Truffle: your favorite language on JVM

without compromises

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Program Agenda

1. Motivation
2. How Truffle Works
3. Graal Compiler
4. Demos

Implementing another (dynamic) language

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

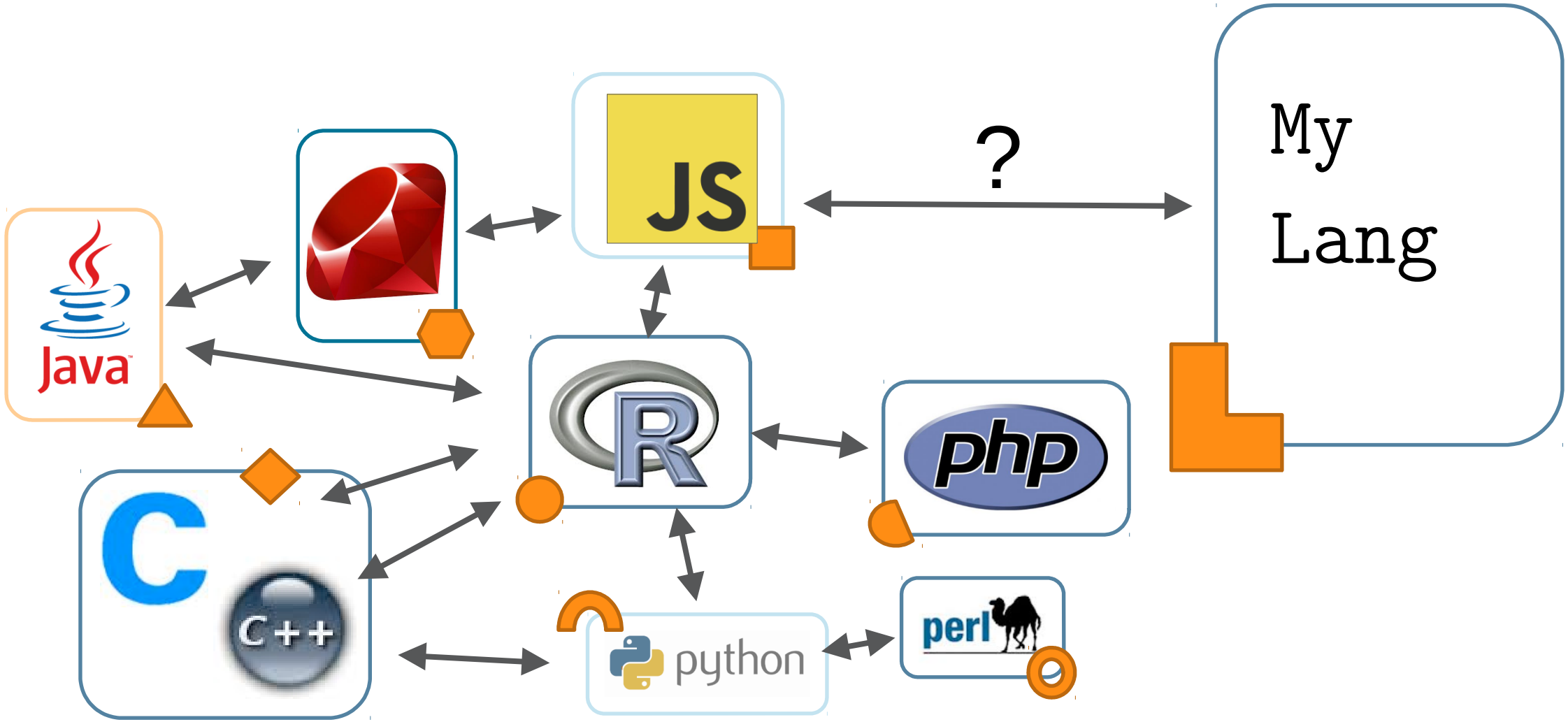
People complain about performance

Define a bytecode format and write bytecode interpreter

Performance is still bad

Write a JIT compiler
Improve the garbage collector
Write an optimizing JIT compiler

Systems come with Various Interfaces



You can execute any language on the JVM / CLR

You can execute any language on the JVM / CLR

- as long as it looks like Java / C#.

Truffle: write your own language with ease!

