JS, Rust, Python and the Holy Graal

Lars Hupel
BOB
2020-02-28

INNOQ

The origins of Java

> “
> *1996 – James Gosling invents Java. Java is a relatively verbose, garbage collected, class based, statically typed, single dispatch, object oriented language with single implementation inheritance and multiple interface inheritance. Sun loudly heralds Java’s novelty.* ”

– James Iry

Sun microsystems

Java: a short history

1994 first JVM version

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JSR 223

Problem

Servlets are cool, but we want to write our web pages in PHP.

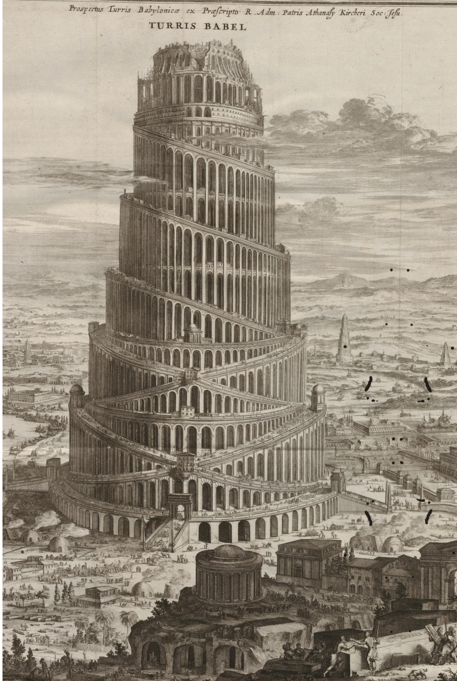
JSR 223

Problem
Servlets are cool, but we want to write our web pages in PHP.

Solution
Define an API for scripting languages to exchange objects with Java.

Scripting languages

- JSR 223 does not define “scripting language”
- wording implies untyped languages
- fundamental problem: most calls require reflection (slow)


Prospectus Turris Babylonicæ ex Præſcripto R. Adm: Patris Athanaſy Kircheri Soc: Jeſu.
TURRIS BABEL

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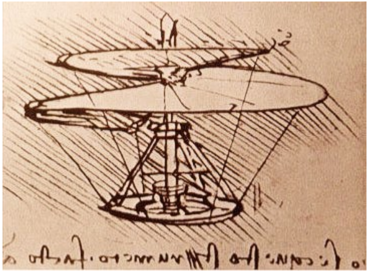
Da Vinci Machine



- started in 2007 as a VM playground
- subprojects: dynamic invocation, continuations, tail-calls, ...

the Da Vinci Machine

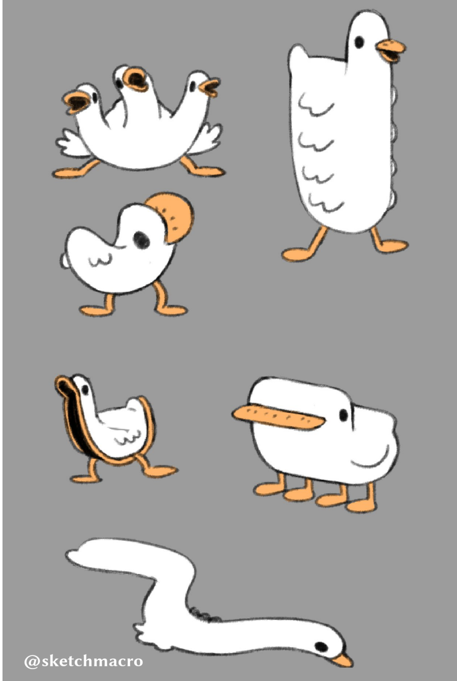
a multi-language renaissance for the Java™ Virtual Machine architecture

```
http://openjdk.java.net/
            /projects/mlvm/
```

invokedynamic

Problem

Scripting languages are cool, but we don't know what the heck `x + y` means



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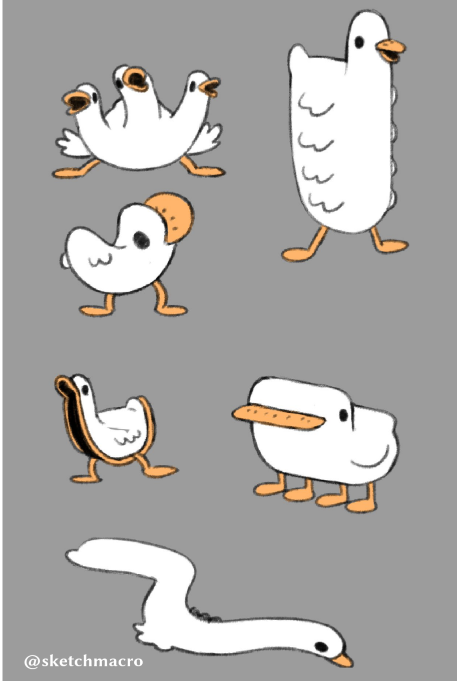
`[object Object]`



