for type migration

Takeaways

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* shallow types do not help

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* **contract** profiling + **deep** types
  = **best** for type migration

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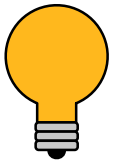
Q. hybrid strategies, shallow profilers?

Takeaways



* the **rational programmer** method
  enables rigorous **experiments**

* **contract** profiling + **deep** types
  = **best** for type migration

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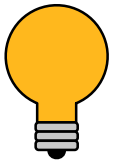
Takeaways



* the **rational programmer** method enables rigorous **experiments**

errors testing?
perf debugging?

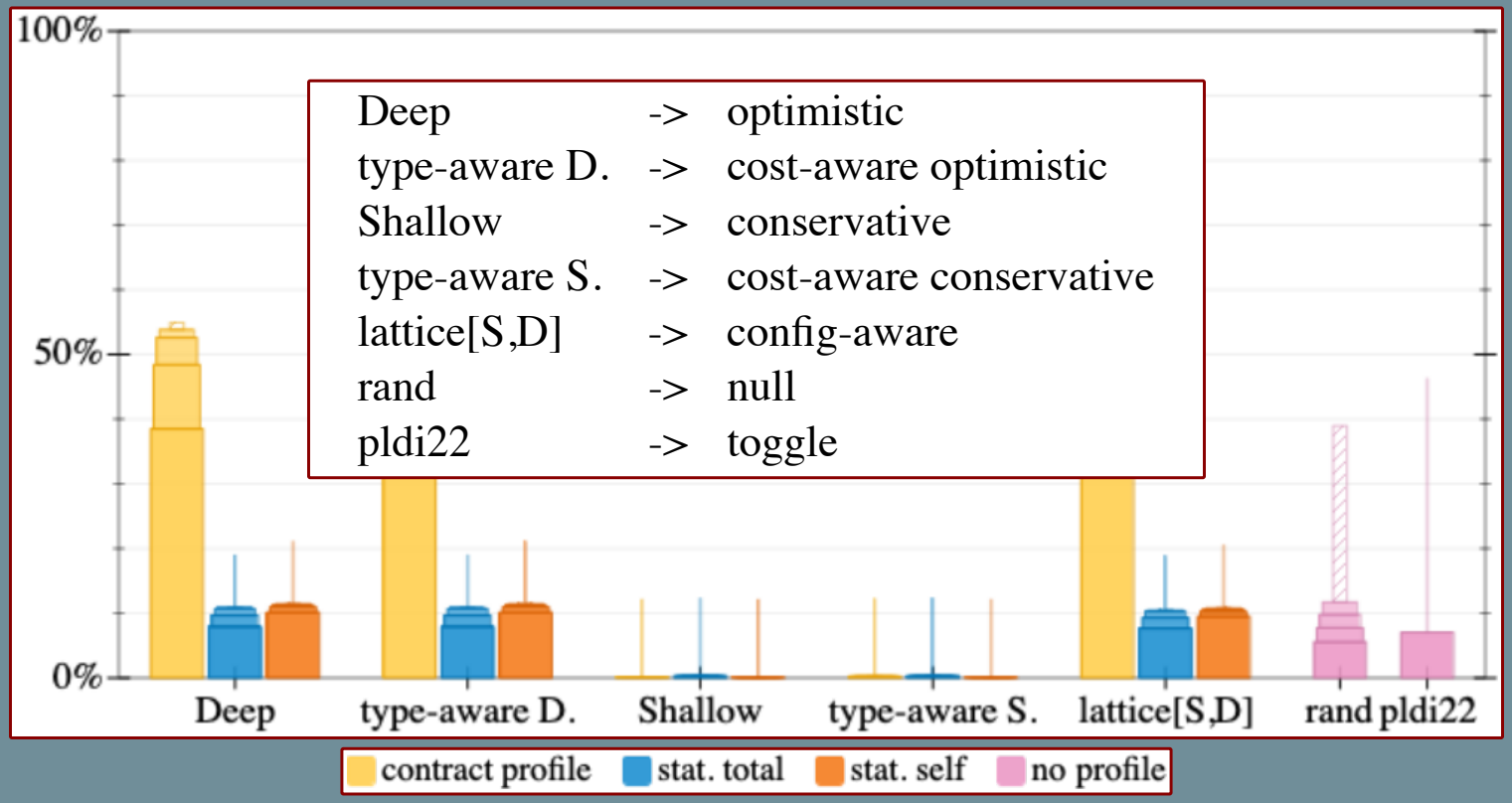
* **contract** profiling + **deep** types = **best** for type migration

