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Graal and Truffle: Modularity and Separation of Concerns as Cornerstones for Building a Multipurpose Runtime

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Disclaimer

Agenda

- **Graal**
- Truffle
- Community
- Q&A

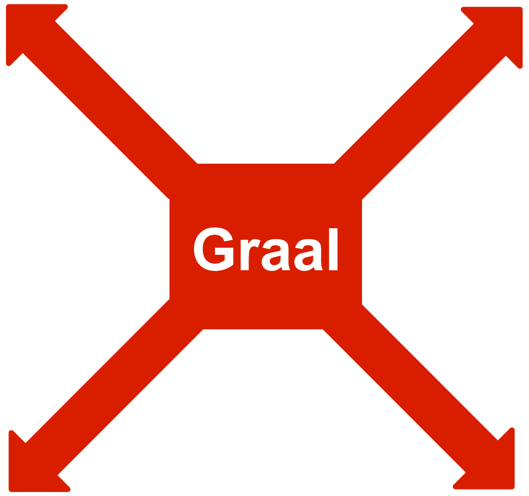
Dimensions of Extensibility

X86, SPARC, HSAIL, PTX, ...

Architectures

HotSpotVM, SubstrateVM, ...

Host Runtimes



Compilation Policy

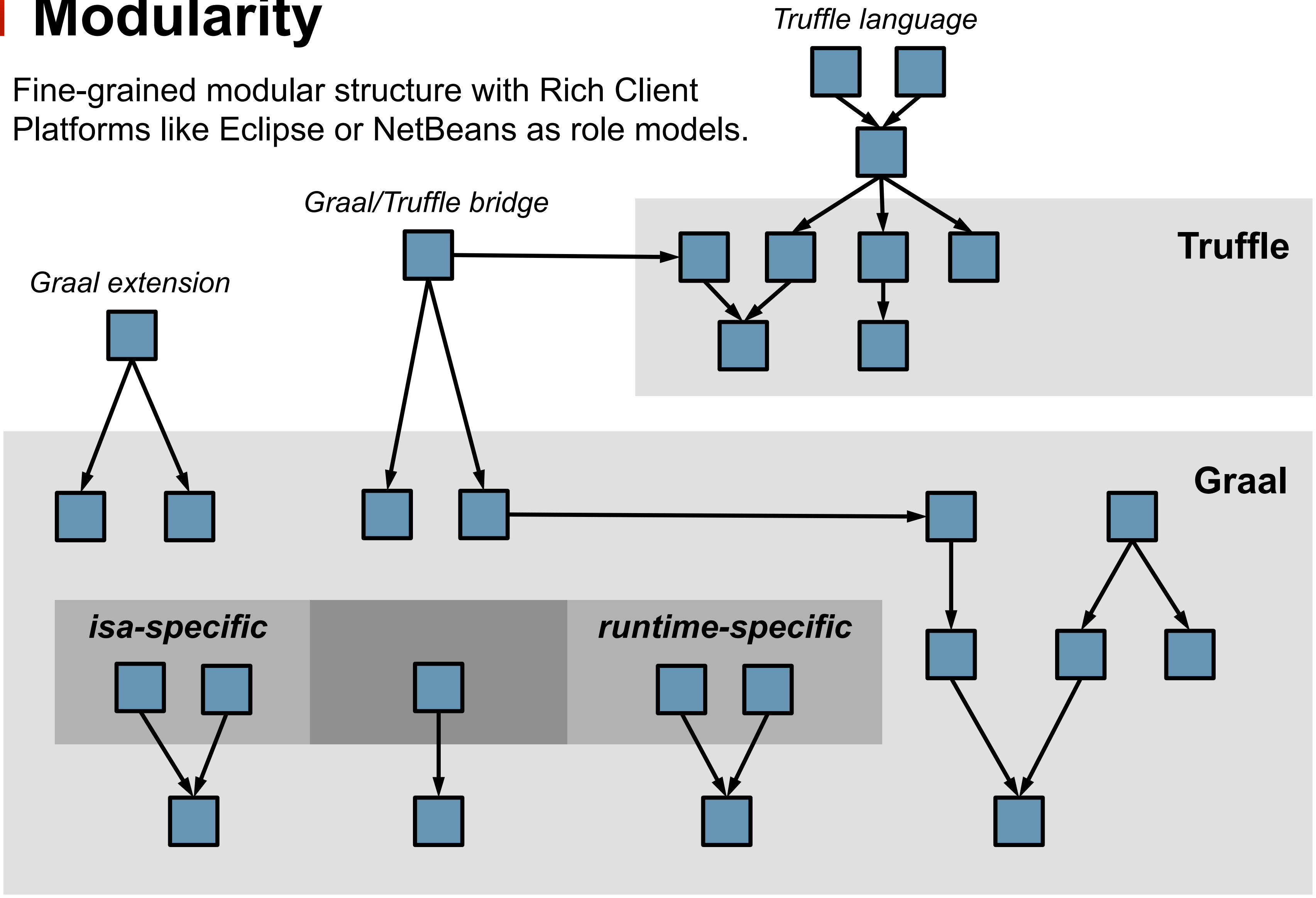
Baseline, Mid-tier, Optimizing, Vectorizing, ...

Programming Languages

Java, JavaScript, Python, R, Ruby, C, Smalltalk, ...

