Debugging Dynamic Language Features in a Multi-Tier Virtual Machine

Smoke and Mirror

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Dynamic Languages are **great**!

The **R** programming language, JS, lua...

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Slow and **complex** runtimes

The problem with optimizing dynamic languages

```
1   # Parent Scope
2   x <- 100
3   f <- function(a) {
4       a;
5       # Function Scope
6       print(x);
7   }
8
9
10
11
12
13
14
15
16
17
```

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2   x <- 100
3   f <- function(a) {
4       a;
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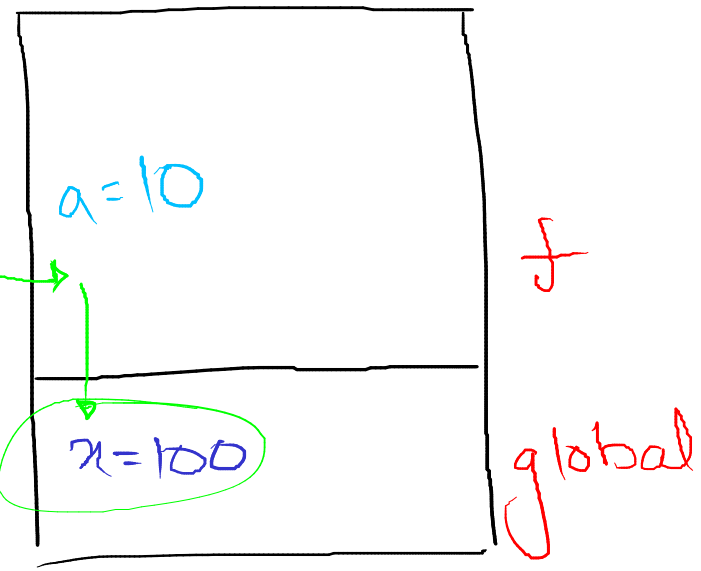
7   }
8
9   f(10)
10
11  # Output: 100
12
13
14
15
16
17
```



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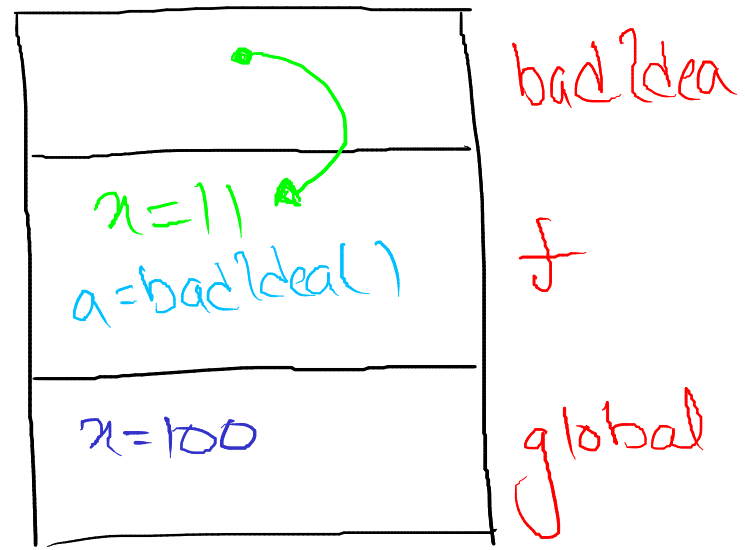


```r
badIdea <- function() { assign("x", 11, sys.frame(-1)); 1; }
f(badIdea())

# Output: 11
```

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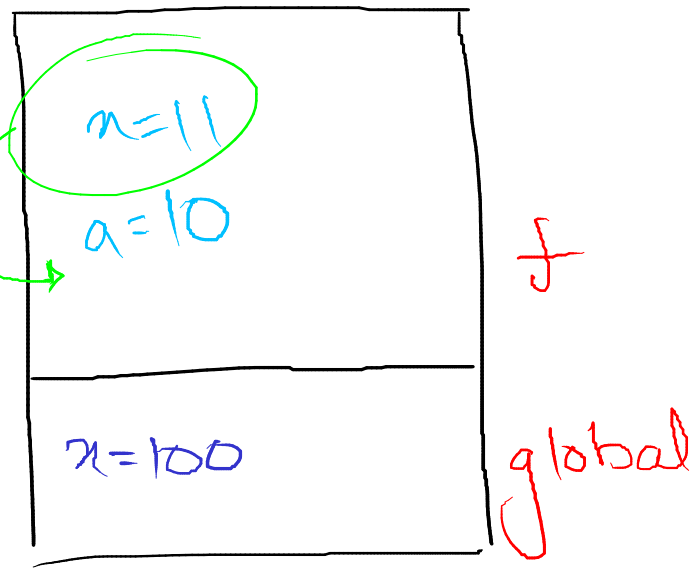


The $\check{\mathbf{R}}$ JIT compiler

Optimize for the most common cases.

