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# One VM to Rule Them All


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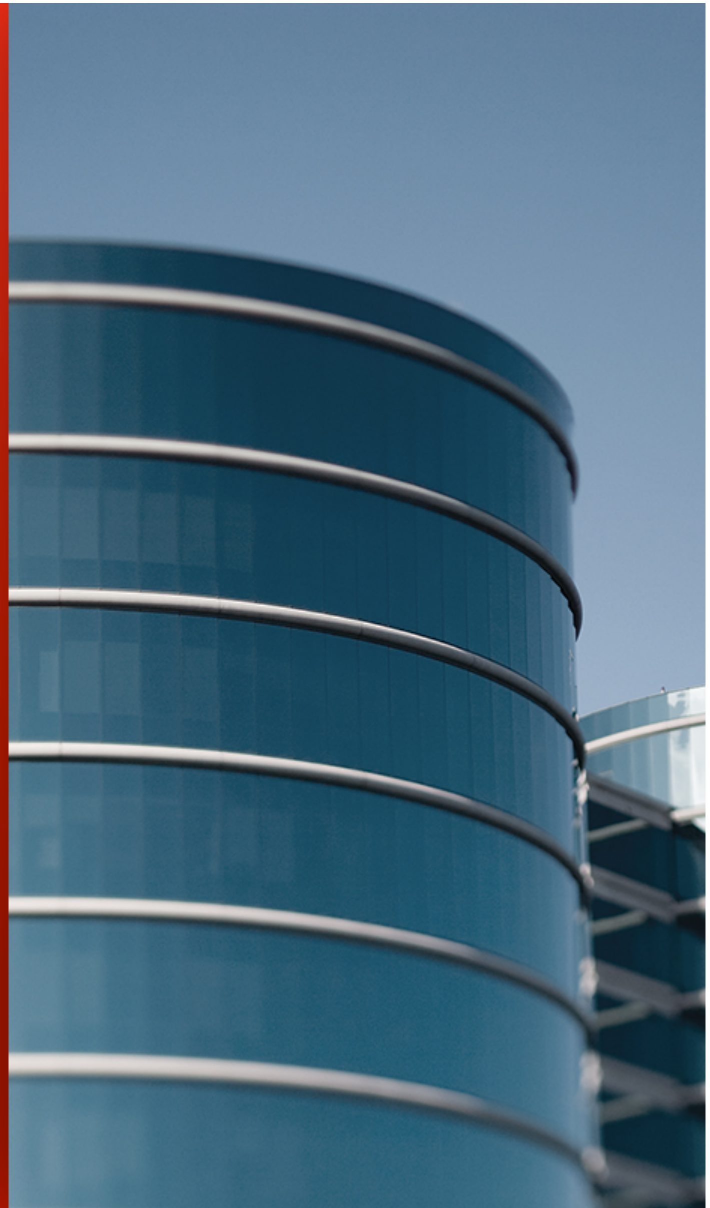

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# One Language to Rule Them All?

## Let's ask Google…

[JavaScript: **One language to rule them all** | VentureBeat]

venturebeat.com/2011/.../javascript-**one-language-to-rule-them**-...
by Peter Yared - in 23 Google+ circles
Jul 29, 2011 - Why code in two different scripting languages, one on the client and one on the server? It's time for **one language to rule them all**. Peter Yared **...**

[PDF] [Python: **One** Script (**Language**) **to rule them all** - Ian Darwin]

www.darwinsys.com/python/python4unix.pdf
Another **Language**? ▸ Python was invented in 1991 by Guido van. Rossum. ▪ Named after the comedy troupe, not the snake. ▸ Simple. ▪ They **all** say that!

[Q & Stuff: **One Language to Rule Them All** - **Java**]

qstuff.**blogspot**.com/2005/10/**one-language-to-rule-them-all-java**.html
Oct 10, 2005 - **One Language to Rule Them All** - **Java**. For a long time I'd been hoping to add a scripting language to LibQ, to use in any of my (or other **...**

[Dart : **one language to rule them all** - MixIT 2013 - Slideshare]

fr.slideshare.net/sdeleuze/dart-mixit2013en
DartSébastien Deleuze - @sdeleuzeMix-IT 2013One **language to rule them all** ...

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# One Language to Rule Them All?

## Let’s ask Stack Overflow…

stackoverflow | Questions | Tags | Tour | Users

Stack Overflow is a question and answer site for professional and enthusiast programmers. It's 100% free, no registration required.

**Why can't there be an “ultimate” programming language?**

closed as not constructive by Tim, Bo Persson, Devon_C_Miller, Mark, Graviton Jan 17 at 5:58

# "Write Your Own Language"

**Current situation**

**Prototype a new language**

Parser and language work to build syntax tree (AST), AST Interpreter

**Write a "real" VM**

In C/C++, still using AST interpreter, spend a lot of time implementing runtime system, GC, …

**People start using it**

**People complain about performance**

Define a bytecode format and write bytecode interpreter

**Performance is still bad**

Write a JIT compiler
Improve the garbage collector

**How it should be**

**Prototype a new language in Java**

Parser and language work to build syntax tree (AST)
Execute using AST interpreter

**People start using it**

And it is already fast

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# Truffle Requirements

Ruby, JavaScript, Python, R, J, Java, Groovy, Clojure, Scala ...

**Simplicity**

**+**

**Generality**

**+**

**Performance**

```
@Specialization(
   rewriteOn=ArithmeticException.class)
int add(int l, int r) {
  return Math.addExact(l, r);
}

@Specialization
double add(double l, double r) {
  return l + r;
}

@Specialization(guards = "isString")
String doString(Object l, Object r) {
  return l.toString() + r.toString();
}
```

```
function f(a, n) {
  var x = 0;
  while (n-- > 0) {
    x = x + a[n];
  }
  return x;
}
```

```
L1: decl rax
jz L2
movl rcx, rdx[16+4*rax]
cvtsi2sd xmm1, rcx
addsd xmm0, xmm1
jmp L1
L2:
```