Modularity

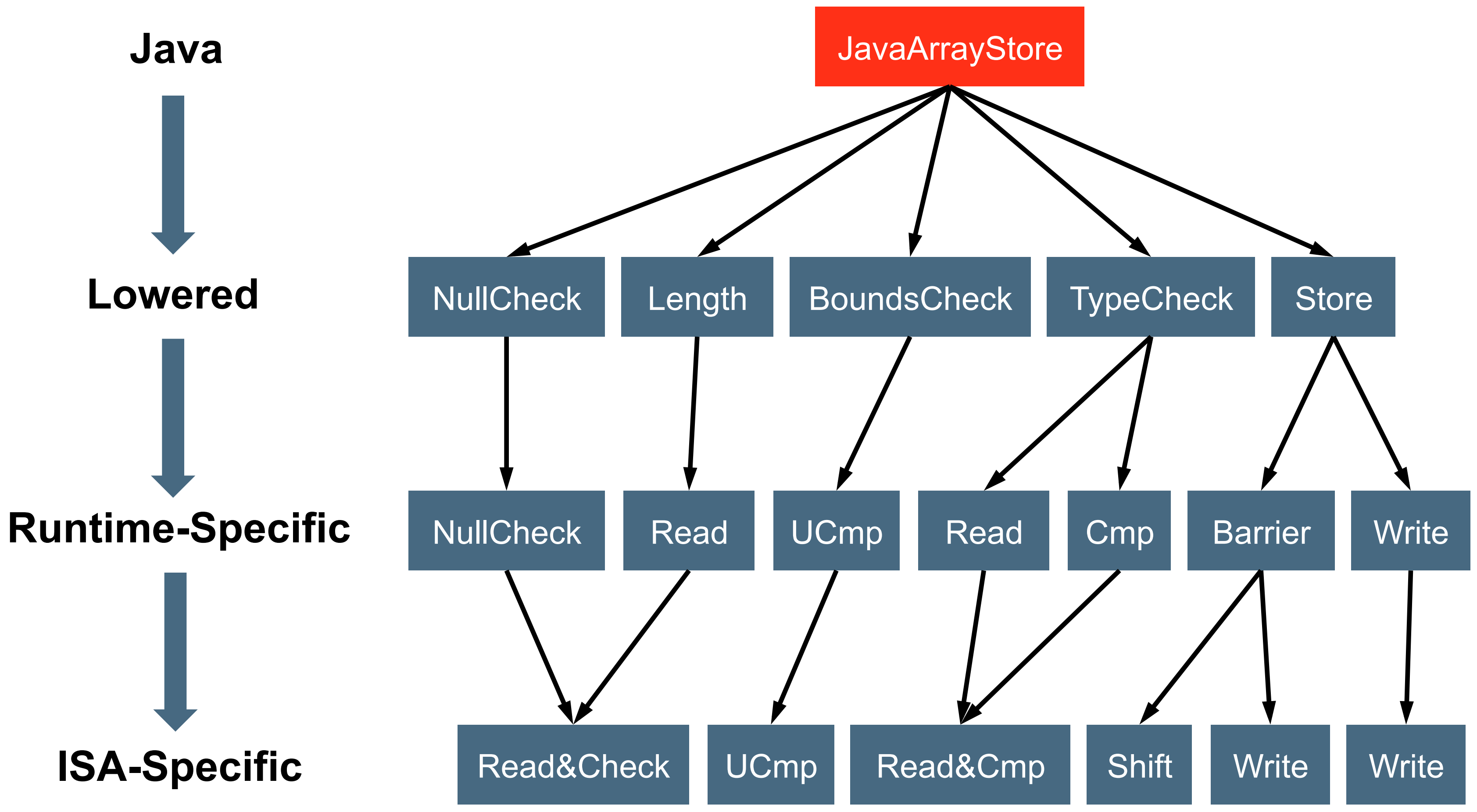
Fine-grained modular structure with Rich Client Platforms like Eclipse or NetBeans as role models.



Specific to Host Runtime

- Field/Array Access
  - object/array layout, read/write barriers, …
- Allocation
  - garbage collector, thread-local buffer, …
- Type Checks
  - class hierarchy organization, …
- Locking
  - monitor system, monitor enter/exit, …
- JDK intrinsifications
  - hashCode, clone, reflection, …
- Invocations
- Safepoints

Levels of Lowering



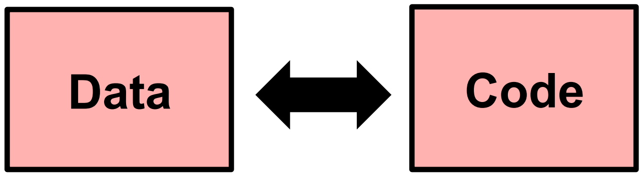
Snippets for Graph Construction

Manual construction:

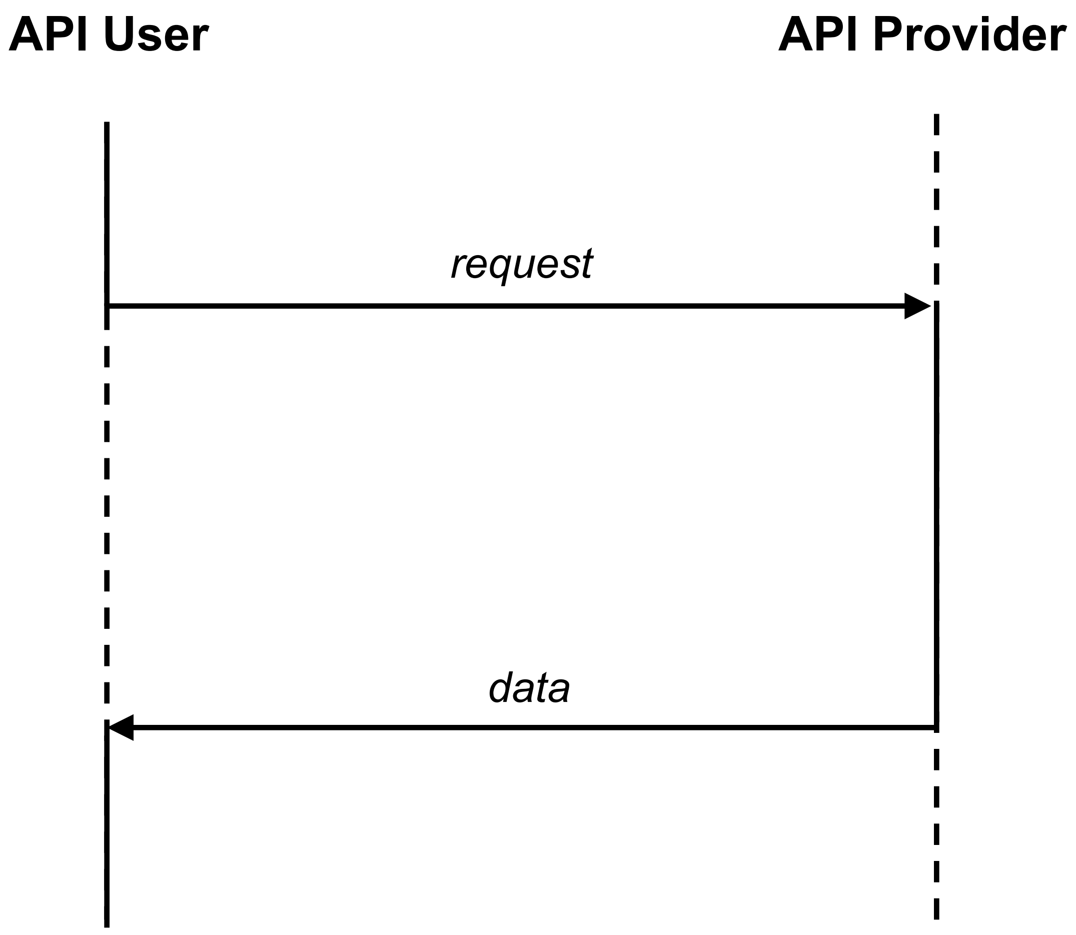
```
Node max(ValueNode a, ValueNode b) {
    IfNode ifNode = new IfNode(new IntegerLessThanNode(a, b));
    ifNode.trueSuccessor().setNext(new ReturnNode(a));
    ifNode.falseSuccessor().setNext(new ReturnNode(b));
    return ifNode;
}
```

Expression as snippet:

```
int max(int a, int b) {
    if (a > b) return a;
    else return b;
}
```