* shallow types do not help

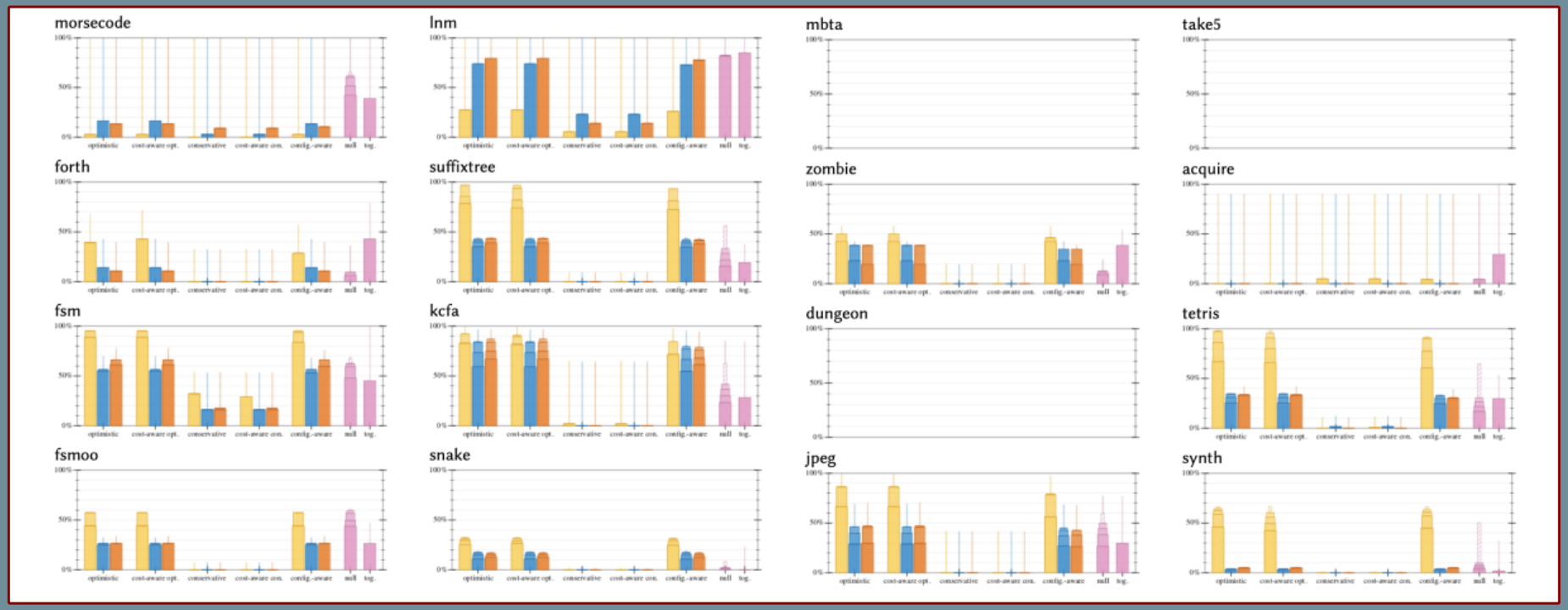
https://github.com/bennn/rational-deep-shallow

