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High-performance Javascript on top of Truffle

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Program Agenda

1. Truffle
2. Truffle/JavaScript
3. Other Truffle Languages
4. Research Directions
5. Summary

Truffle

“Write Your Own Language”

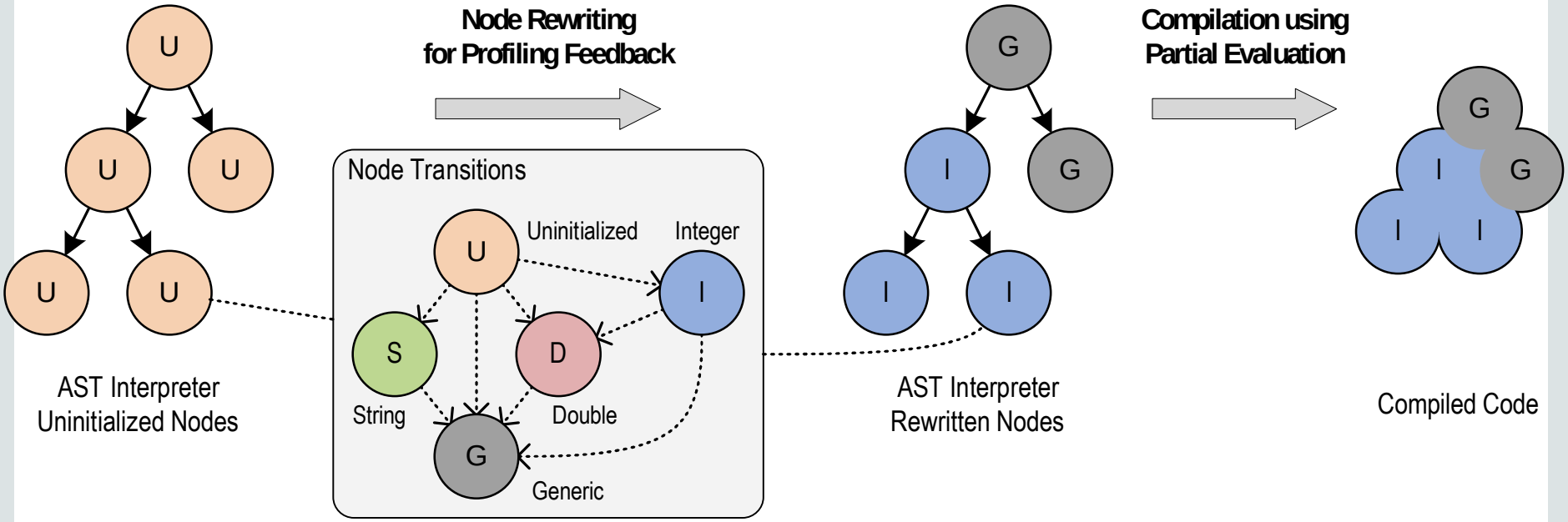
Current situation

- 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

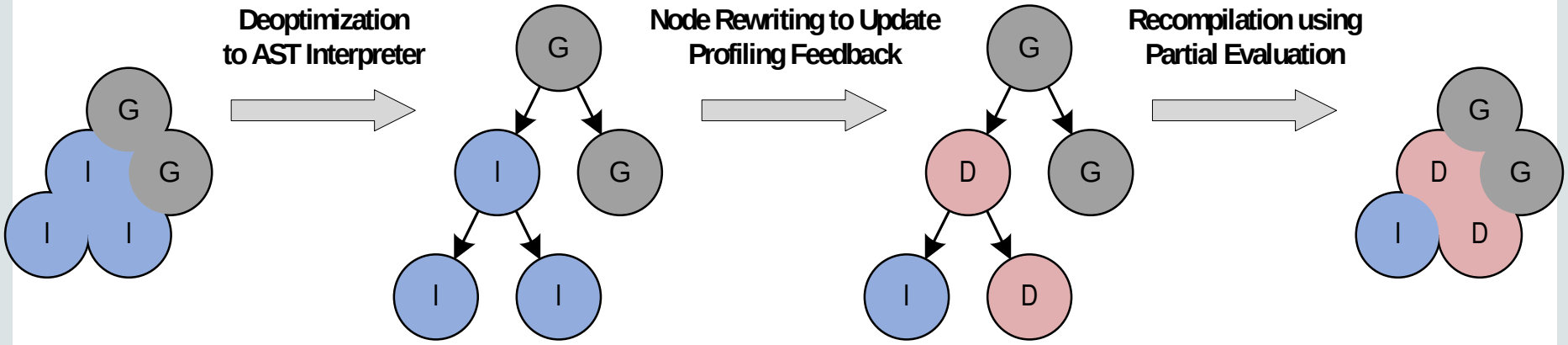
How it should be

- 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

Speculate and Optimize …



… and Deoptimize and Reoptimize!