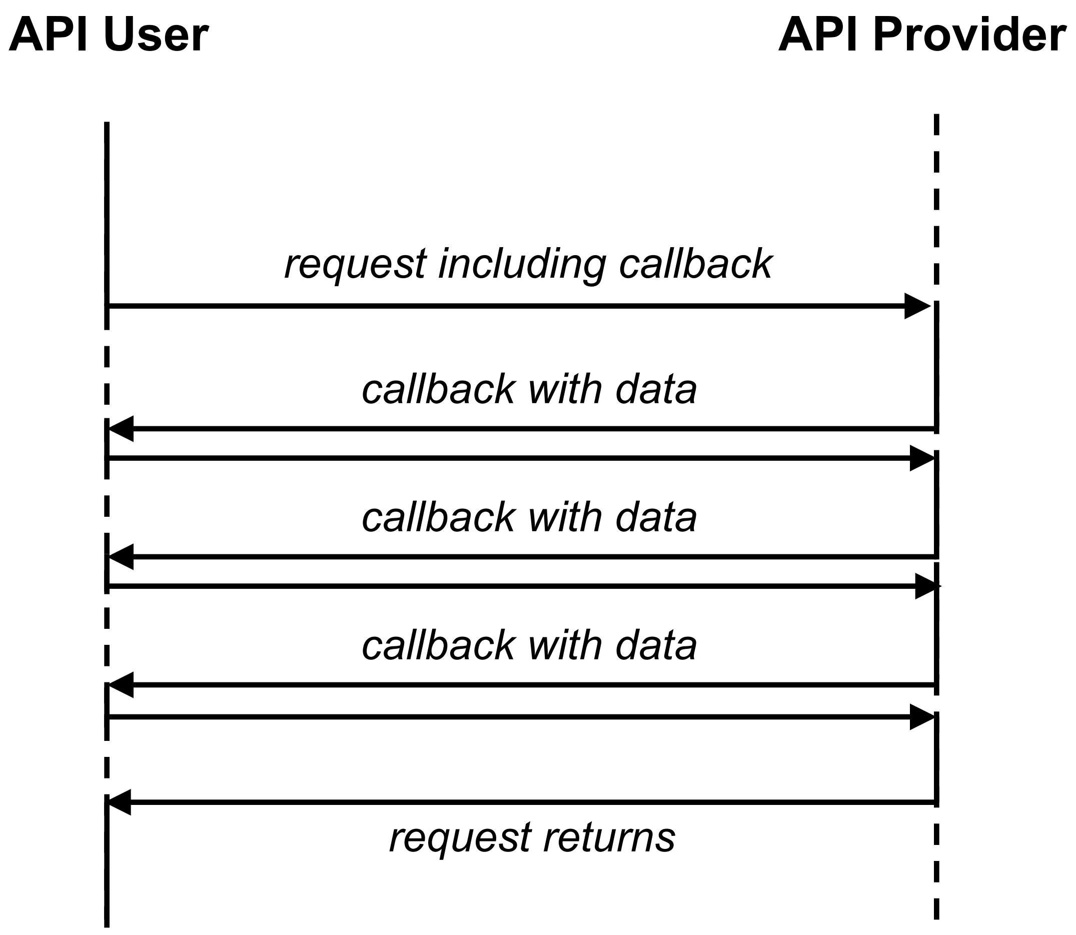
Simple API



✓ Can capture statically

x Limited flexibility

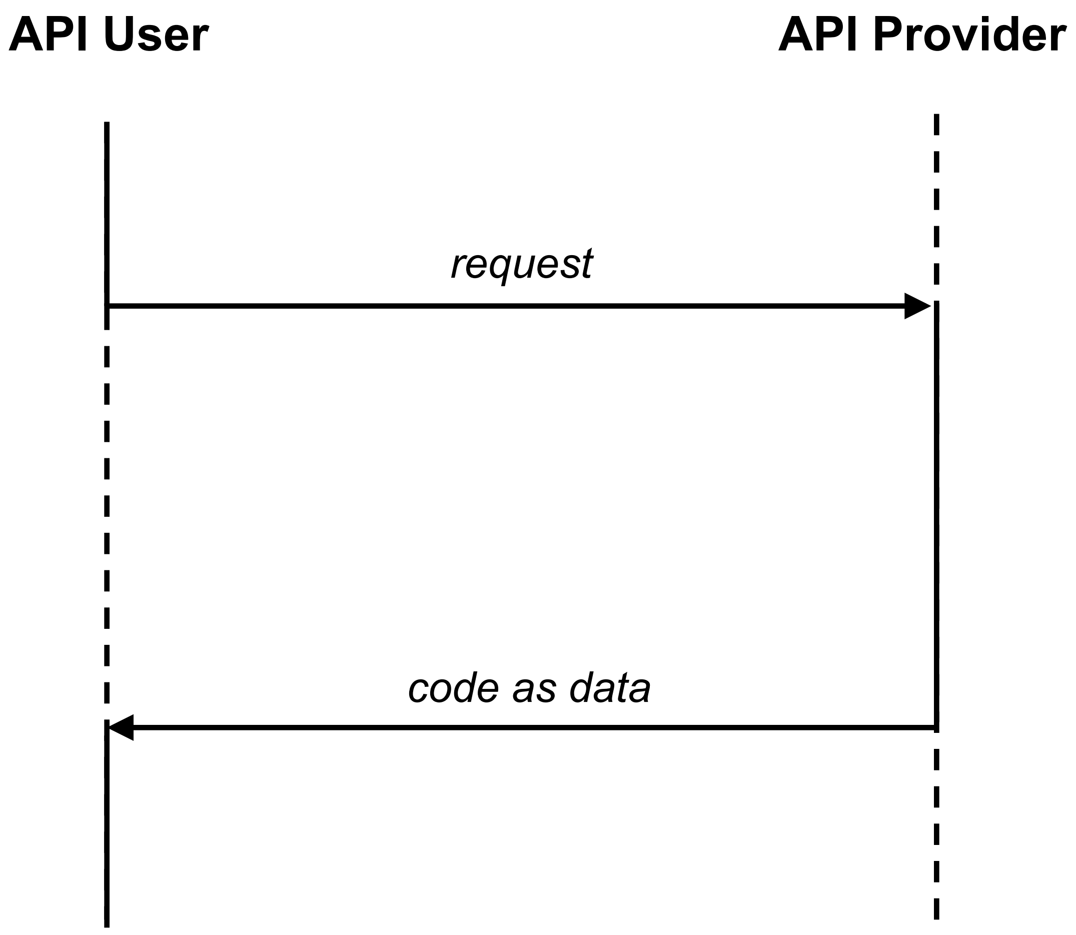
Callback API



✓ High flexibility

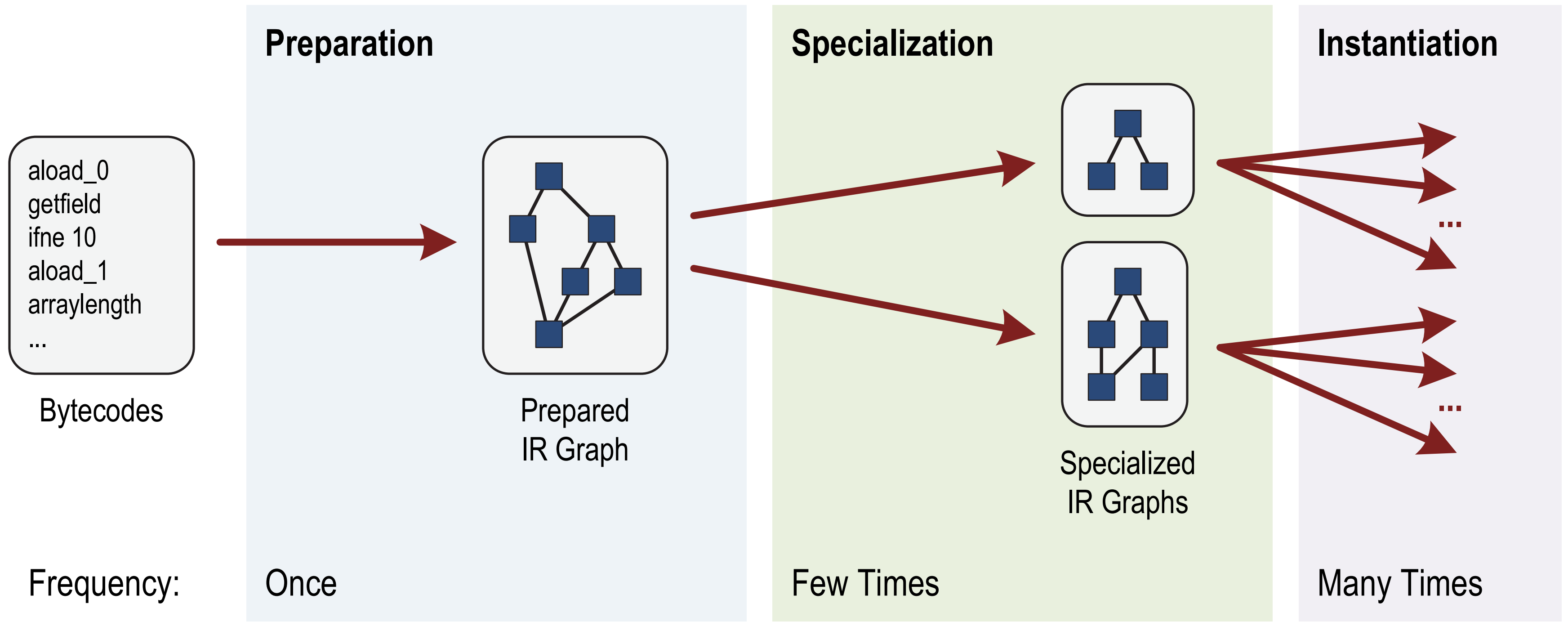
x Cannot capture statically

Snippet API



✓ High flexibility ✓ Can capture statically

Snippet Lifecycle



Snippet Example: Convert

```
@Snippet