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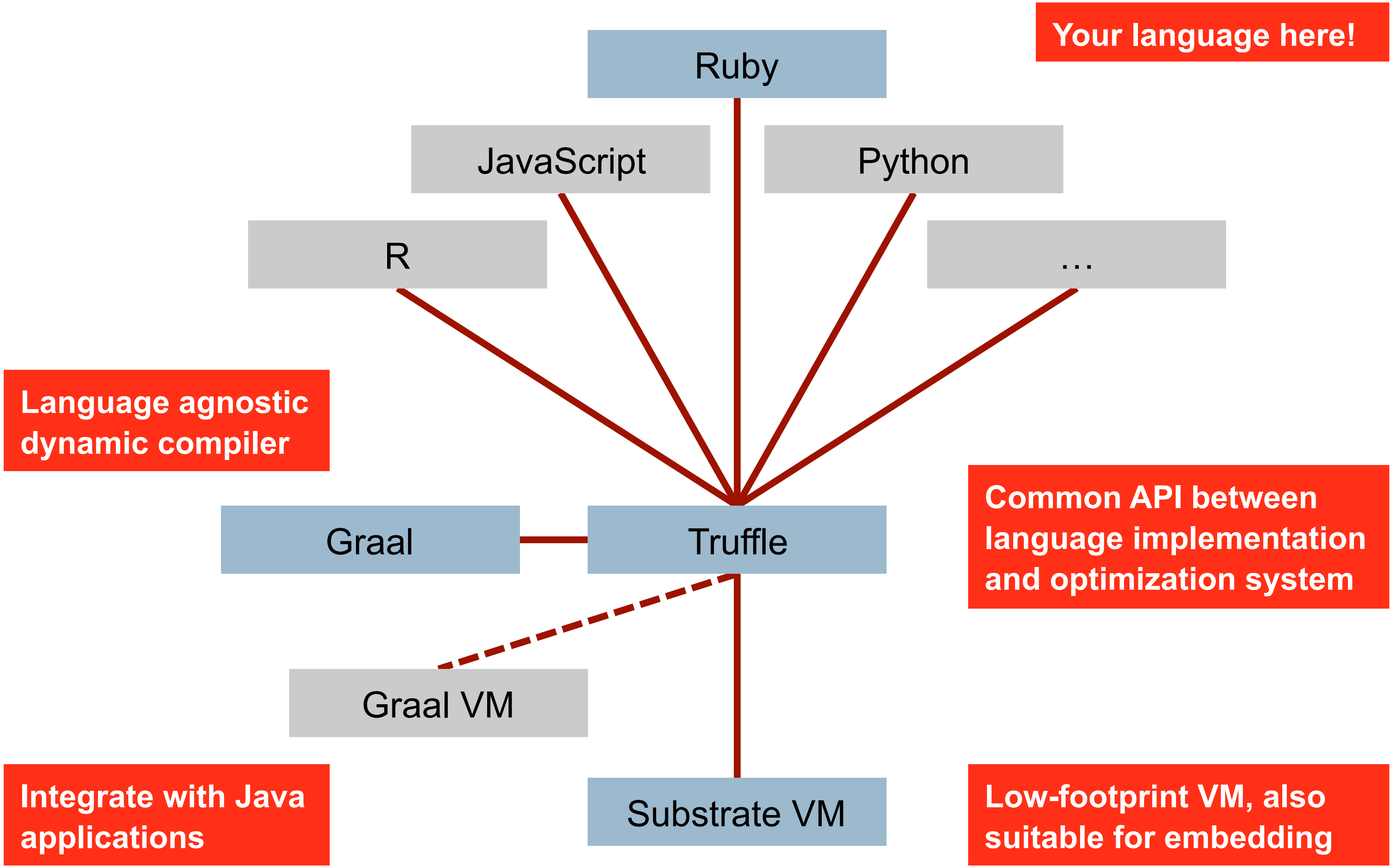
# System Structure

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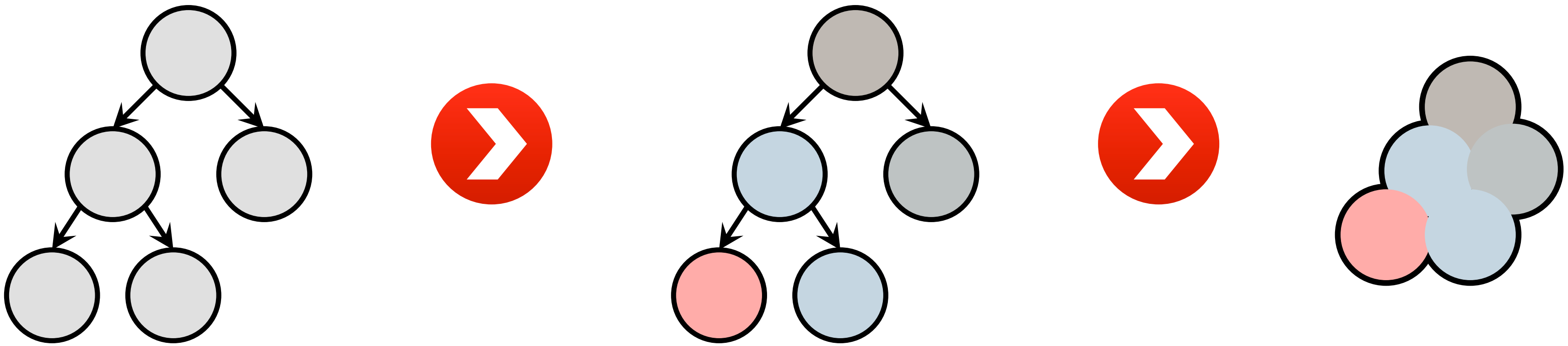
# Truffle Approach

**Node Rewriting for Type Feedback**

**Automatic Partial Evaluation**



AST Interpreter
Uninitialized Nodes

AST Interpreter
Rewritten Nodes

Compiled Code

- Eliminate boxing of primitive values
- Eliminate dynamic type checks
- AST Inlining

- Syntax tree nodes are “stable”
- Aggressive constant folding, method inlining, escape analysis
- Deoptimize compiled code on tree rewrite