Truffle DSL

```
@Specialization(rewriteOn=ArithmeticException.class)
int addInt(int a, int b) {
  return Math.addExact(a, b);
}

@Specialization
double addDouble(double a, double b) {
    return a + b;
}

@Generic
Object addGeneric(Frame f, Object a, Object b) {
  // Handling of String omitted for simplicity.
  Number aNum = Runtime.toNumber(f, a);
  Number bNum = Runtime.toNumber(f, b);
  return Double.valueOf(aNum.doubleValue() +
           bNum.doubleValue());
}
```

Truffle API Compiler Directives

- Guards

```
if(condition) {
  // some code that is only valid if condition is true
} else {
  CompilerDirectives.transferToInterpreter();
}
```

- Profiles

```
if (empty.profile(input.isEmpty()) // speculate on condition
```

```
{ branch.enter(); ... } // speculate on branch
```

- Assumptions

```
Assumption assumption = Truffle.getRuntime().createAssumption();
```

```
assumption.check();
// some code that is only valid if assumption is true
```

```
assumption.invalidate();
```

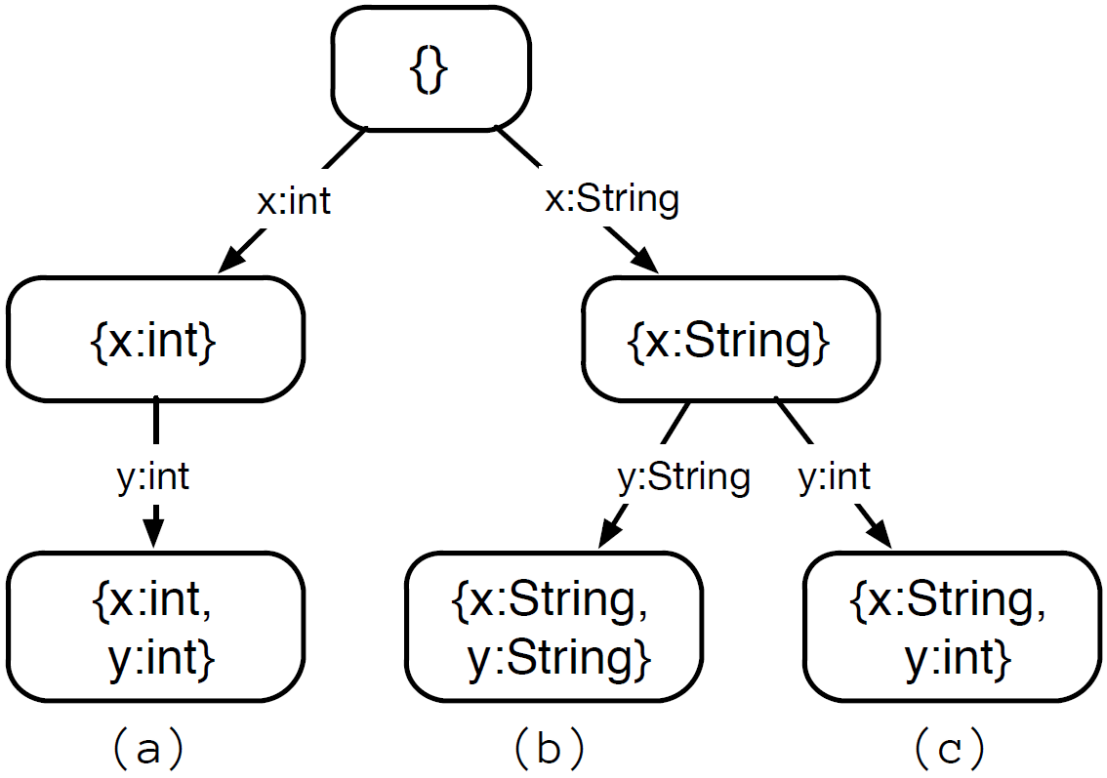
Truffle/JavaScript

Truffle/JavaScript

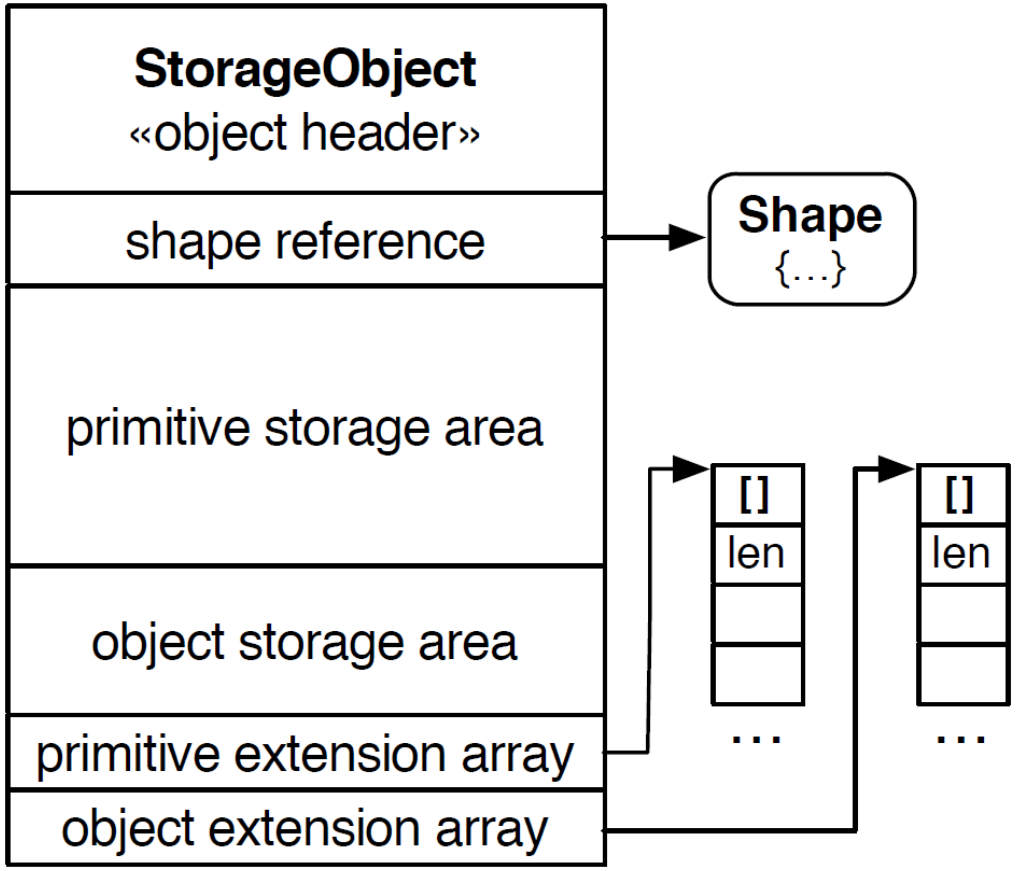
- Oracle Labs, closed source
- A complete language to show Truffle's power
- Supported JavaScript
  - Pass 100% of ECMAScript 5 standard tests
  - Growing support for non-standard extensions
  - Growing support for Node.JS/Avatar.JS applications
- ES5 compliant engine has 60.000 LOC

Object Model

```
var a = {}; a.x = 1; a.y = “foo”;
var b = {}; b.x = “bar”; b.y = “foo”;
var c = {}; c.x = “baz”; c.y = 42;
```