@sketchmacro

invokedynamic

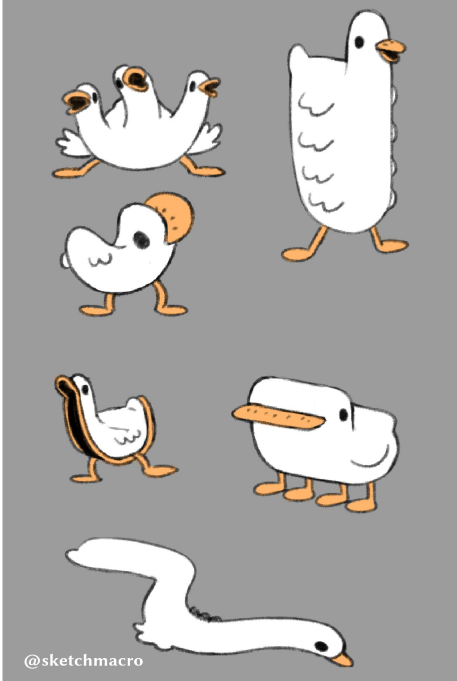
Problem

Scripting languages are cool, but we don't know what the heck `x + y` means

[object Object]

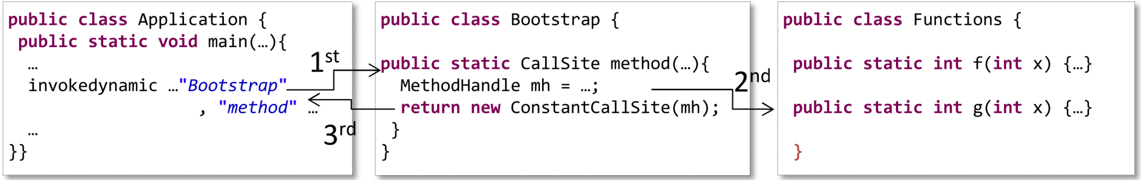
Solution

Allow compiler implementers to implement custom dispatching



@sketchmacro

An invokedynamic instruction *is linked* just before its first execution.



```
public class Application {
 public static void main(…){
  …
  invokedynamic …"Bootstrap"
                    , "method" …
  …
}}
```

```
public class Bootstrap {

public static CallSite method(…){
  MethodHandle mh = …;
  return new ConstantCallSite(mh);
 }
}
```

```
public class Functions {

 public static int f(int x) {…}

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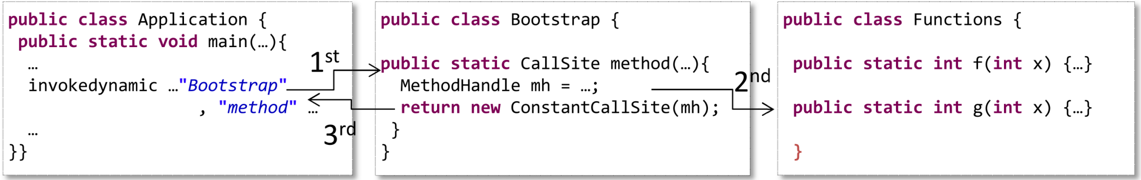

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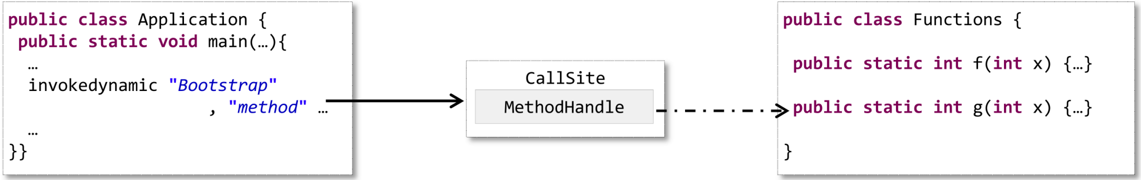
The call site then becomes *permanently linked* to the invokedynamic instruction.



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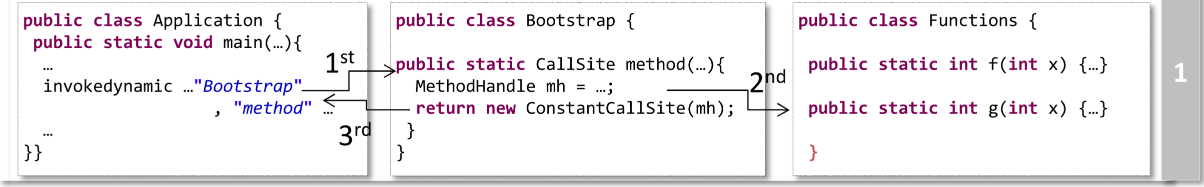

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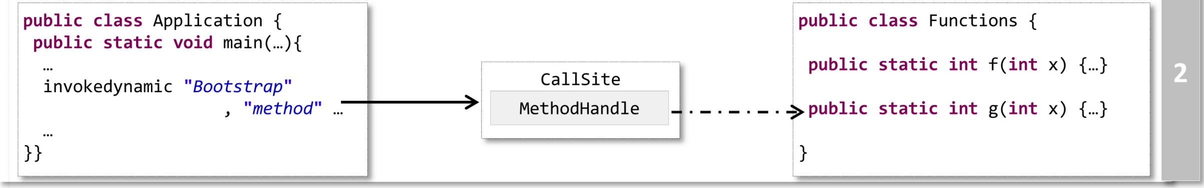

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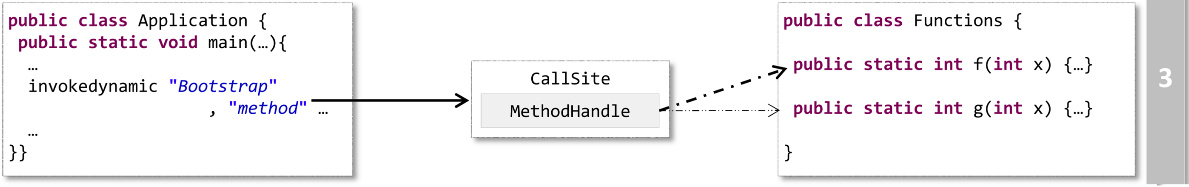