- Runtime profiling
  - Collect information about **types**, **call sites**, **branches**.

The Řr JIT compiler

Optimize for the most common cases.

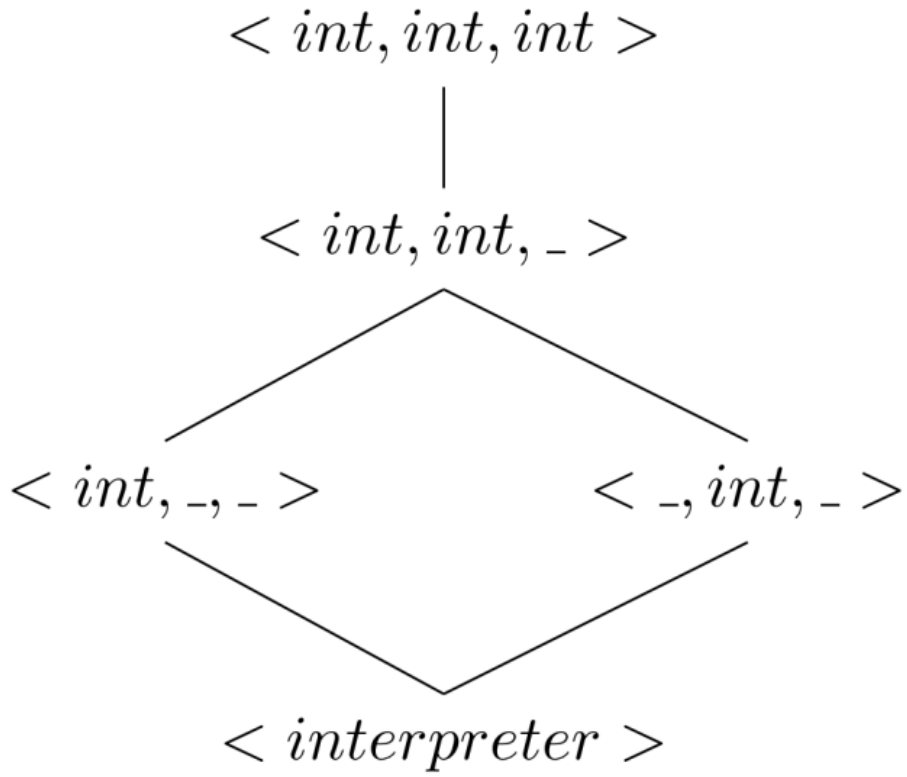
- Runtime profiling
  - Collect information about **types**, **call sites**, **branches**.
- Contextual Specialization
  - Optimize for **classes of behaviours**.