Current situation	How it should be
Prototype a new language	Prototype a new language in Java
Parser and language work to build syntax tree (AST), AST Interpreter	Parser and language work to build syntax tree (AST) Execute using AST interpreter
Write a “real” VM	Integrate with VM-building framework
In C/C++, still using AST interpreter, spend a lot of time implementing runtime system, GC, …	Integrate with Modular VM Add small language-specific parts
People start using it	People start using it
People complain about performance	And it is already fast
Define a bytecode format and write bytecode interpreter	
Performance is still bad	
Write a JIT compiler Improve the garbage collector	

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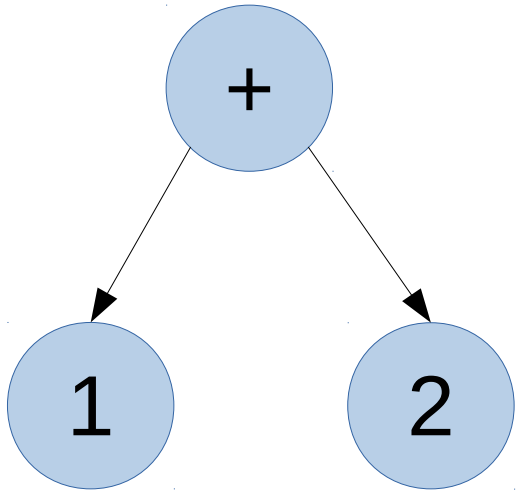
AST Interpreter

```
interface Node { Object execute(); }

class Add implements Node {
  public Node left;
  public Node right;
  @Override
  public Object execute() {
    return left.execute() + right.execute();
  }
}

class Constant implements Node {
  public int value;
  @Override
  public Object execute() { return value; }
}
```