A non-constant call site may be *relinked* by changing its method handle.



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2019 first version of GraalVM

Enter GraalVM!

- polyglot JVM developed by Oracle
- tons of features

GraalVM™

What is Truffle?

> *“The Truffle framework allows you to run programming languages efficiently on GraalVM. It simplifies language implementation by automatically deriving high-performance code from interpreters.”*

Partial application

```
A => B => C
```

Partial application

```
A => B => C

     +

     A
```

Partial application

A => B => C

+

A

=

B => C

Partial evaluation

```
A => B => C

     +

     A

     =

  B => C
```

Compilers perform partial evaluation all the time!

Constant folding

Bounds-checking elimination

Inlining

Loop unrolling

Deforestation

Dead code elimination

Example

```c
int f(int x, int y) {
  int res = 0;
  for (int i = 0; i < x; ++i)
    res += y;
  return res;
}
```

Example

```
int f(int x, int y) {
  int res = 0;
  for (int i = 0; i < x; ++i)
    res += y;
  return res;
}

stream.map(y => f(3, y));
```

Example

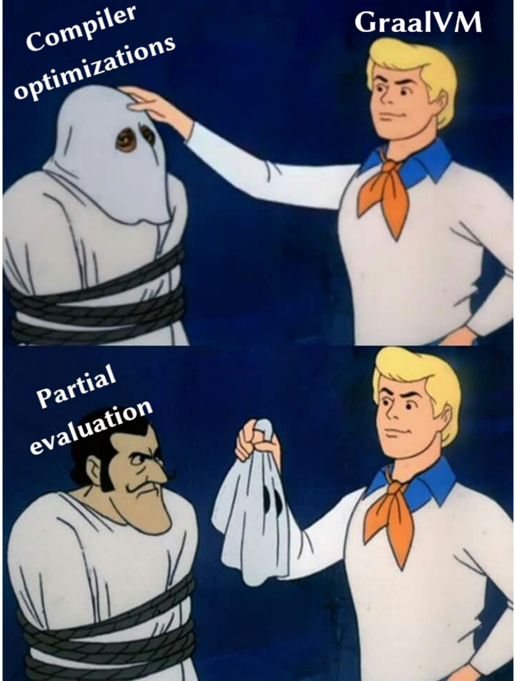
```
int f_x3(int y) {
  int res = 0;
  res += y;
  res += y;
  res += y;
  return res;
}