Contextual Dispatch

```
f (1L, 2L, 3L)

f (1L, 2L, 12.3)

f (1L, "a", 3L)
```



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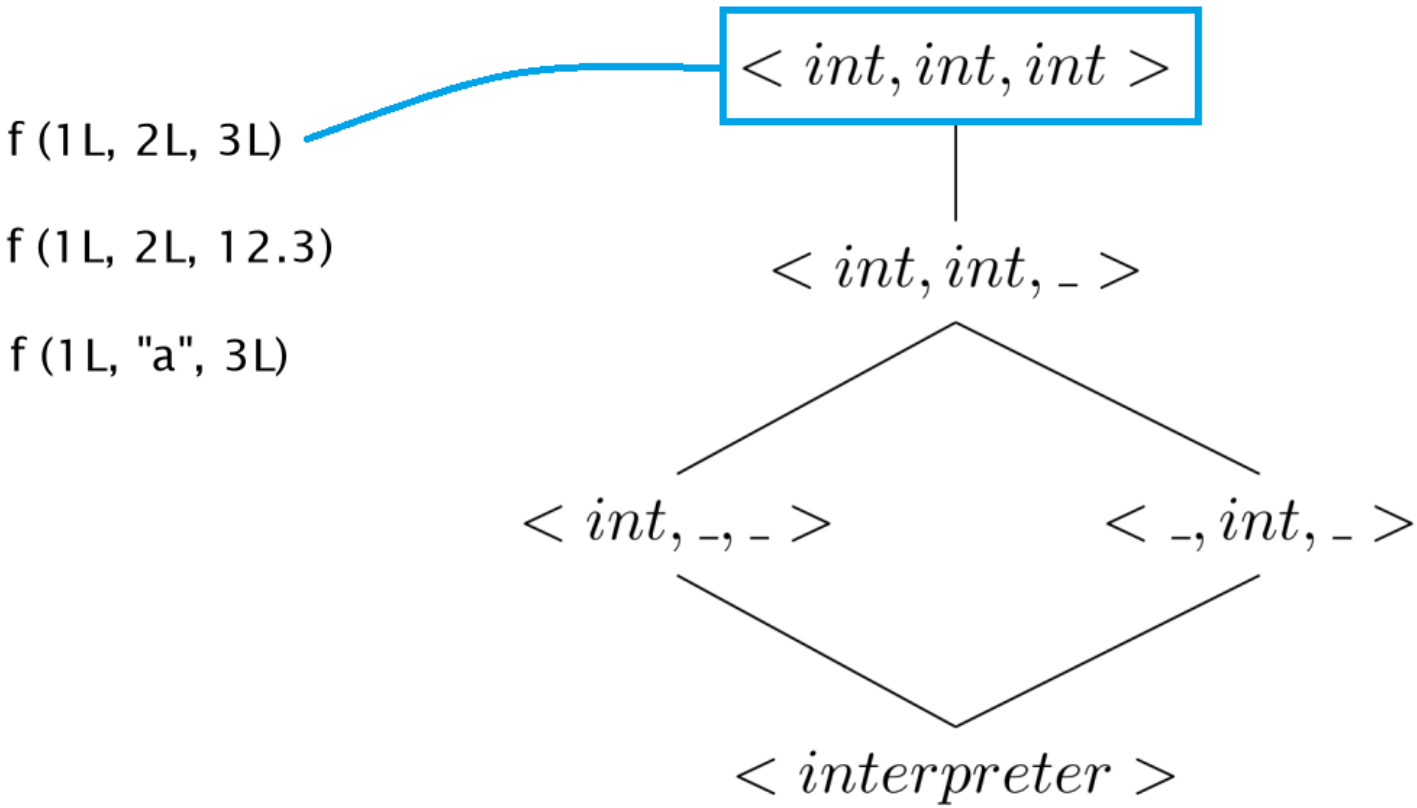

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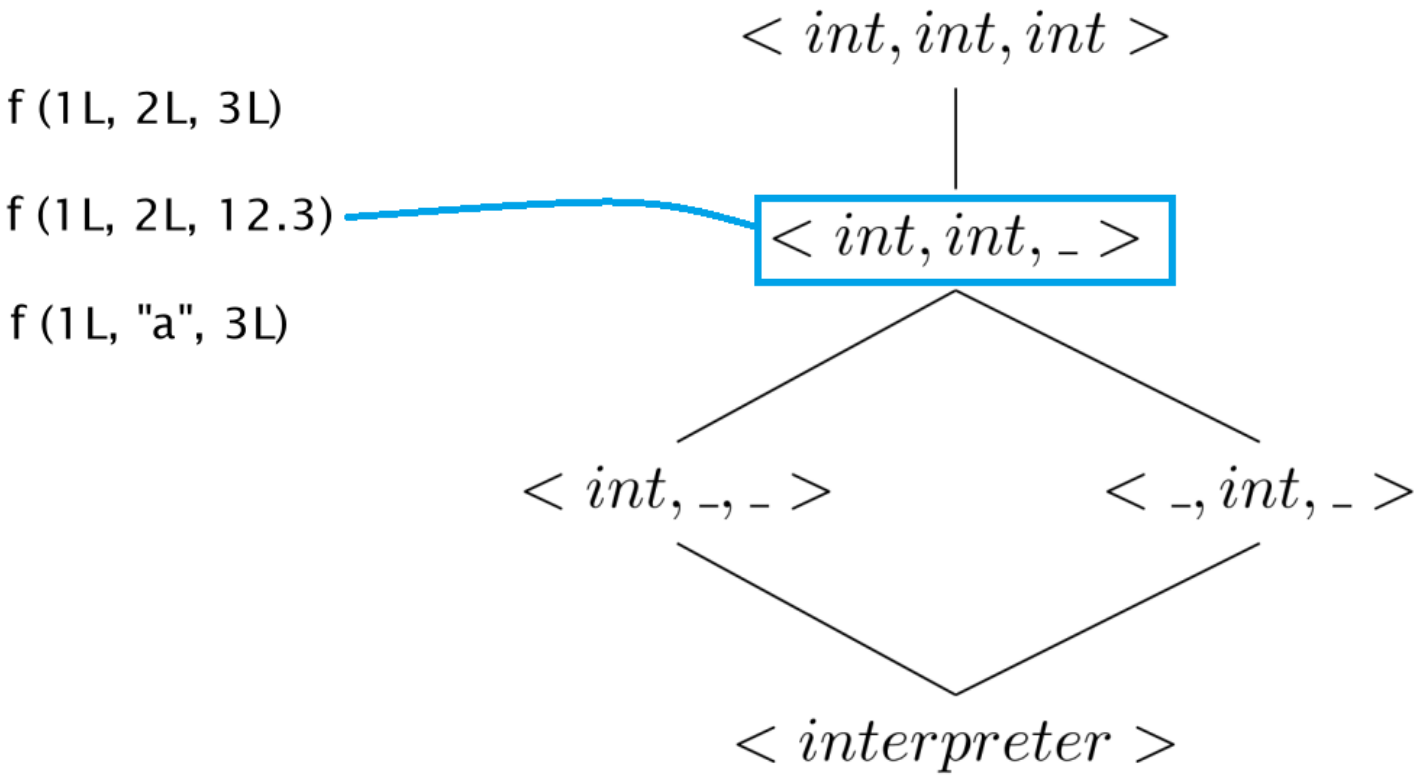

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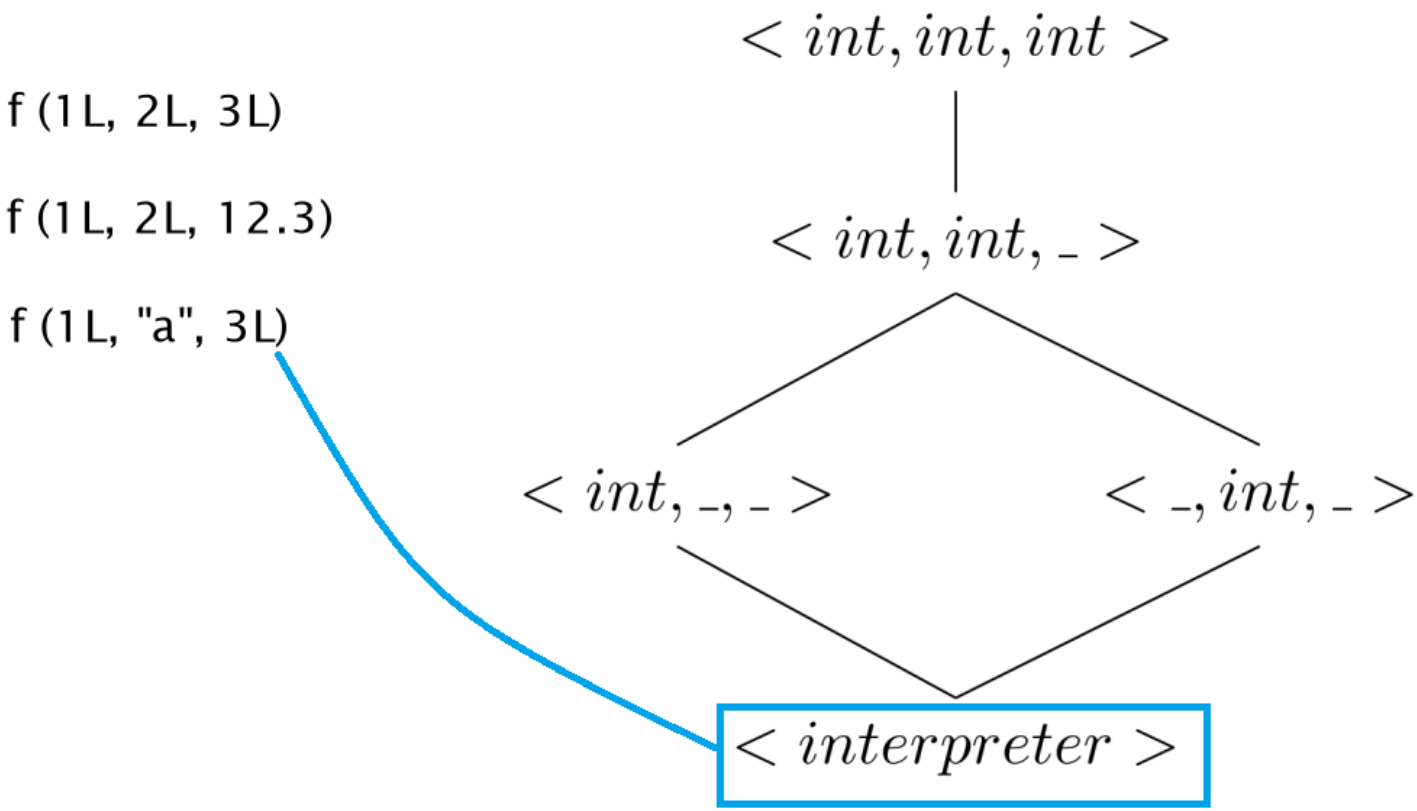