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# More Details on Truffle

Accepted for Onward! 2013, October 26-31 2013, Indianapolis, IN

## One VM to Rule Them All

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### Abstract

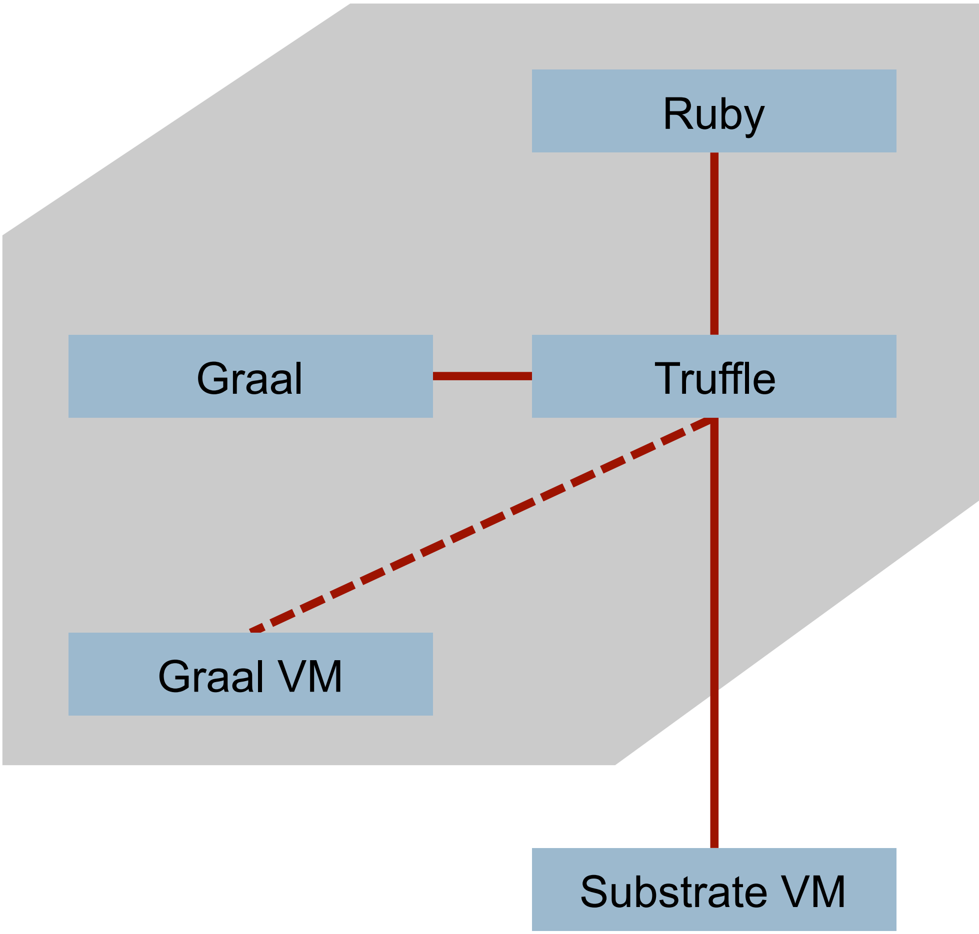
Building high-performance virtual machines is a complex and expensive undertaking; many popular languages still have low-performance implementations. We describe a new approach to virtual machine (VM) construction that amortizes much of the effort in initial construction by allowing new languages to be implemented with modest additional effort. The approach relies on abstract syntax tree (AST) interpretation where a node can rewrite itself to a more specialized or more general node, together with an optimizing compiler that exploits the structure of the interpreter. The compiler uses speculative assumptions and deoptimization in order to produce efficient machine code. Our initial experience suggests that high performance is attainable while preserving a modular and layered architecture, and that new high-performance language implementations can be obtained by writing little more than a stylized interpreter.

as Microsoft's Common Language Runtime, the VM of the .NET framework [43]. These implementations can be characterized in the following way:

- Their performance on typical applications is within a small integer multiple (1-3x) of the best statically compiled code for most equivalent programs written in an unsafe language such as C.
- They are usually written in an unsafe, systems programming language (C or C++).
- Their implementation is highly complex.
- They implement a single language, or provide a bytecode interface that preferentially advantages a narrow set of languages to the detriment of other languages.

In contrast, there are numerous languages that are popular, have been around for about 20 years, and yet still have

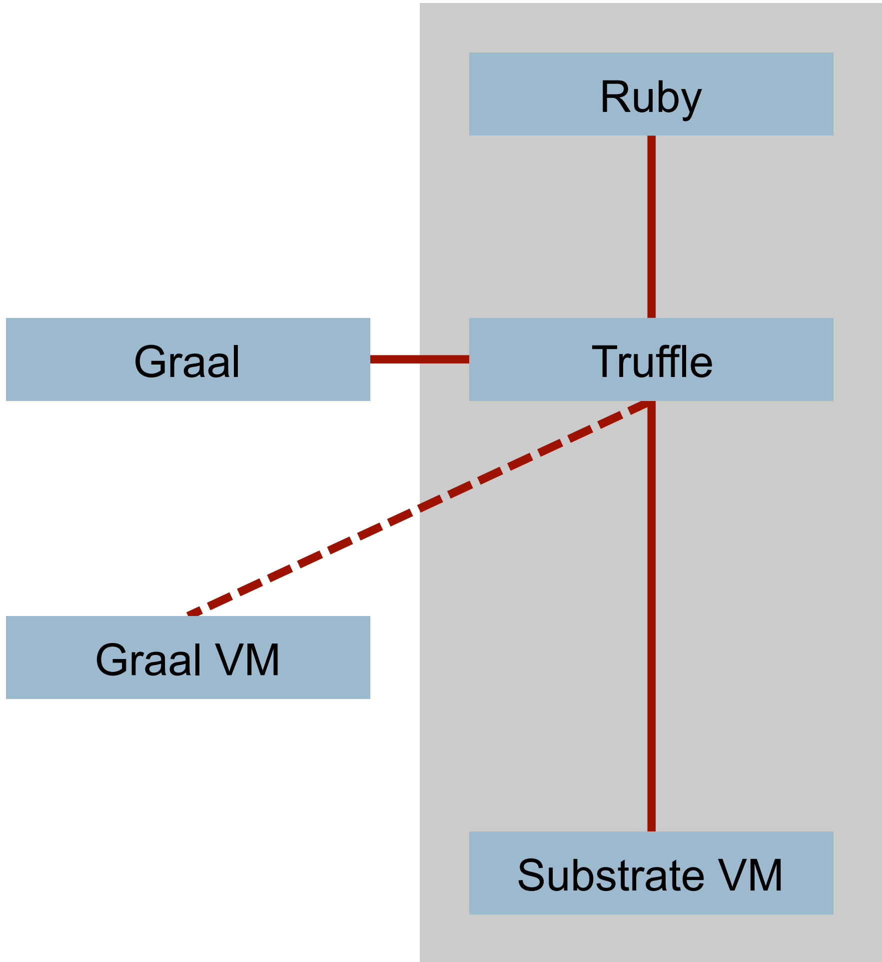
# Ruby Prototype: High Performance




**Fastest Ruby implementation …**

**… for the few benchmarks that we looked at**

# Ruby Prototype: Low Footprint




**Startup time ("Hello World") comparable to MRI**



# Ruby Prototype: Completeness

- RubySpec
  - A library of executable assertions that covers the language, core library and standard library
  - This is the defacto Ruby spec
  - Gives us a quantifiable result for how much of Ruby we implement correctly