stream.map(y => f_x3(y));
```

Example

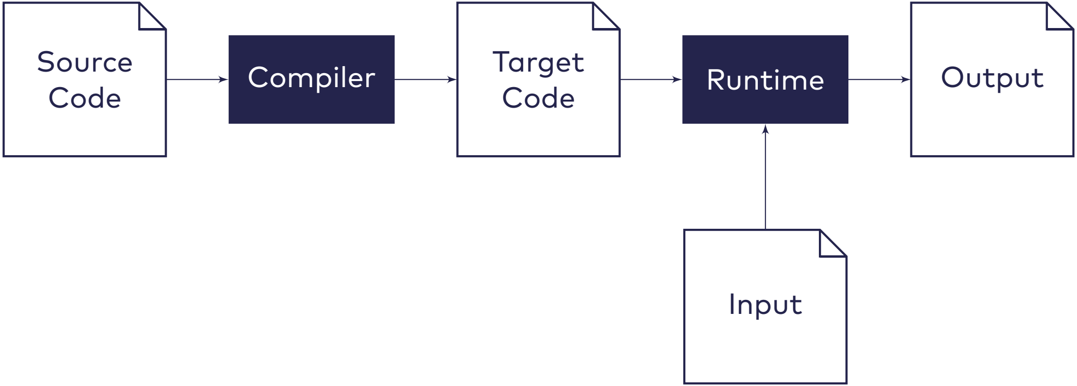
```
int f_x3(int y) {
  return 3 * y;
}

stream.map(y => f_x3(y));
```

Example

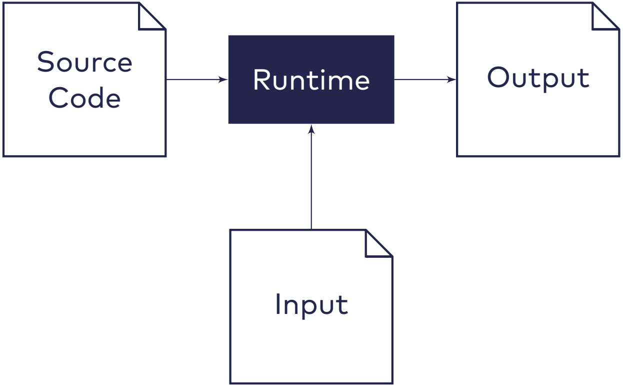
```
stream.map(y => 3 * y);
```


Compiler optimizations
GraalVM
Partial evaluation

Compiler



Interpreter



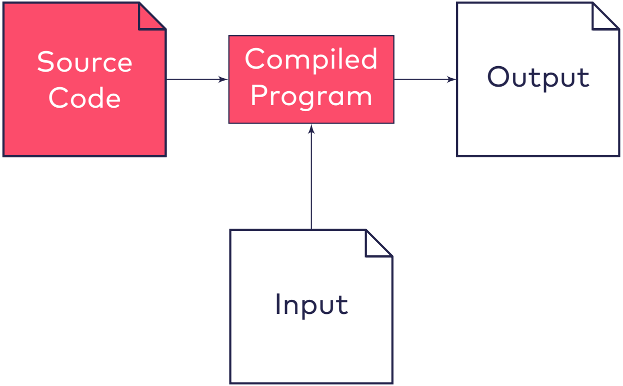
Partial Evaluation of Computation Process—An Approach to a Compiler-Compiler

YOSHIHIKO FUTAMURA
Central Research Laboratory, Hitachi, Ltd., Kokubunji, Tokyo, Japan 185

Abstract. This paper reports the relationship between formal description of semantics (i.e., interpreter) of a programming language and an actual compiler. The paper also describes a method to automatically generate an actual compiler from a formal description which is, in some sense, the partial evaluation of a computation process. The compiler-compiler inspired by this method differs from conventional ones in that the compiler-compiler based on our method can describe an evaluation procedure (interpreter) in defining the semantics of a programming language, while the conventional one describes a translation process.

FUTAMURA

Futamura projection



Code → Result

Code →
Result

(Code,
Interpreter) →
Executable

Code → Result

(Code, Interpreter) → Executable

Interpreter → Compiler

Code → Result

Interpreter → Compiler

(Code, Interpreter) → Executable

(Interpreter → Compiler) → Supercompiler

Futamura projections

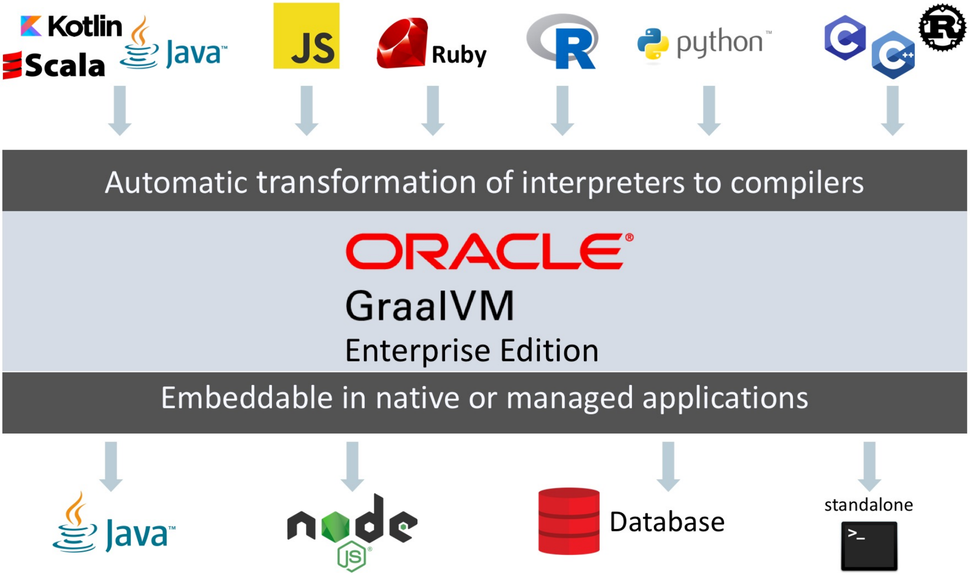
conjectured by Yoshihiko Futamura in the 1980's

Applying Futamura projections to compose Languages and Tools in GraalVM

PEPM 2019

Christian Humer

VM Research Group, Oracle Labs, Zurich



Automatic transformation of interpreters to compilers

ORACLE®

GraalVM

Enterprise Edition

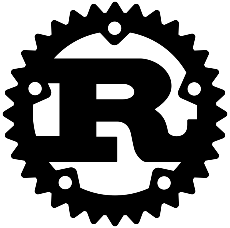
Embeddable in native or managed applications

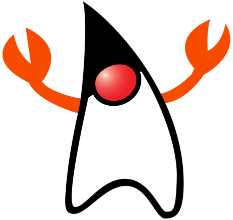
```java
public abstract class JSMultiplyNode extends JSBinaryNode {