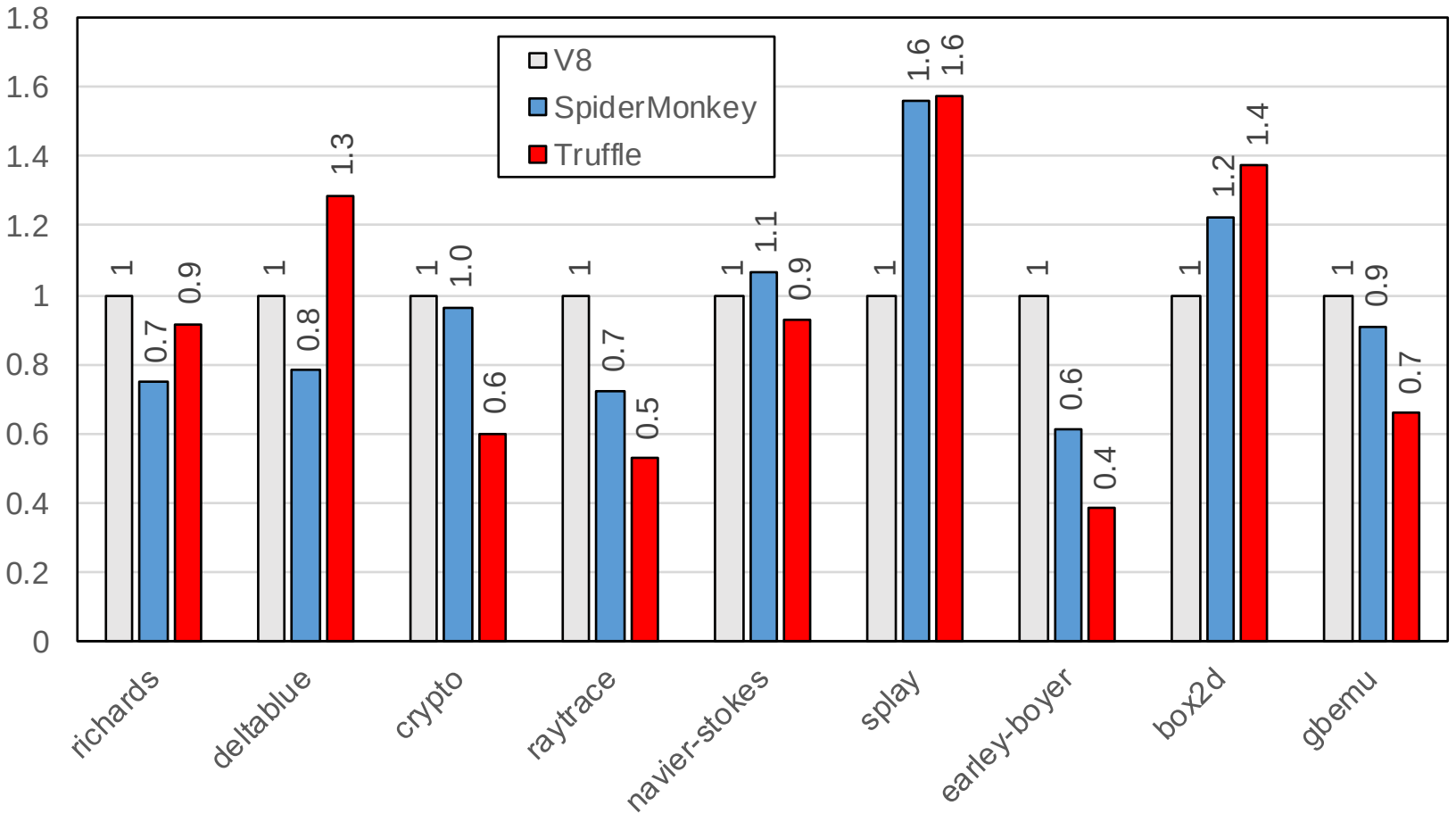


Object Storage Model



Wöß, Wirth, Bonetta, Seaton, Humer, and Mössenböck. **An object storage model for the truffle language implementation framework** (PPPJ '14)

Performance



Other Truffle Languages

Other Truffle Languages

C

- Truffle/C: Oracle Labs, JKU Linz
- Closed source

Ruby

- Oracle Labs, experimental part of JRuby
- Open source: https://github.com/jruby/jruby

R

- FastR: Oracle Labs, JKU Linz, Purdue University
- Open source: https://bitbucket.org/allr/fastr

Python

- ZipPy: UC Irvine
- Open source: https://bitbucket.org/ssllab/zippy/

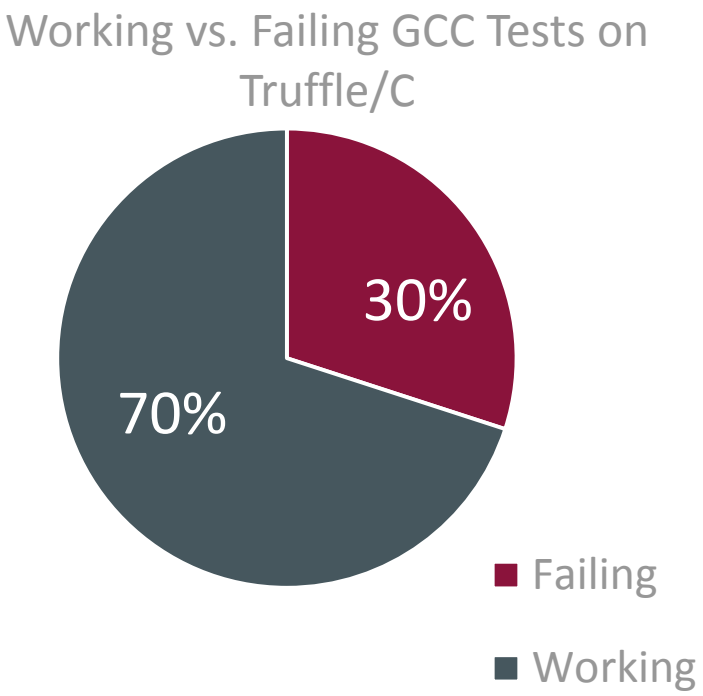
SOM (Smalltalk)