**Over 45% of RubySpec**

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# Completeness

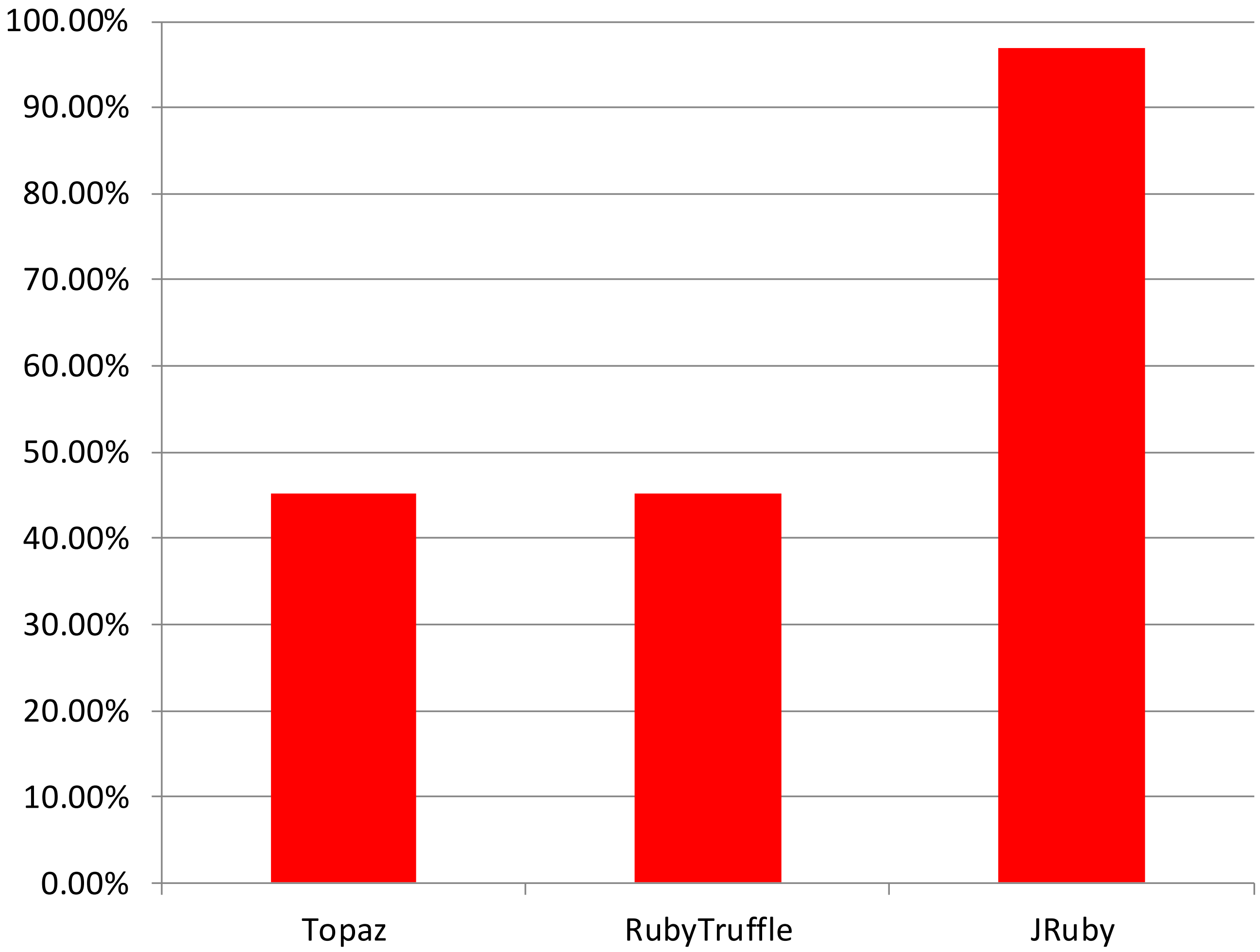
# Completeness: Informally

| Language Feature | Implemented | Notes |
|---|---|---|
| Fixnum to Bignum promotion | ✓ | |
| Support for floating point | ✓ | |
| Closures | ✓ | |
| Bindings and eval | ✓ | |
| callcc and Continuation | ✓ | Very limited support, the same as JRuby |
| Fibers | ✓ | Slightly limited support, the same as JRuby |
| Frame local variables | ✓ | |
| C extensions | | |
| Ruby 1.9 encoding | ✓ | |
| Garbage collection | ✓ | |
| Concurrency and parallelism | ✓ | We currently use a GIL |
| Tracing and debugging | ✓ | |
| ObjectSpace | ✓ | |
| Method invalidation | ✓ | |
| Constant invalidation | ✓ | |
| Ruby on Rails | | |

Charles Nutter: ‘So You Want to Optimize Ruby’ http://blog.headius.com/2012/10/so-you-want-to-optimize-ruby.html

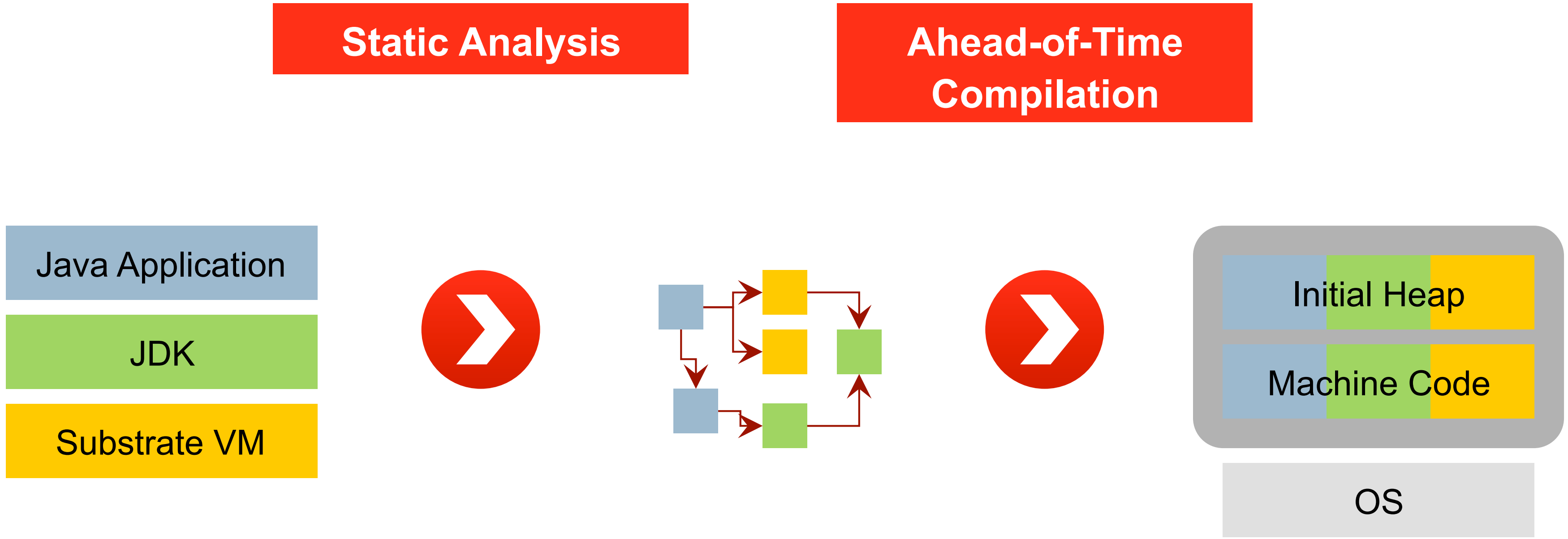
# Completeness: More formally via RubySpec