The Biggest Problem of Dynamic Languages

```
interface Node { Object execute(); }

class Add implements Node {
  public Node left;
  public Node right;
  @Override
  public Object execute() {
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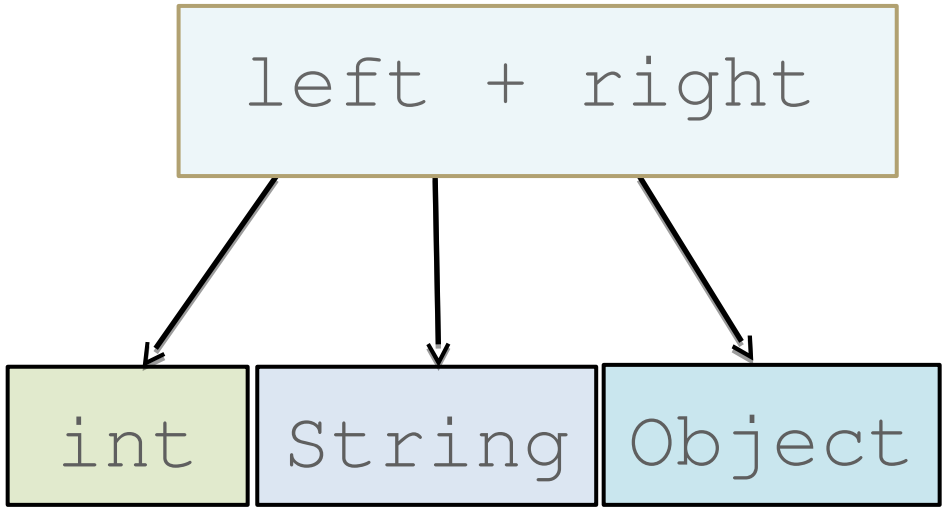
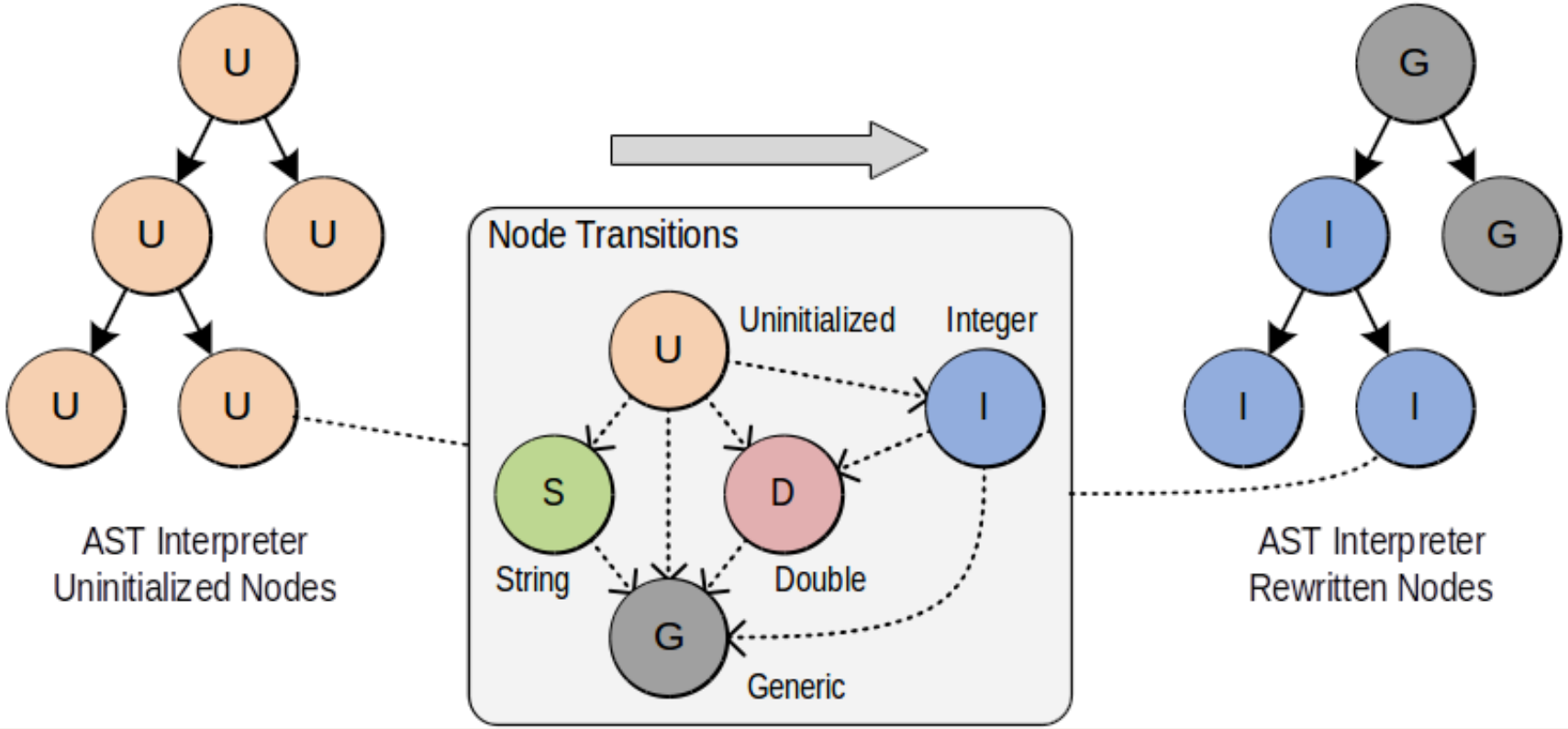


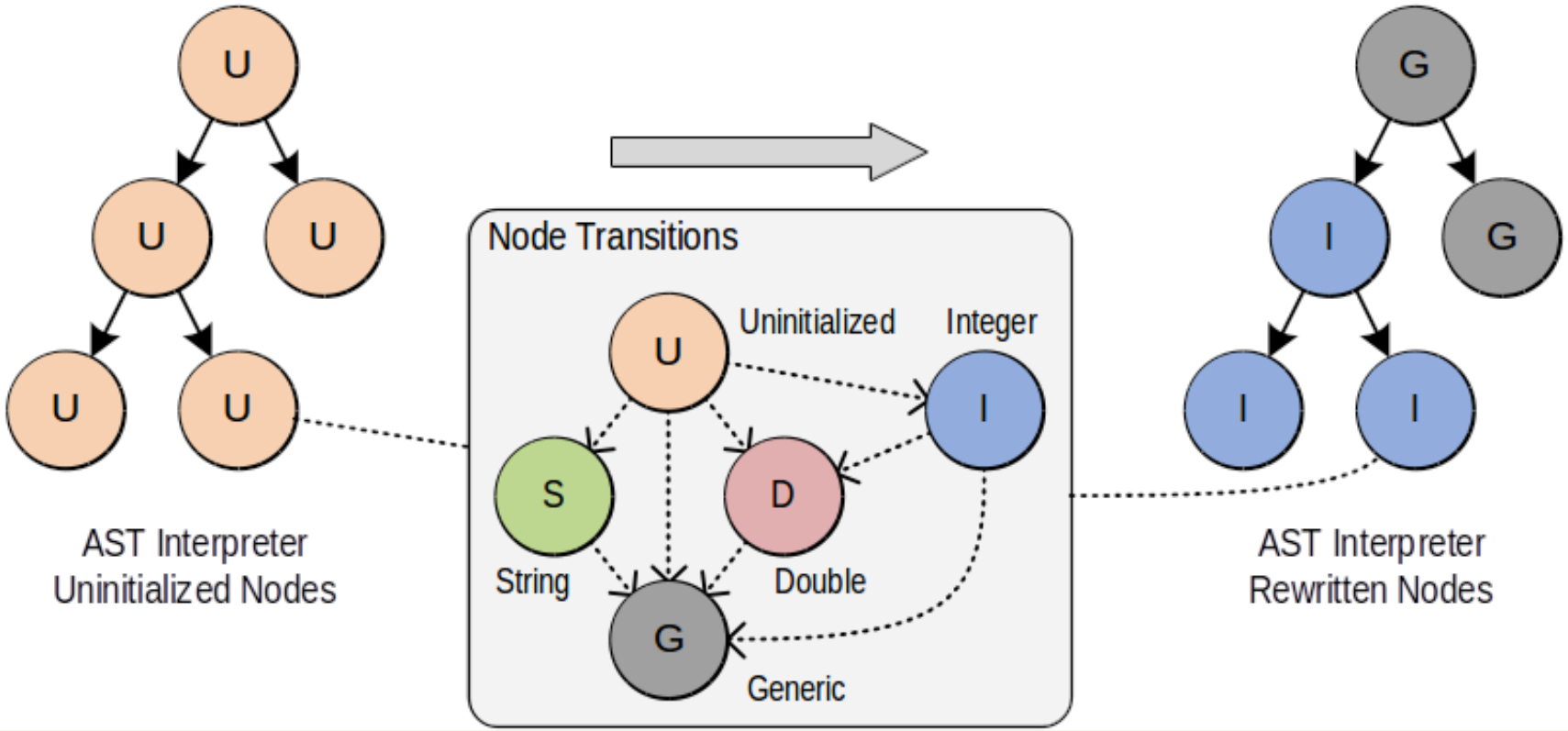
Self Optimizing AST Interpreter

- Unitinitialized node
  - are left and right operands integers => rewrite to integer addition
  - are left and right operands strings => rewrite to string concatenation
  - ...



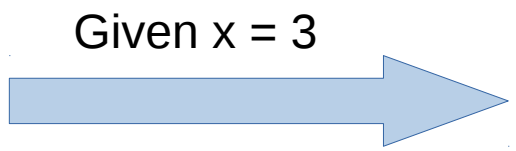
Self Optimizing AST Interpreter

- Integer addition node
  - operands are not of integer types => rewrite the node
  - integer addition



Intermezzo: Partial Evaluation