- Stefan Marr, INRIA
- Open source: https://github.com/smarr/TruffleSOM

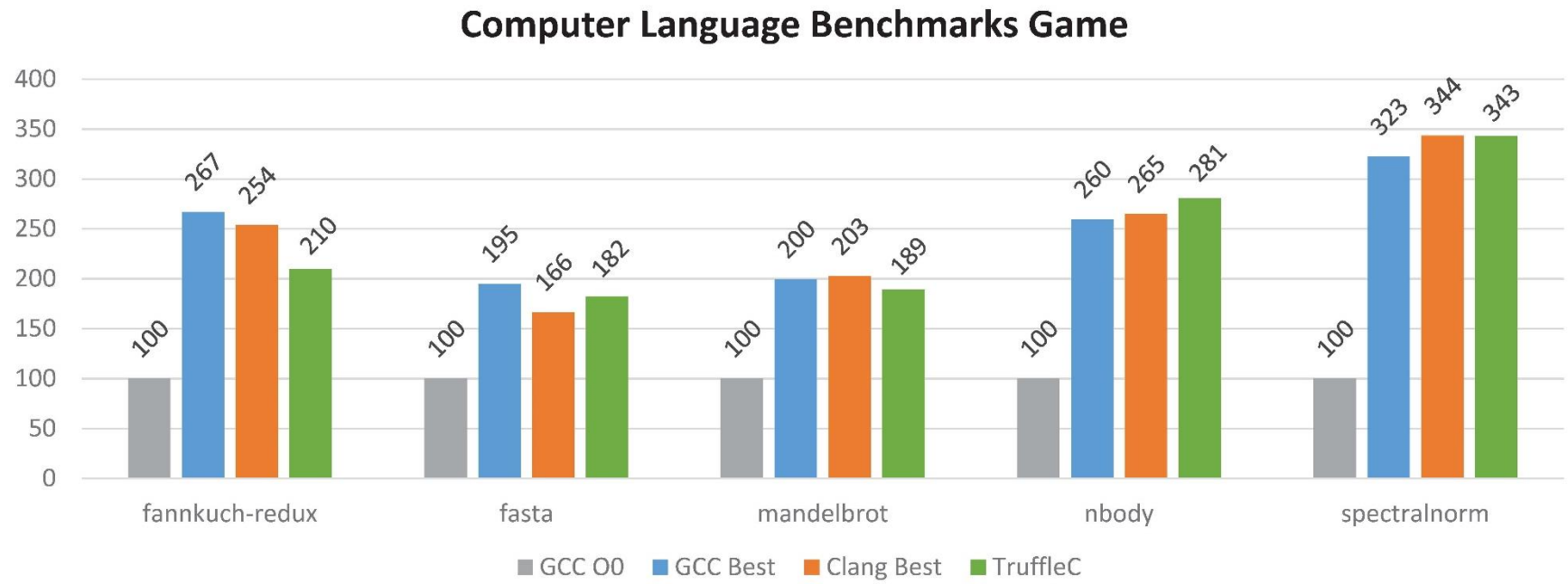
Truffle/C

How complete is Truffle/C?

- Close to ANSI C90
- GCC test suite: torture tests



Truffle/C Performance



Higher is better

100% Baseline is GCC –O0

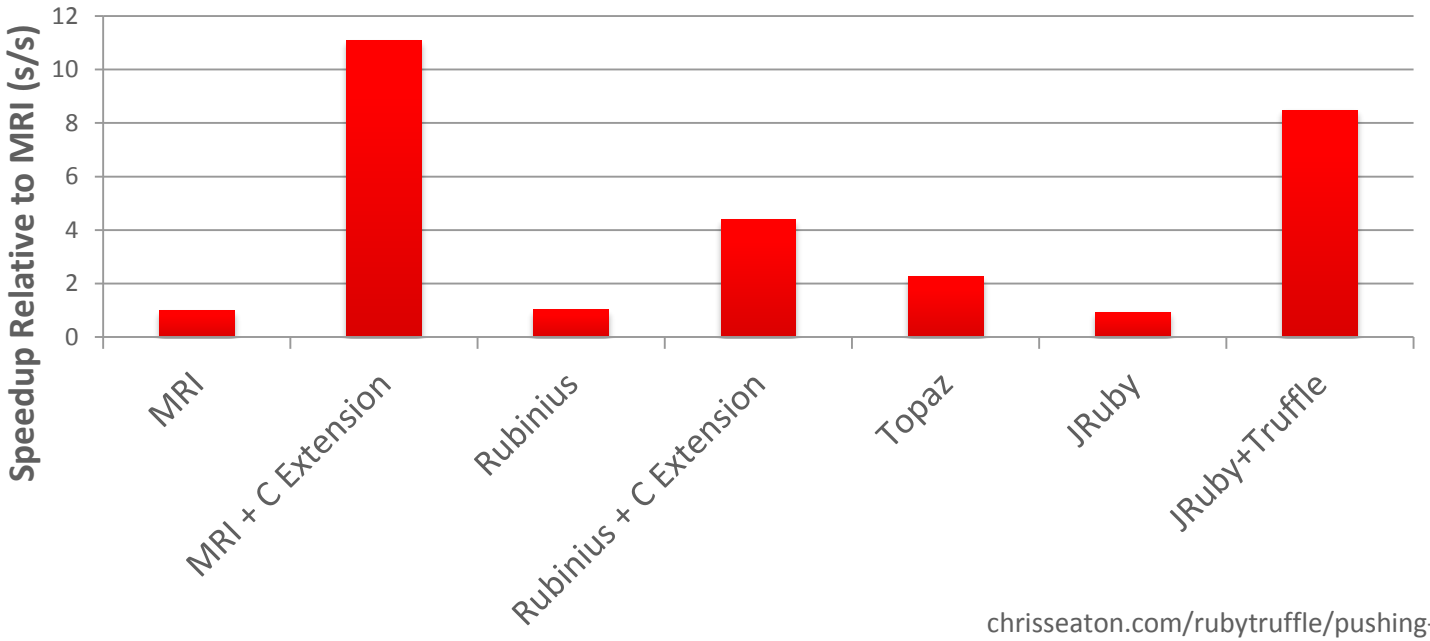
GCC = max(GCC O1, O2, O3)