## Running language tests



# Low Footprint

# Substrate VM Execution Model



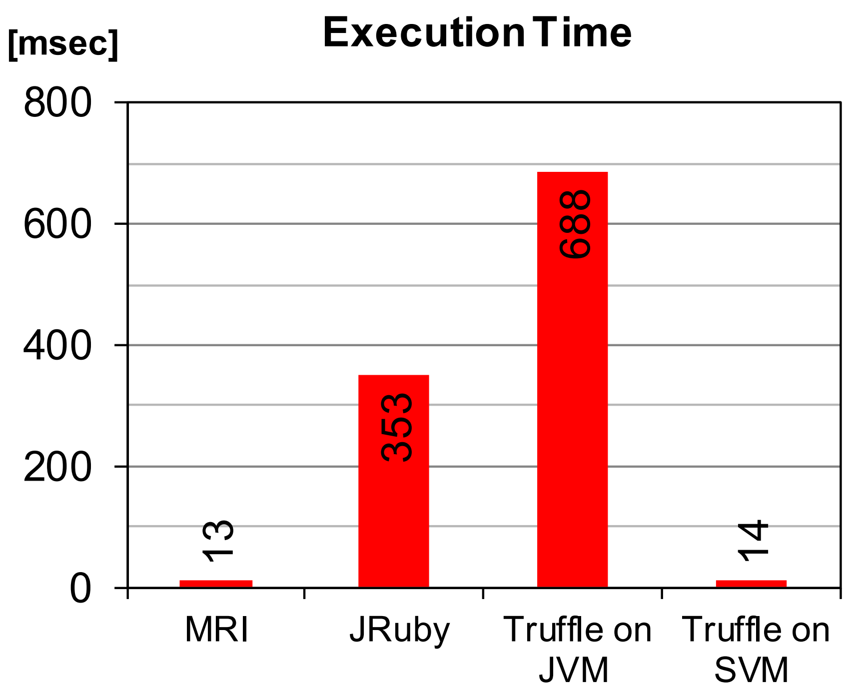

All Java classes from application, JDK, and Substrate VM

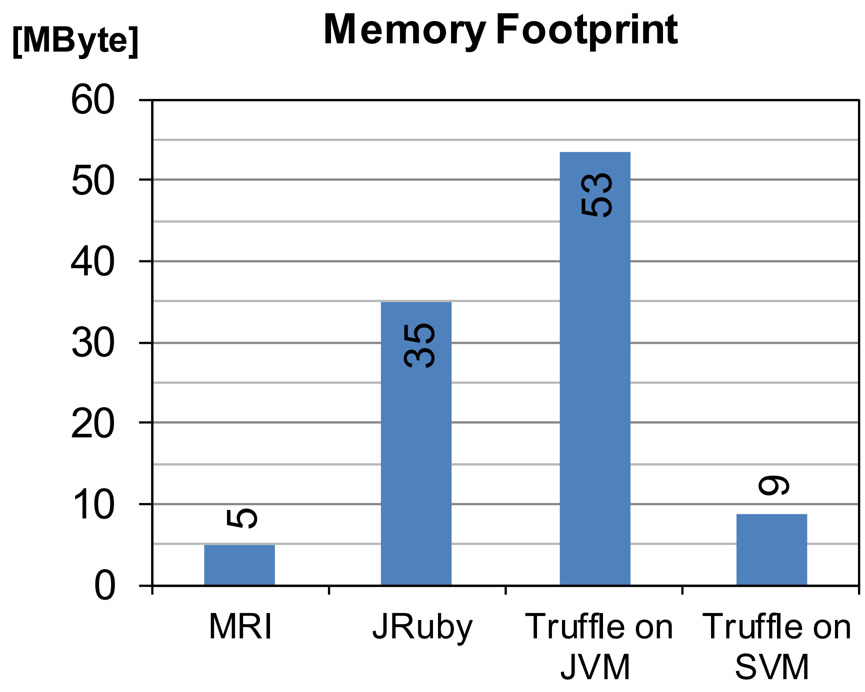
Reachable methods, fields, and classes

Application running without compilation or class loading

# Startup Performance

## Running "Hello World"




Execution time: `time -f "%e"`

Memory footprint: `time -f "%M"`

# High Performance

# Why is Ruby Slow?

```
-b + (Math.sqrt(b**2 - 4*a*c)) / 2*a
```

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# Why is Ruby Slow?

## -b + (Math.sqrt(b**2 - 4*a*c)) / 2*a

execute b
**check that b is a Float**
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execute c
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# Improving Performance Using Truffle

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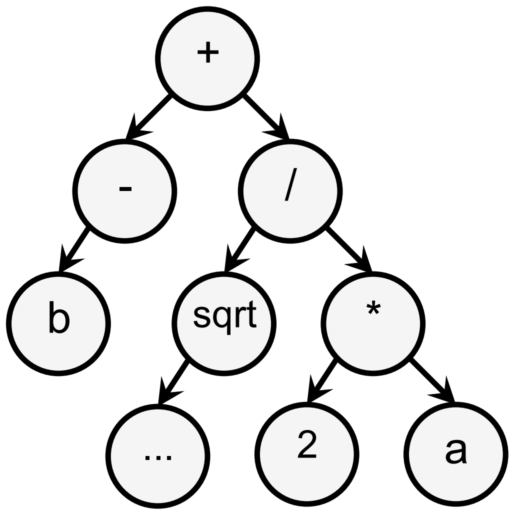


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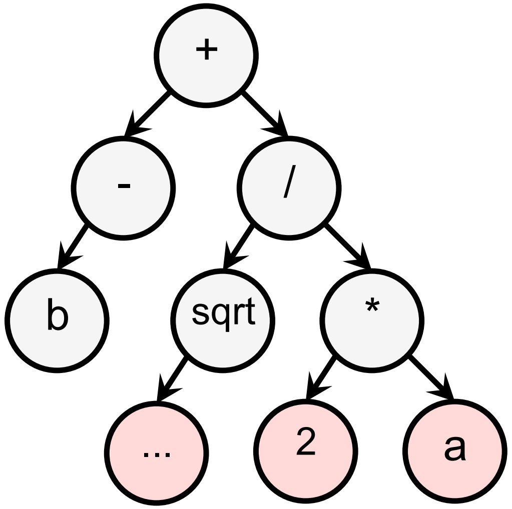

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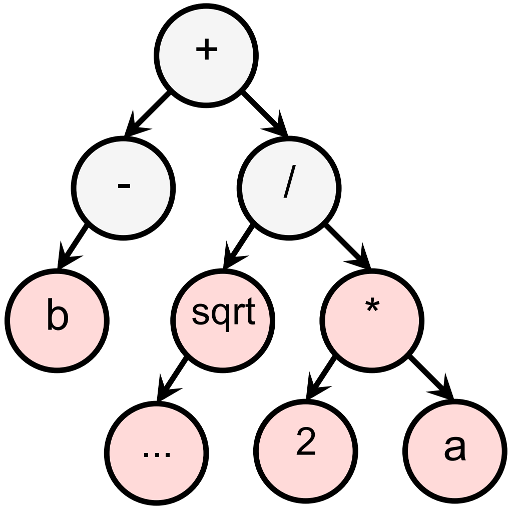