Translation: talk -> paper

strict success | 1 loose | 2 loose | 3 loose | N loose | strict 3x



Skylines per Benchmark

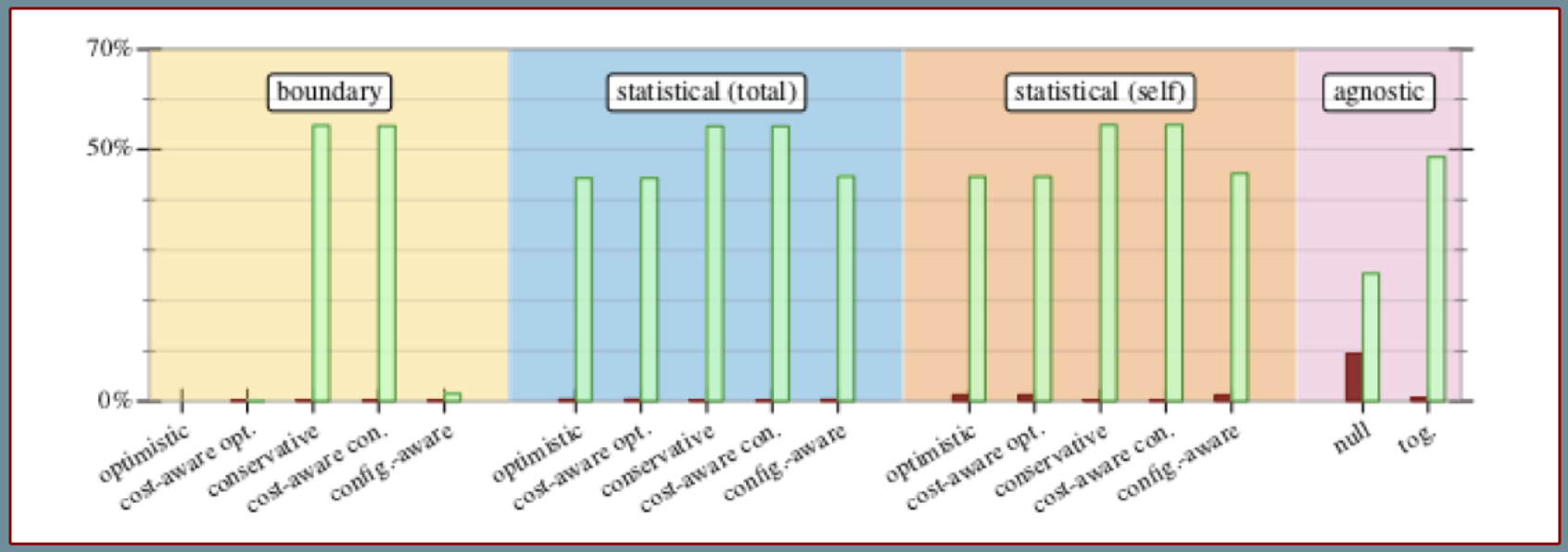


Hopeful Scenarios

Table 3. How many scenarios can possibly reach 1x without removing types?

Benchmark	# Scenario	% Hopeful	Benchmark	# Scenario	% Hopeful
morsecode	67	100.00 %	lnm	295	100.00 %
forth	76	36.84 %	suffixtree	718	100.00 %
fsm	62	100.00 %	kcfa	2,031	100.00 %
fsmoo	68	100.00 %	snake	6,559	100.00 %
mbta	72	0.00 %	take5	6,558	0.00 %
zombie	74	35.14 %	acquire	19,532	5.45 %
dungeon	242	0.00 %	tetris	18,791	100.00 %
jpeg	230	100.00 %	synth	59,046	100.00 %

Opt-Boundary vs. the others



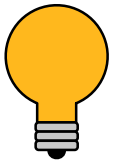
Where are the Fast Configs?

Table 4. Which levels of the migration lattice have any acceptable configurations?

Benchmark	#acceptable					
morsecode	1	2	4	4	3	
forth	1	2	1	1	0	
fsm	1	3	4	7	4	
fsmoo	1	2	4	2	4	
mbta	1	4	4	0	0	
zombie	1	2	3	1	0	
dungeon	1	0	0	0	0	0
jpeg	1	2	1	1	4	4

Benchmark	#acceptable by lattice level										
lnm	1	9	38	93	138	116	39				
suffixtree	1	1	0	0	1	4	4				
kcfa	1	8	22	33	24	24	29	15			
snake	1	0	0	0	0	0	0	0	1		
take5	1	2	0	0	0	0	0	0	0		
acquire	1	8	28	51	45	16	2	0	0	0	
tetris	1	12	56	121	169	128	118	133	112	42	
synth	1	1	0	0	0	0	0	0	0	0	1

Takeaways



* the **rational programmer** method
  enables rigorous **experiments**

* **contract** profiling + **deep** types
  = **best** for type migration

* shallow types do not help