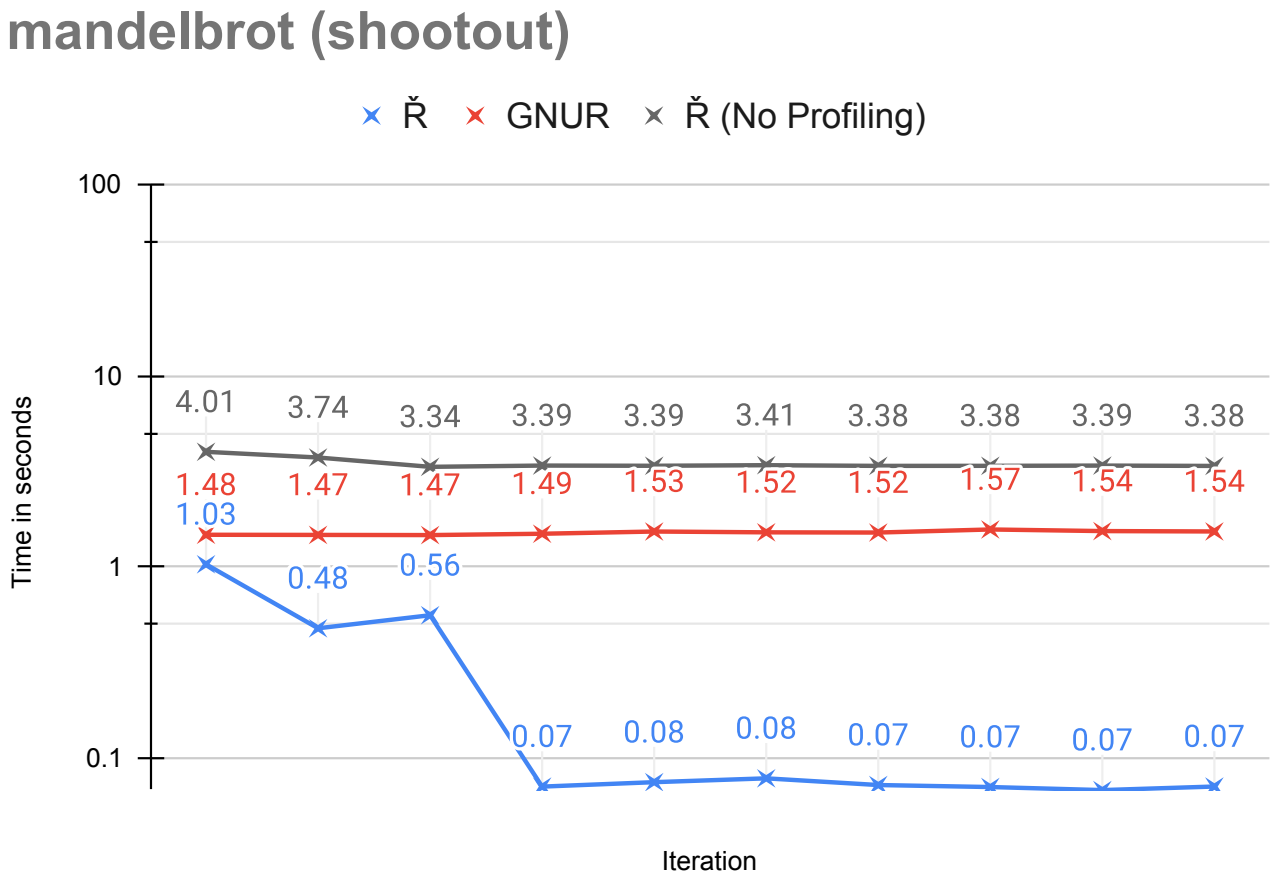


Performance



The regressions

reg-s4.R

- Normal GNUR: *$\tilde{0}$.35 sec*

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- **Insights:** Real research begins **here**.

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Existing state of the art: fast and reliable

- Segfaults: GDB

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- **Trace visualizer:** $\check{\mathrm{R}}$-viz ($\tilde{2}$ weeks)
- **Runtime debuggers:** Rsh Dynamic Visualizer and Debugger (BTech MTP @ IITMandi)
- **Event querying:** General Event Query Engine ($\tilde{2}$ days)

A little bit of **React**, **C++**, **JS** and some **sockets**.

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Reality: Number of contexts are usually manageable, but there are too many compilations!

Insight: Compilation heuristic warrants deeper investigation.

Data Collection

Hypothesis: All compiled functions are equally responsible for peak performance.

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Hypothesis: Compilation heuristics are buggy, leading to unnecessary compilations.

> **Insight:** Yes, there is evidence to prove that.