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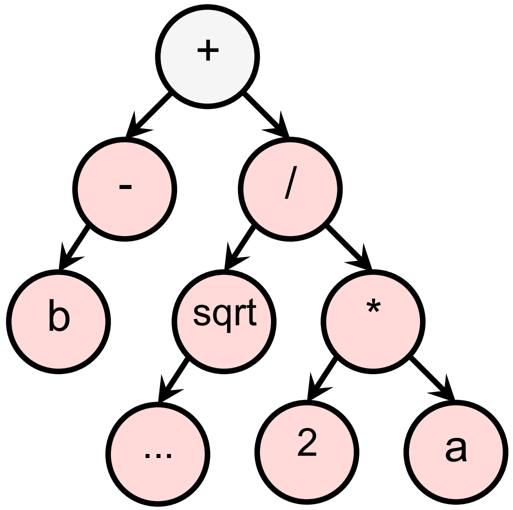

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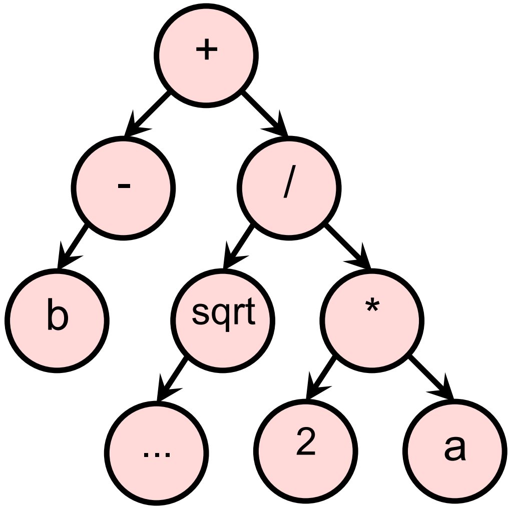

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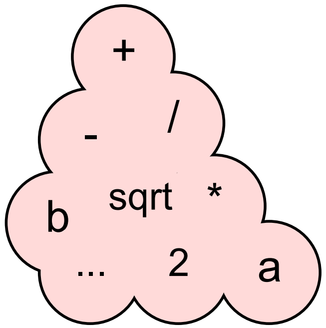

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# Improving Performance Using Graal

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class Float

⚑ modified?

module Math

⚑ modified?

# Improving Performance Using Graal

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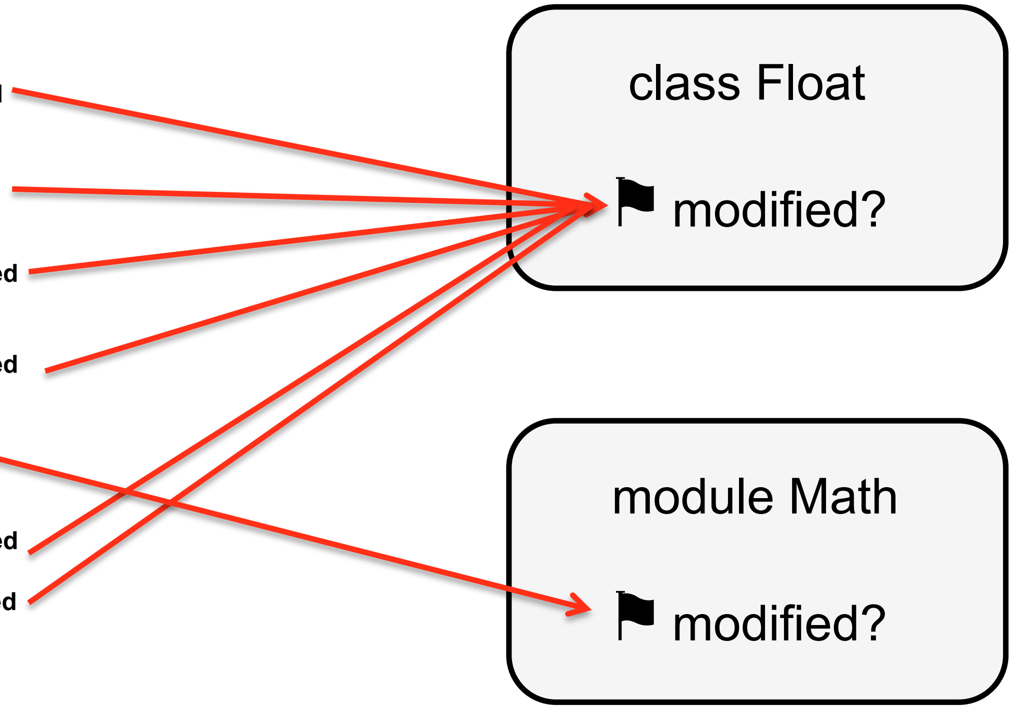

# Improving Performance Using Graal

## -b + (Math.sqrt(b**2 - 4*a*c)) / 2*a

### java object InstalledCode

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.invalidate()

### class Float

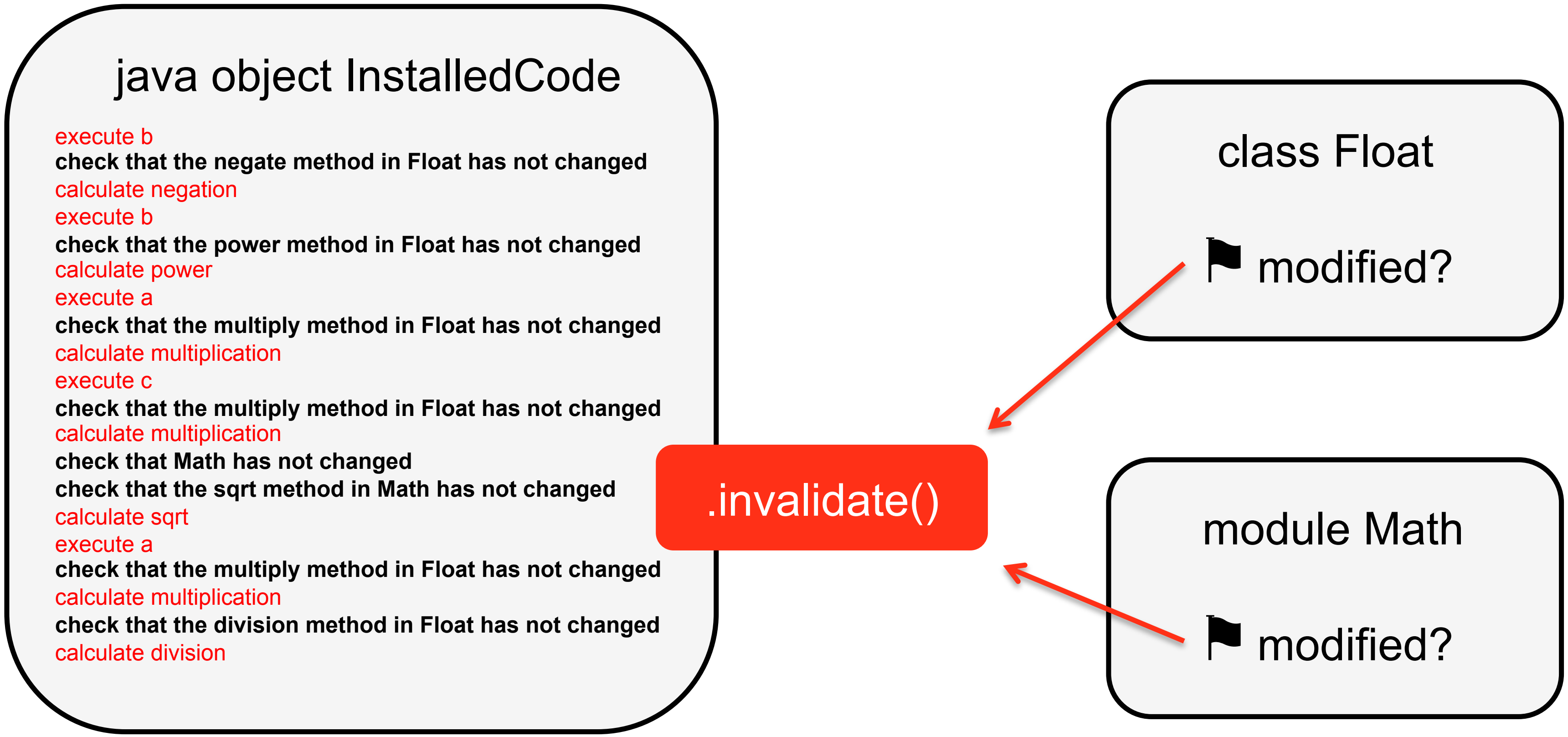
⚑ modified?