```
int f(int x, int y){
   return x*42 + y;
}
```




```
int f(int y) {
   return 126 + y;
}
```

Intermezzo: Partial Evaluation

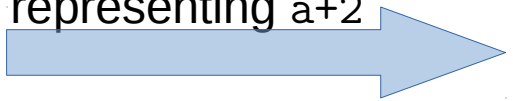
```
int f(int x, int y){
   return x*42 + y;
}
```

Given x = 3

```
int f(int y) {
   return 126 + y;
}
```

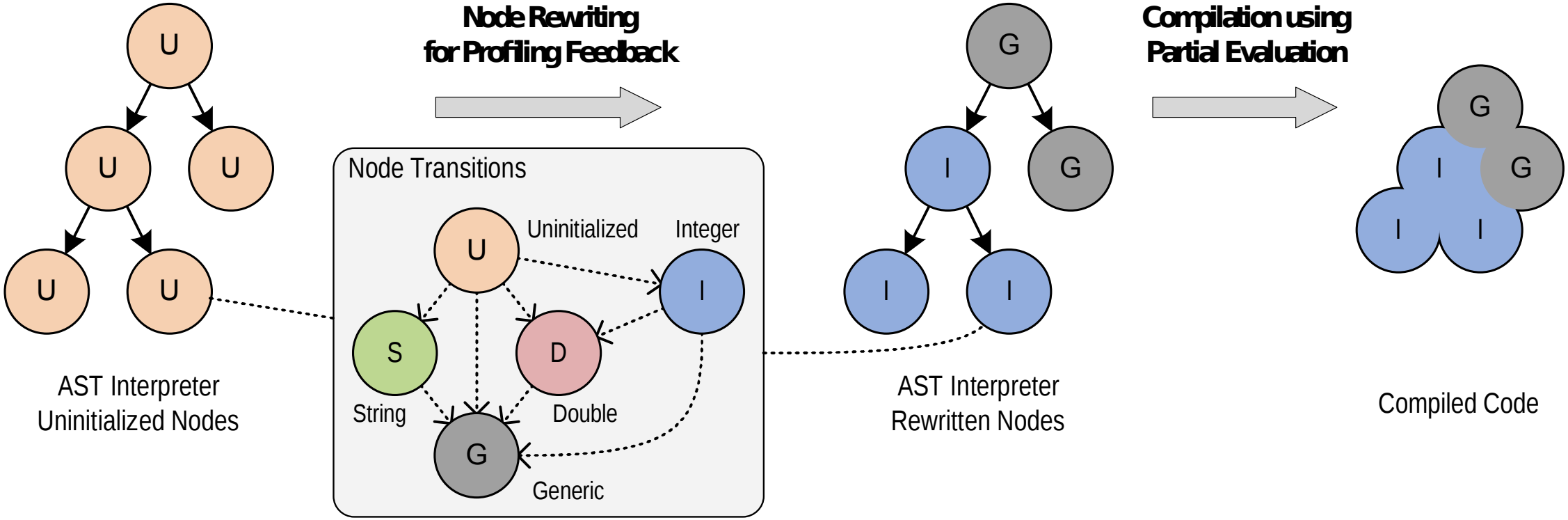
```
run(node, vars){