static int f2i(float input, int result) {
  if (probability(SLOW_PATH,
                  result == Integer.MIN_VALUE)) {

    if (Float.isNaN(input)) {
      return 0;
    } else if (input > 0.0f) {
      return Integer.MAX_VALUE;
    }
  }
  return result;
}
```

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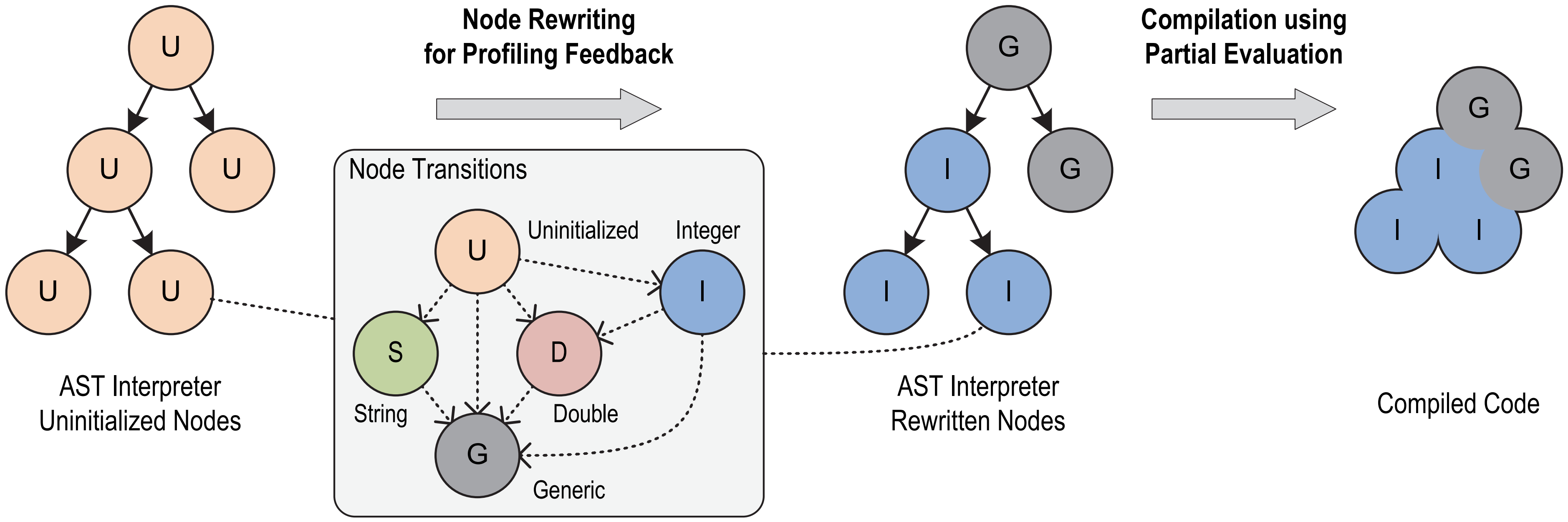
Technical Approach