### module Math

⚑ modified?

# Improving Performance Using Graal

## -b + (Math.sqrt(b**2 - 4*a*c)) / 2*a



# Improving Performance Using Graal

```
unmodified = new Assumption();

unmodified.check();

unmodified.invalidate();
```

# Improving Performance Using Graal

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execute b
calculate negation
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execute c
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# Improving Performance

**-b + (Math.sqrt(b**2 - 4*a*c)) / 2*a**

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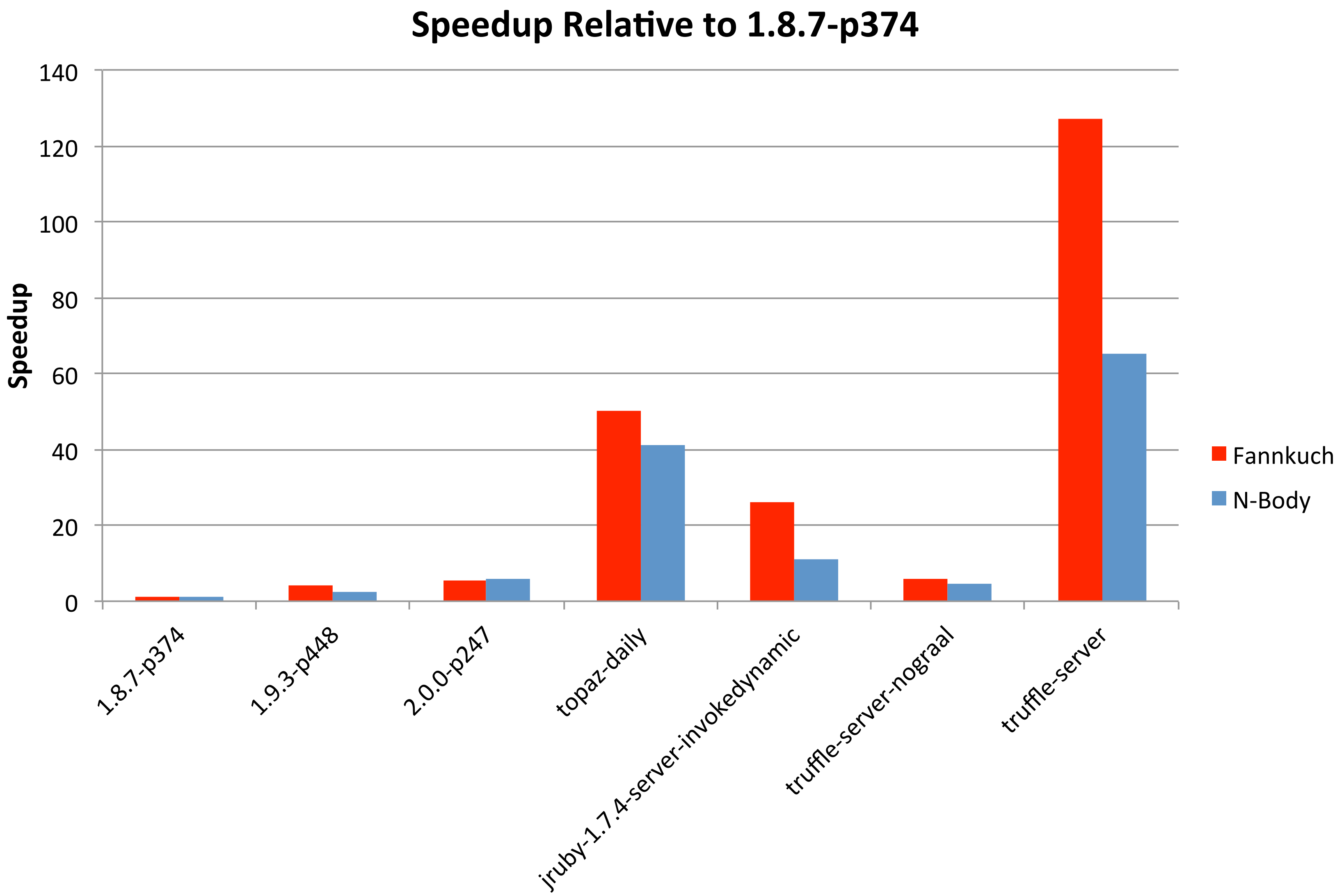
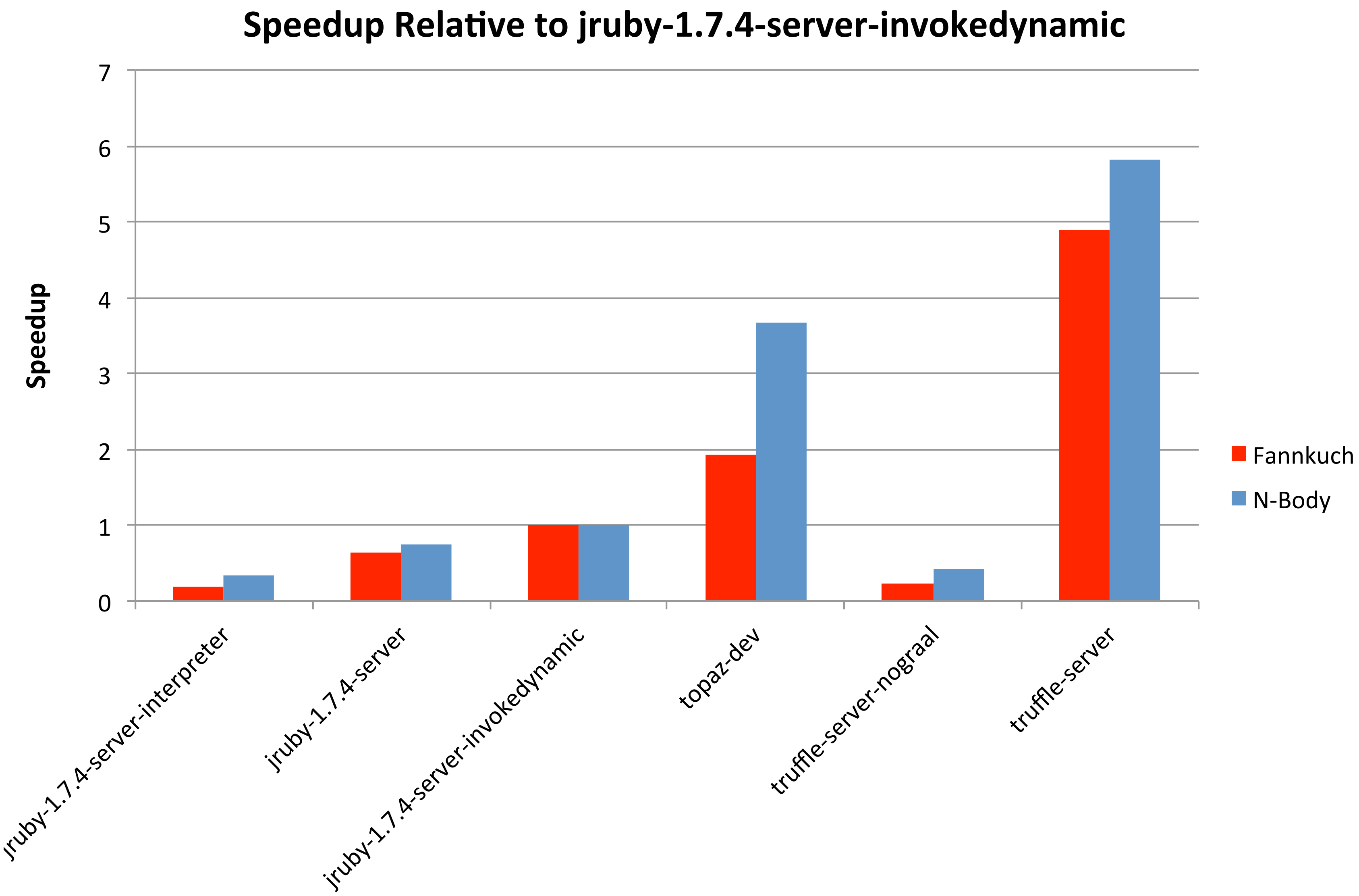
# Peak Performance