   node.execute(vars);
}
```

Given a fixed node representing a+2



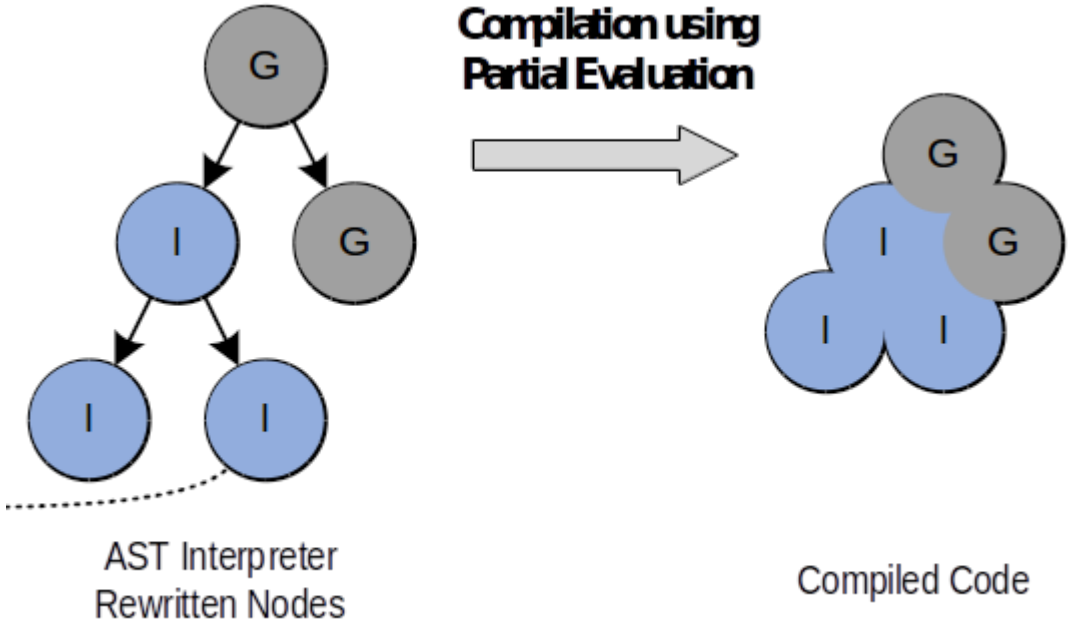
```
run(vars) {
   vars.a + 2;
}
```

Partially Evaluated Self Optimizing AST



Partially Evaluated Self Optimizing AST

- Integer addition node
  - operands are not of integer type => rewrite the node
  - integer addition

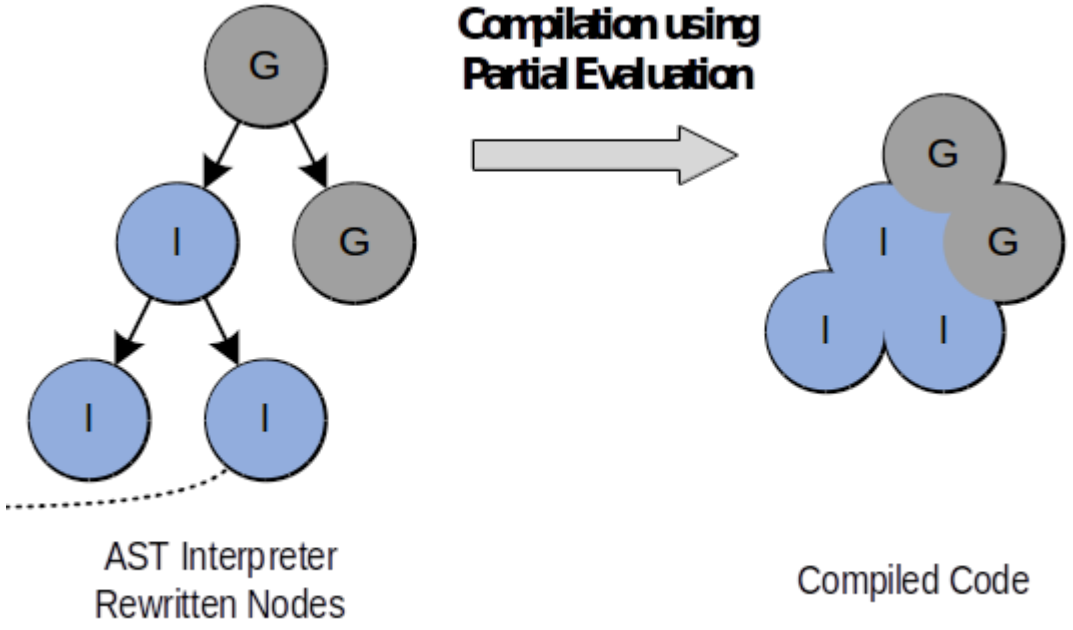