Speculate and Optimize…



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AST Interpreter Uninitialized Nodes
Node Rewriting for Profiling Feedback
Node Transitions
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Uninitialized
Integer
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Generic
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AST Interpreter Rewritten Nodes
Compilation using Partial Evaluation
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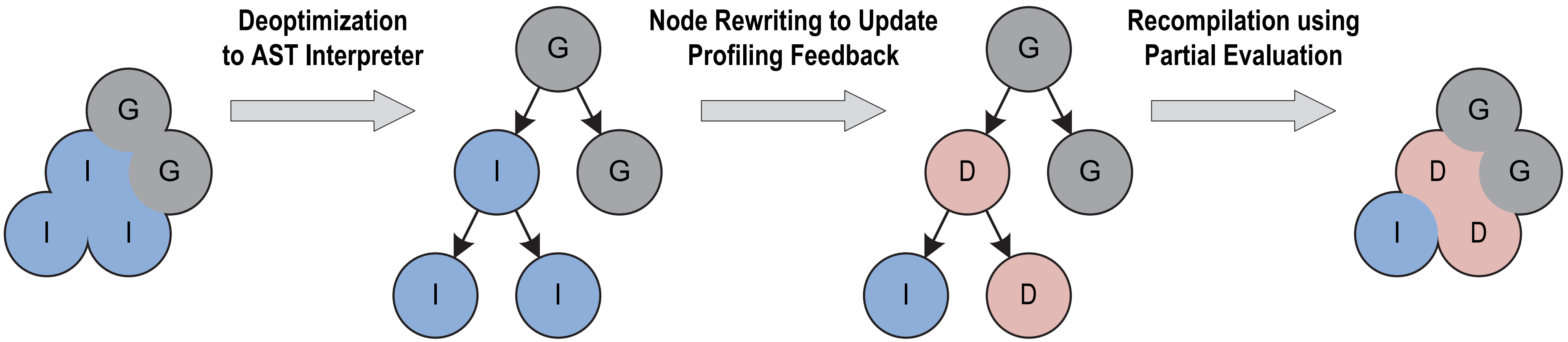
Compiled Code

Technical Approach

… and Deoptimize and Reoptimize!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Deoptimization to AST Interpreter
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Node Rewriting to Update Profiling Feedback
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Recompilation using Partial Evaluation
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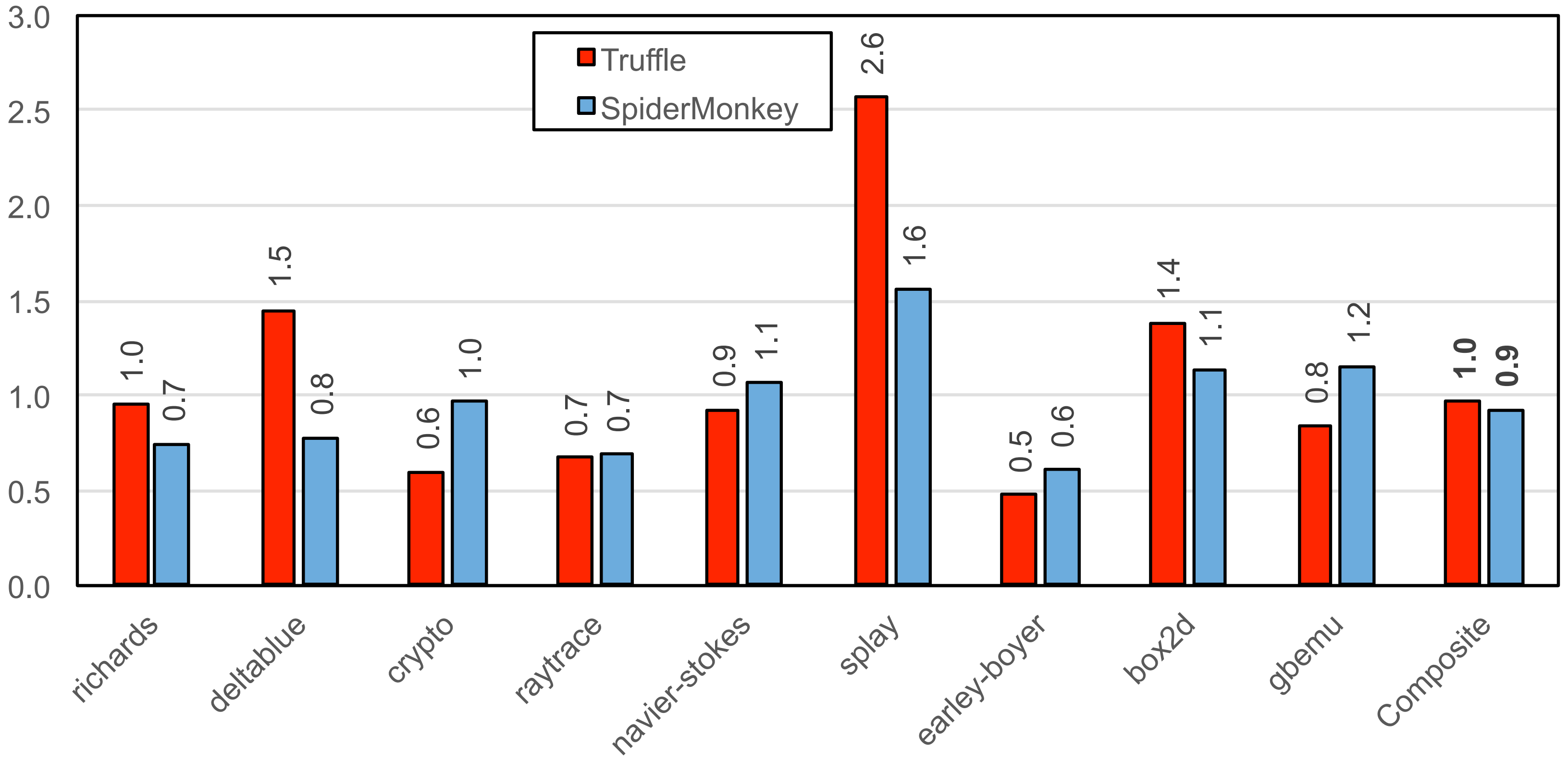
Technical Approach