    public abstract Object execute(Object a, Object b);

    @Specialization(guards = "b > 0", rewriteOn = ArithmeticException.class)
    protected int doIntBLargerZero(int a, int b) { /* ... */ }

    @Specialization(rewriteOn = ArithmeticException.class)
    protected int doInt(int a, int b) { /* ... */ }

    @Specialization
    protected double doDouble(double a, double b) {
        return a * b;
    }

    // ...
}
```

JVM + Polyglot = Profit

- languages may call each other
- languages benefit from the JVM:
  - parallelism
  - tooling
  - libraries
  - ...

Native code





Q & A

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LARS HUPEL

Consultant
innoQ Deutschland GmbH

Lars enjoys programming in a variety of languages, including Scala, Haskell, and Rust. He is known as a frequent conference speaker and one of the founders of the Typelevel initiative which is dedicated to providing principled, type-driven Scala libraries.

Image sources

- James Gosling: Peter Campbell, CC-BY-SA 4.0, https://commons.wikimedia.org/w/index.php?title=File:James_Gosling_2008.jpg&oldid=149207971
- Conde-Clemente, Patricia & Ortin, Francisco. (2014). JINDY: A java library to support invokedynamic.
- Spices: https://pixabay.com/photos/spices-spice-mix-market-73776/
- Duck typing: https://twitter.com/sketchymacro/status/1229046533359689730
- GraalVM architecture: https://blogs.oracle.com/graalvm/announcement
- GraalVM slide: https://popl19.sigplan.org/details/pepm-2019-papers/2/Applying-Futamura-Projections-to-Compose-Languages-and-Tools-in-GraalVM-Invited-Talk
- Rainbow: https://pixabay.com/photos/rainbow-seaside-coast-beach-sky-675832/
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- Da Vinci VM slide: https://openjdk.java.net/projects/mlvm/pdf/LangNet20080128.pdf
- LLVM logo: Apple
- Duke: Oracle
- Field: https://unsplash.com/photos/4miBe6zg5r0
- Cat with yarn: https://www.publicdomainpictures.net/en/view-image.php?image=161669&picture=cat-isolated-on-the-white