Clang = max(Clang O1, O2, O3)

JRuby+Truffle

- Truffle is an experimental backend in JRuby
- Working to be 100% compliant with MRI
  - All language features implemented
  - Pure engineering effort to support whole library
- Better support for some features than JRuby
  - Full **ObjectSpace** and **set_trace_func** are always enabled
  - Aliasing of methods like **binding** and **eval**
  - Pure Ruby call stacks with all Ruby local variables

Performance on chunky_png and psd.rb



chrisseaton.com/rubytruffle/pushing-pixels

- Real code, unmodified from the original gems
- Includes diverse Ruby code such as arithmetics, method calls, dynamic features like #send, …
- Geometric mean across all benchmarks

Research Directions

Research Contributions

- Würthinger, Wimmer, Wöß, Stadler, Duboscq, Humer, Richards, Simon, and Wolczko. 2013. One **VM to rule them all**. In *Proceedings of the 2013 ACM international symposium on New ideas, new paradigms, and reflections on programming & software* (Onward! '13).
- Würthinger, Wöß, Stadler, Duboscq, Simon, and Wimmer. 2012. **Self-optimizing AST interpreters**. In *Proceedings of the 8th symposium on Dynamic languages* (DLS '12).
- Grimmer, Rigger, Schatz, Stadler, and Mössenböck. 2014. **TruffleC: dynamic execution of C on a Java virtual machine**. In *Proceedings of the 2014 International Conference on Principles and Practices of Programming on the Java platform: Virtual machines, Languages, and Tools* (PPPJ '14).
- Grimmer, Würthinger, Wöß, and Mössenböck. 2014. **An efficient approach for accessing C data structures from JavaScript**. In *Proceedings of the 9th International Workshop on Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems PLE* (ICOOOLPS '14).
- Seaton, Van De Vanter, and Haupt. 2014. **Debugging at Full Speed**. In *Proceedings of the Workshop on Dynamic Languages and Applications* (Dyla'14).
- Wöß, Wirth, Bonetta, Seaton, Humer, and Mössenböck. 2014. **An object storage model for the truffle language implementation framework**. In *Proceedings of the 2014 International Conference on Principles and Practices of Programming on the Java platform: Virtual machines, Languages, and Tools* (PPPJ '14).
- Humer, Wimmer, Wirth, Wöß, and Würthinger. 2014. **A domain-specific language for building self-optimizing AST interpreters**. In *Proceedings of the 2014 International Conference on Generative Programming: Concepts and Experiences* (GPCE 2014)