Three main parts for driving partial evaluation

- Limit partial evaluation expansion
  - Annotation `@SlowPath` on a method stops the inclusion of a method in the expansion.
- Dynamic speculation
  - Call to `CompilerDirectives.transferToInterpreter()` advises the partial evaluator to stop and place a deoptimization exit.
- Global speculation
  - Assumption objects can be used for global speculations about the system state. Checking the assumption in compiled code poses no runtime overhead.

Peak Performance: JavaScript

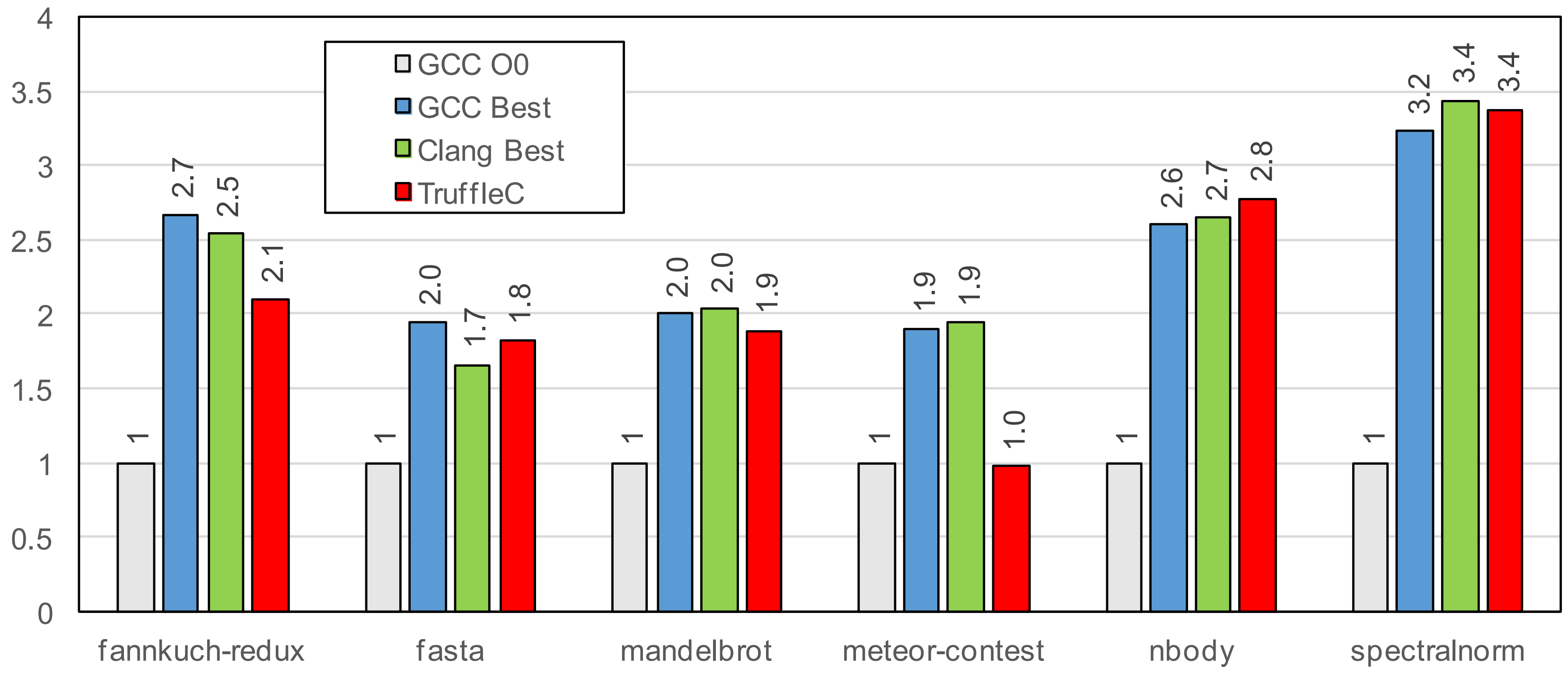
Speedup relative to V8



Selection of benchmarks from Google's Octane benchmark suite v1.0
latest versions of V8, Truffle, and SpiderMonkey as of December 2013