# Peak Performance



# Simplicity

- One intern working for five months on the Ruby implementation
- New to Truffle, Graal and Ruby

- Written using Eclipse
- Debugged as a normal Java program using the server compiler
- Run using Graal for testing and performance numbers

- No mention in the implementation of bytecode, classloaders, assembly, system calls, OSR
- One very minor use of Unsafe, one very minor use of reflection

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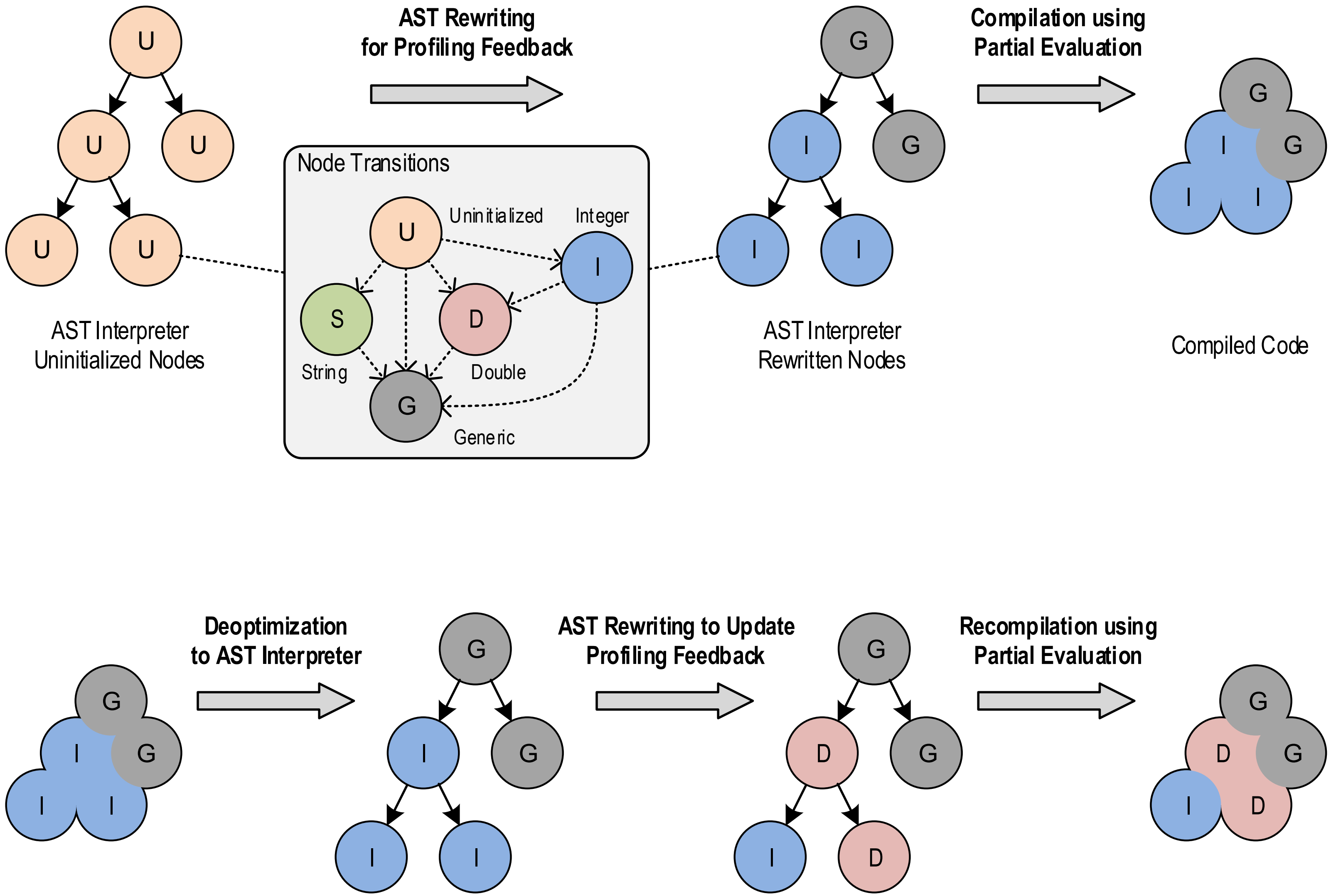
# Truffle Approach (Details)



# System Structure (Details)