… and more by our research partners

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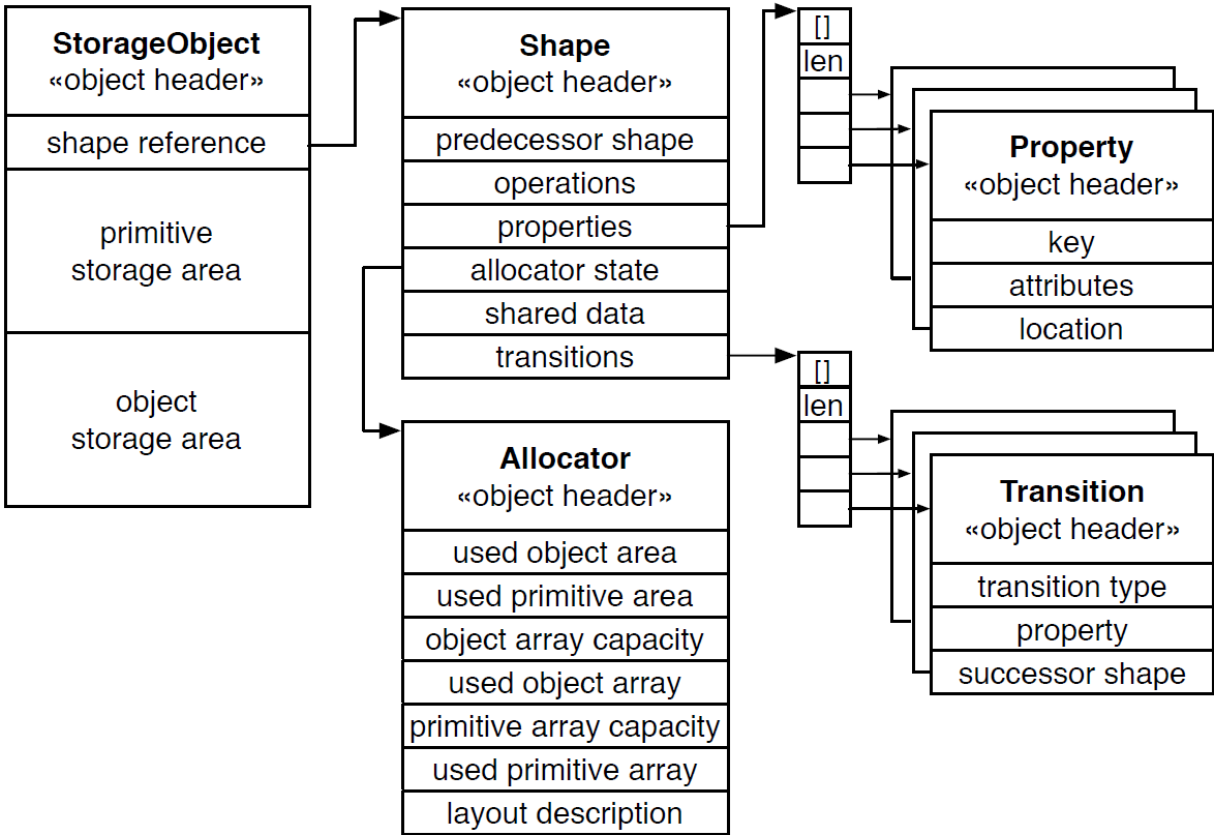
Object Storage Model for Truffle



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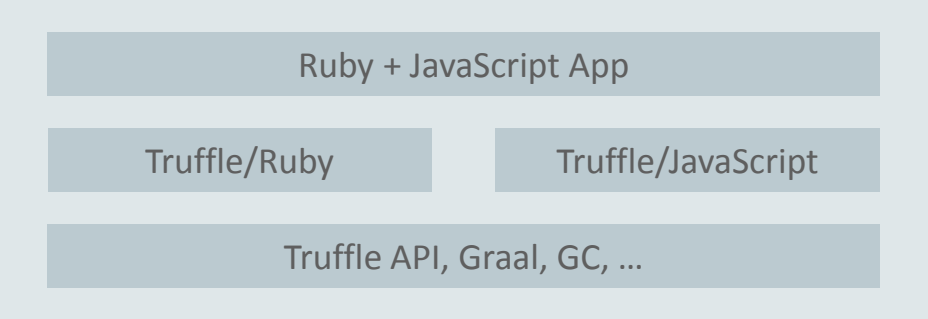
Language Interoperability