Peak Performance: C

Speedup relative to GCC O0



Grimmer, Rigger, Schatz, Stadler, Mössenböck: *TruffleC: Dynamic Execution of C on the Java Virtual Machine*; to be submitted

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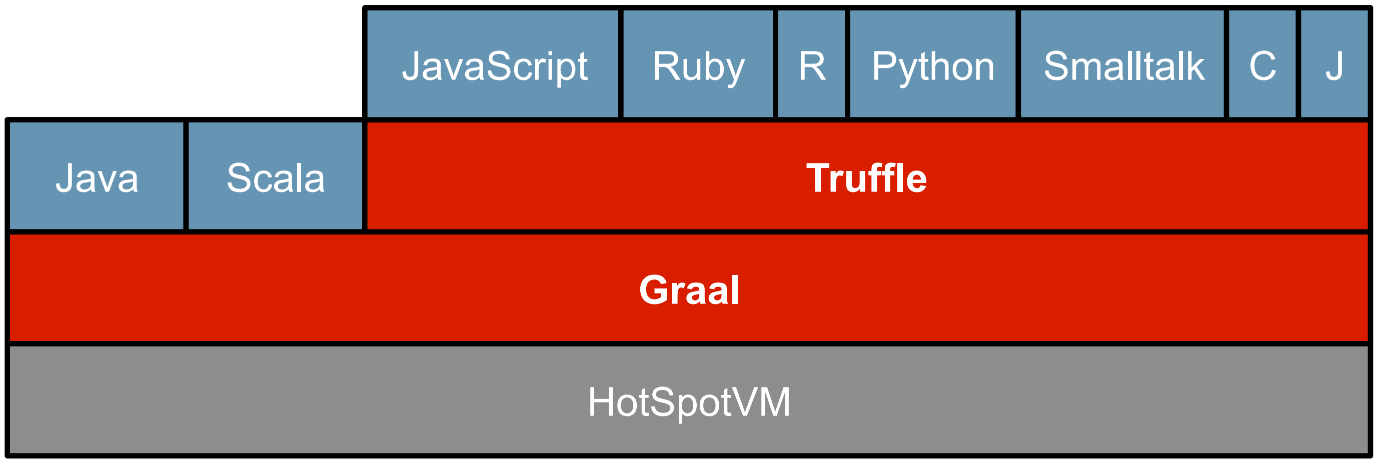
Graal OpenJDK Project

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

- Development of Graal/Truffle core artifacts and APIs
- Highly active: 30+ contributors over last 12 months
- Highly modular: 80+ individual modules



Research Areas

Language Implementation	Experimentation with new language features, new languages, new execution models	**Truffle Interpreters**
General Language Research	Language-independent instrumentation, cross-language research, automatic partial evaluation experiments	**Truffle**
Compiler Construction	Core compiler construction research, heterogenuous computing, advanced architectures and backends	**Graal**

Graal/Truffle Related Research Projects (1)

- TruffleRuby
  - Development in the JRuby repository (lead Chris Seaton).
  - https://github.com/jruby/jruby
  - http://blog.jruby.org/2014/01/truffle_graal_high_performance_backend/
- FastR
  - Joint effort of a group from Purdue University (Prof. Jan Vitek) and a team at Oracle Labs (lead Michael Haupt).
  - https://bitbucket.org/allr/fastr
- ZipPy
  - Development by a group from University of California, Irvine (Prof. Michael Franz).
  - https://bitbucket.org/ssllab/zippy
- TruffleSOM
  - Development by Stefan Marr at: https://github.com/smarr/

Graal/Truffle Related Research Projects (2)

- C and Language Interoperability
  - Experiment by students at JKU Linz (Matthias Grimmer and Manuel Rigger).
- JavaScript
  - Effort done by the core Graal/Truffle team.
- Debugging
  - Effort by Micheal van de Vanter from Oracle Labs.
- SubstrateVM
  - Team at Oracle Labs led by Christian Wimmer is developing an alternative host runtime.
- Graal IR Instrumentation
  - Research by Yudi Zheng (USI Lugano) on instrumenting Graal IR.
- GPU Offload
  - Research by Christopher Dubach et al. from the University of Edinburgh.
  - Graal is the compiler of choice for Project Sumatra (HSAIL/PTX offload).

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Your Language or Compiler Extension?

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
```

- Graal Resources

  https://wiki.openjdk.java.net/display/Graal/Main

- Truffle API License: GPLv2 with Classpath Exception
- Graal License: GPLv2

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Prof. Peter Marwedel
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Ingo Korb

University of California, Davis
Prof. Duncan Temple Lang
Nicholas Ulle

And many more…

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

graal-dev@openjdk.java.net

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Q/A

Hardware and Software

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