Partially Evaluated Self Optimizing AST

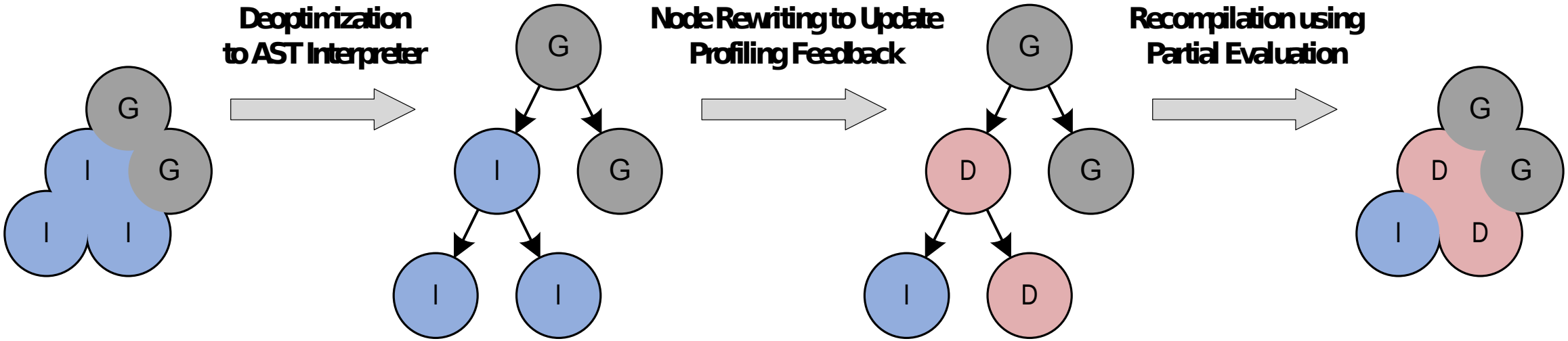
- Integer addition node
  - operands are not of integer type => rewrite the node
  - integer addition

→

- Do not PE
- Insert DEOPT

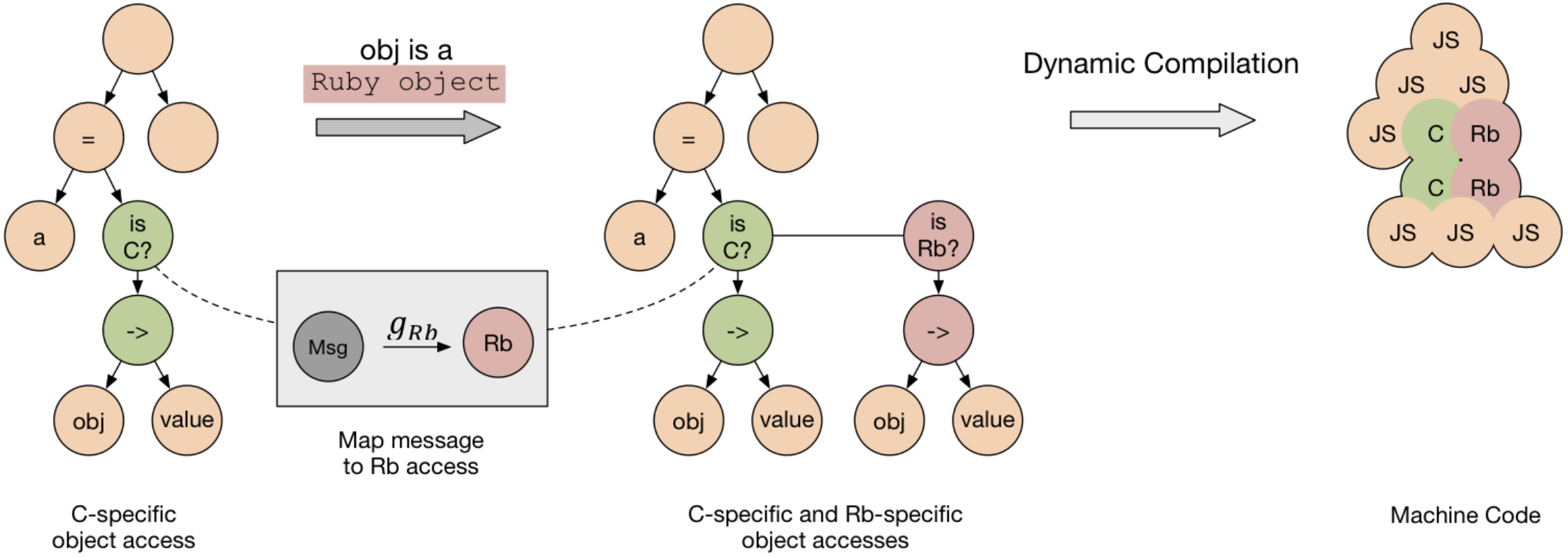


The argument is suddenly double...



High performance interoperability