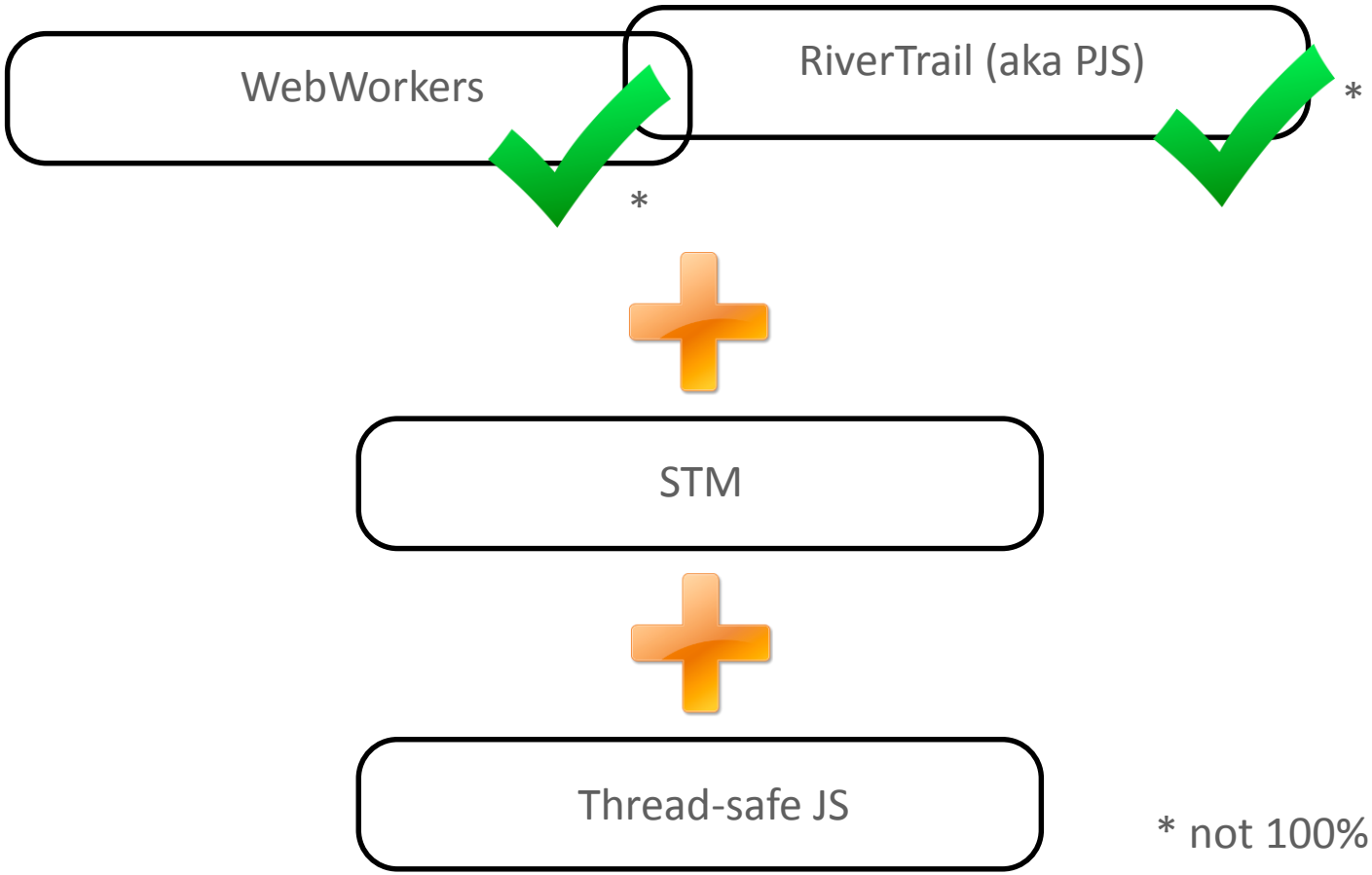
One Modular VM to Rule Them All

The shared optimization infrastructure of Truffle allows simple and fast language integration

- Our claim: performance of combined language execution is as good as the individual VMs
  - The compiler fuses language checks into existing inline cache checks
  - Approach performs cross-language method inlining
  - Approach exchanges primitive values between languages without boxing or conversions

Grimmer, Würthinger, Wöß, and Mössenböck: **An efficient approach for accessing C data structures from JavaScript** (ICOOOLPS '14)

Parallel JavaScript



* not 100% complete

Substrate VM

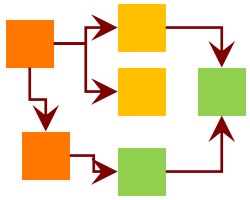
Static Analysis

Ahead-of-Time Compilation

Truffle Language

JDK

Substrate VM



Machine Code

Initial Heap

DWARF Info

ELF / MachO Binary

All Java classes from Truffle language (or any application), JDK, and Substrate VM

Reachable methods, fields, and classes

Application running without compilation or Java class loading

Summary

Summary

- Language implementation framework
- High-performance language engine
- Open-source engines for several languages available
- Ongoing research in several directions

Your language?

http://openjdk.java.net/projects/graal/

graal-dev@openjdk.java.net

```
$ hg clone http://hg.openjdk.java.net/graal/graal
$ cd graal
$ ./mx --vm server build
$ ./mx ideinit
$ ./mx --vm server unittest SumTest
```

Truffle API Resources

https://wiki.openjdk.java.net/display/Graal/Truffle+FAQ+and+Guidelines

Truffle API License: GPLv2 with Classpath Exception

Hardware and Software
Engineered to Work Together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