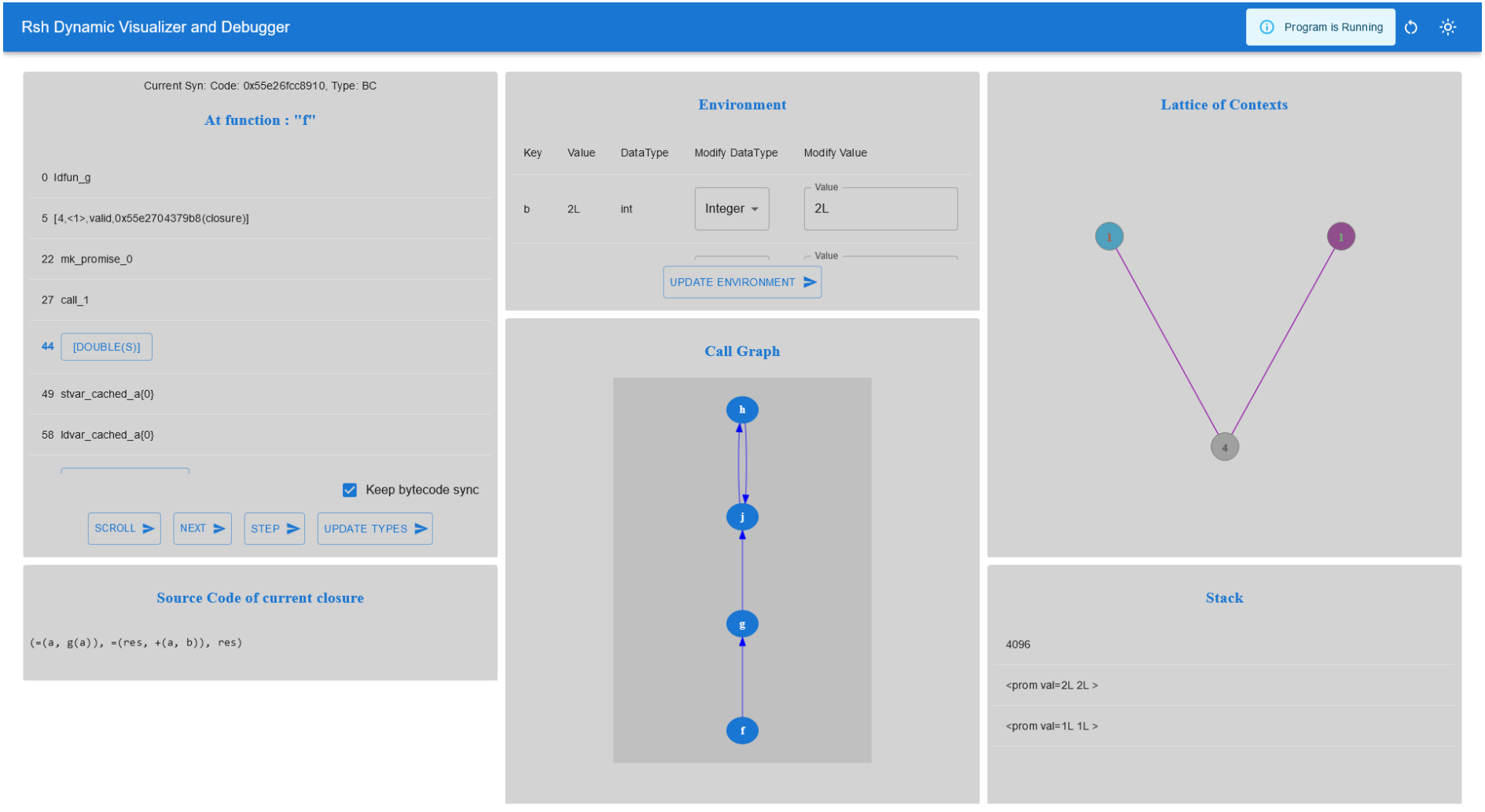
Hypothesis: Contextual compilation sounds good in theory, but in reality, only a generic context becomes dominant.

> **Insight:** No, in most cases the call-box shows that most contexts are used equally throught the runtime.

Runtime Debugger

Goal: Learn about the **internal working** of the system.

Team: Aayush Sharma and Anmolpreet Singh (**just-in**-graduation-**time**).



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GEQE: https://meetesh06.github.io/General-Event-Query-Engine/

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The good

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Road ahead

- These tools can be quickly retrofit to other use cases.