```
var a = obj.value;
```



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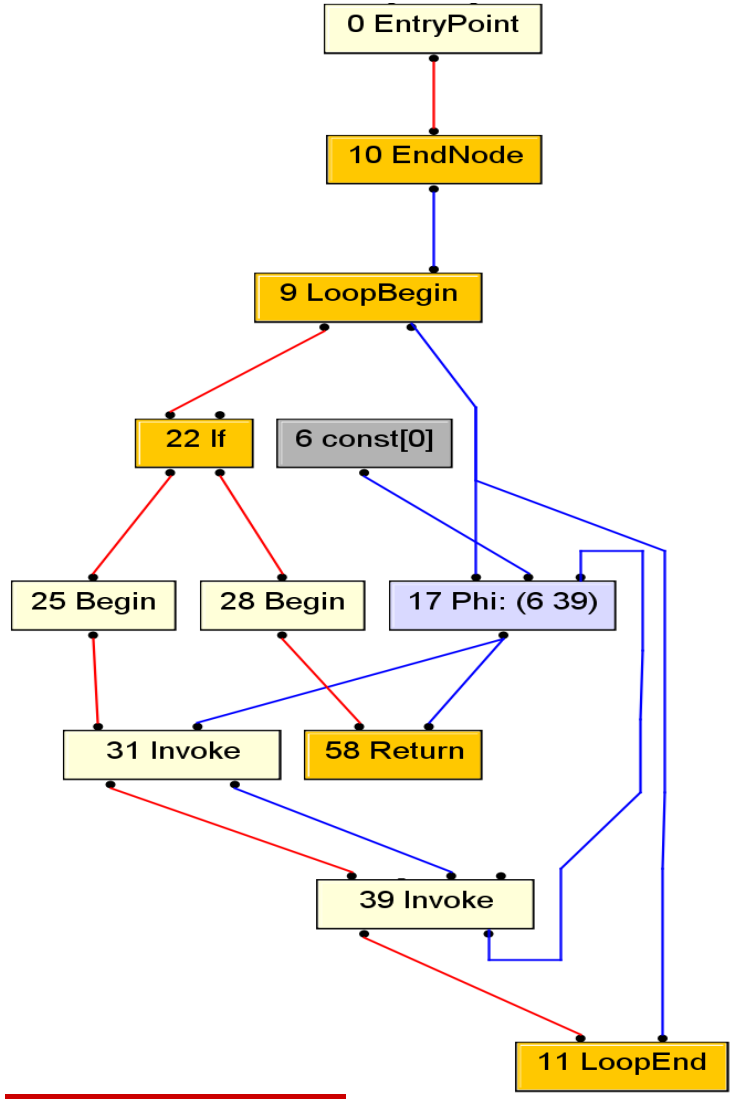
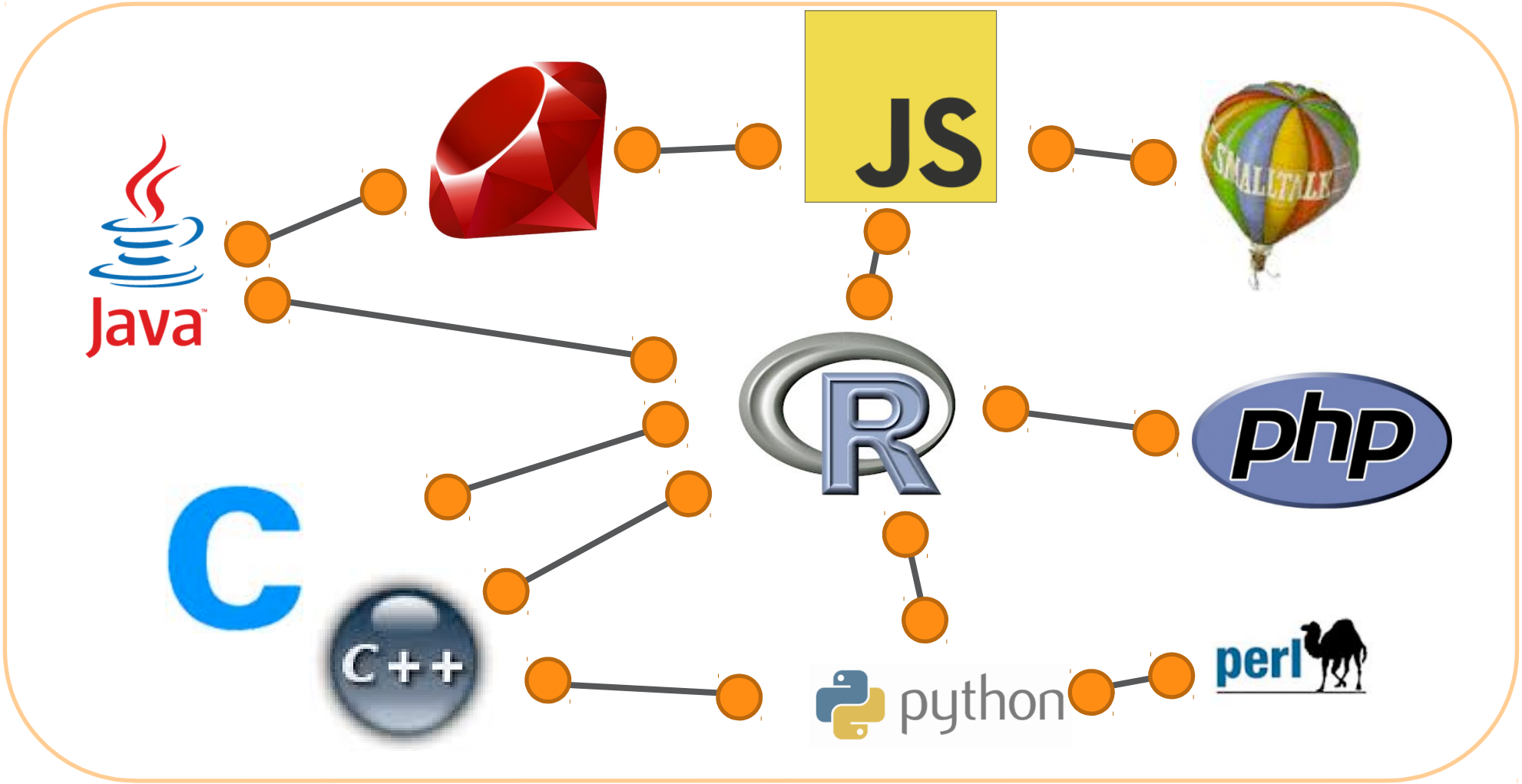
Graal Compiler



- Modern alternative to HotSpot C2
  - Maintainable code base
  - Toolable, approachable
  - Ready for today's code
  - JEP 243: Java Compiler Interface (JVMCI)
- Partial evaluation
- Aggressive speculations
- Smooth de-optimizations

GraalVM: One VM to Rule them all!



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Q/A

oracle.com/technetwork/oracle-labs/program-languages
github.com/graalvm

Integrated Cloud

Applications & Platform Services