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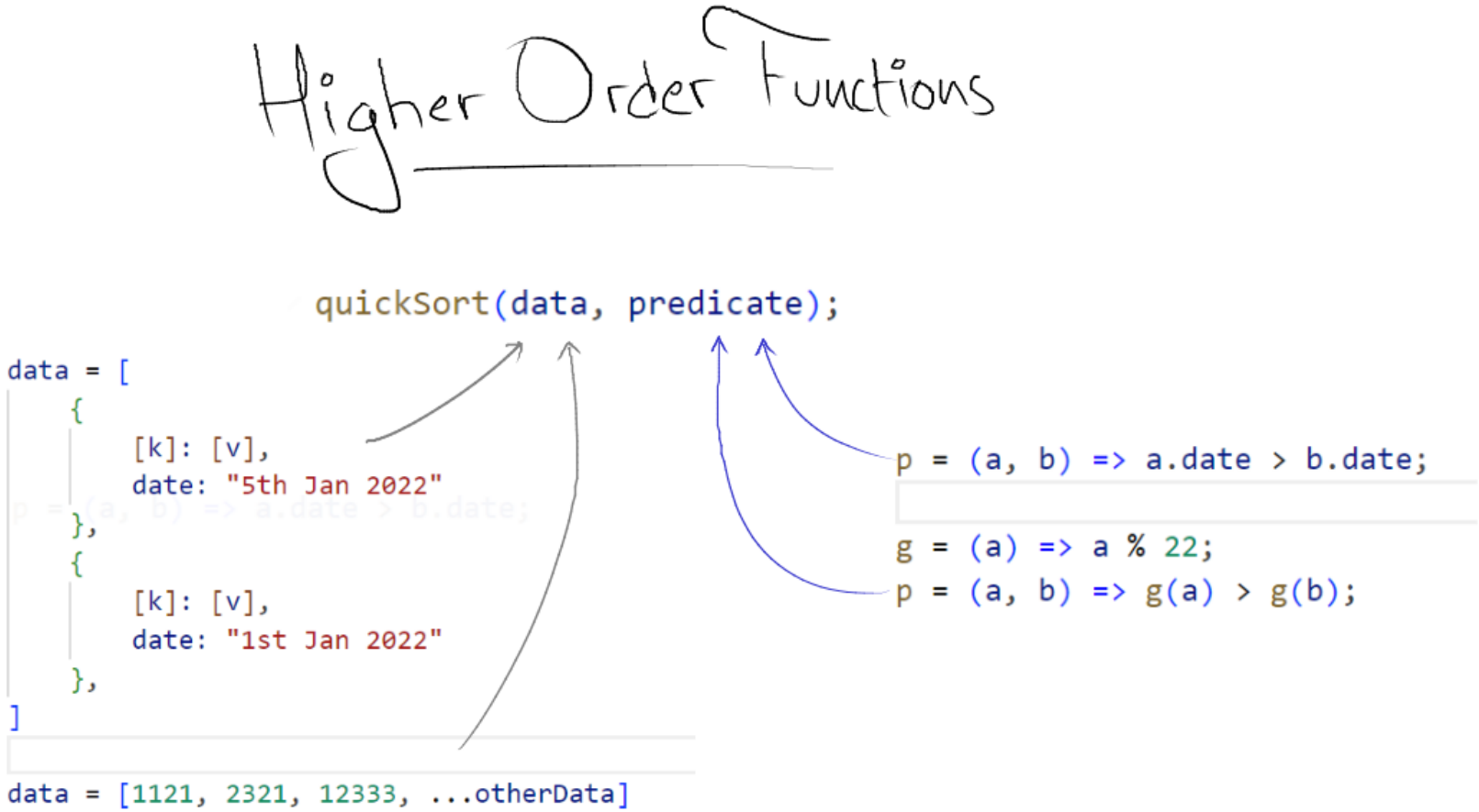

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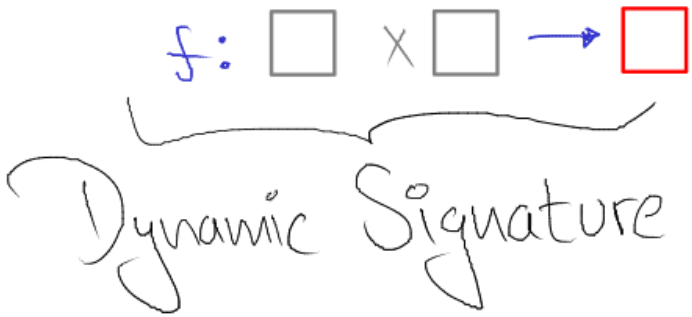
```
f <- function(a, b) {
    if (isS4(a, b)) {
        add.s4(a.rep, b.rep);
    } else if (isS3(a, b)){
        add.s3(a, b)
    } else {
        add.default(a,b)
    }
}
```



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