THE QUEST FOR DYNAMIC LANGUAGE PERFORMANCE ON THE JVM

[NASHORN WAR STORIES]

(from a battle scarred veteran of `invokedynamic`)

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[NASHORN RANTS]

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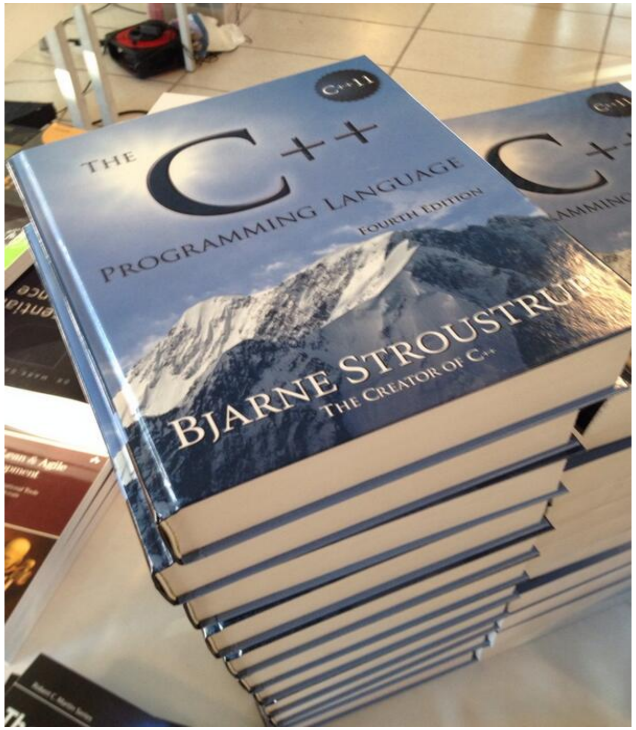
Who am I?

@lagergren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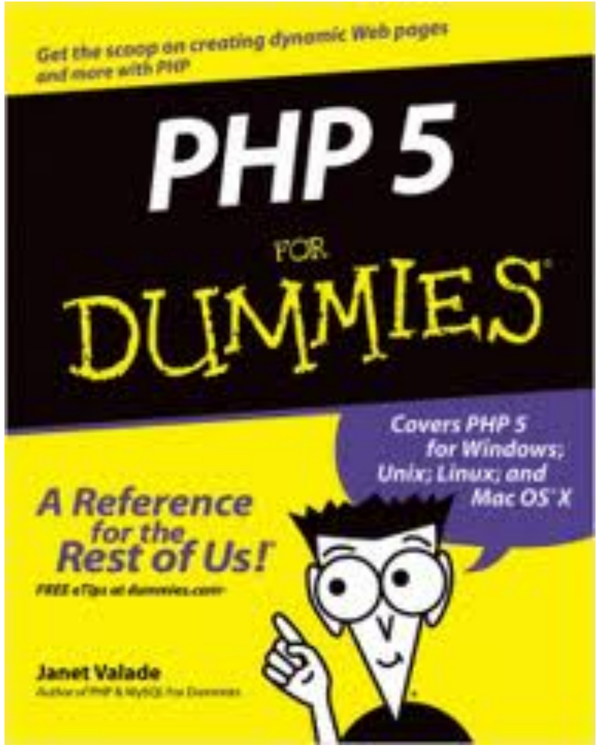
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I am here to talk about…

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What we've suffered through so far to implement a dynamic language on the JVM

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What we've suffered through so far to
implement a dynamic language on the JVM

The **Nashorn** Project

Also – a parade of JavaScript horrors

Agenda

- What is Nashorn and why?
- The problem of compiling an alien language to Java [sic] bytecode
  - Types
  - Optimistic assumptions
- The JVM and its issues

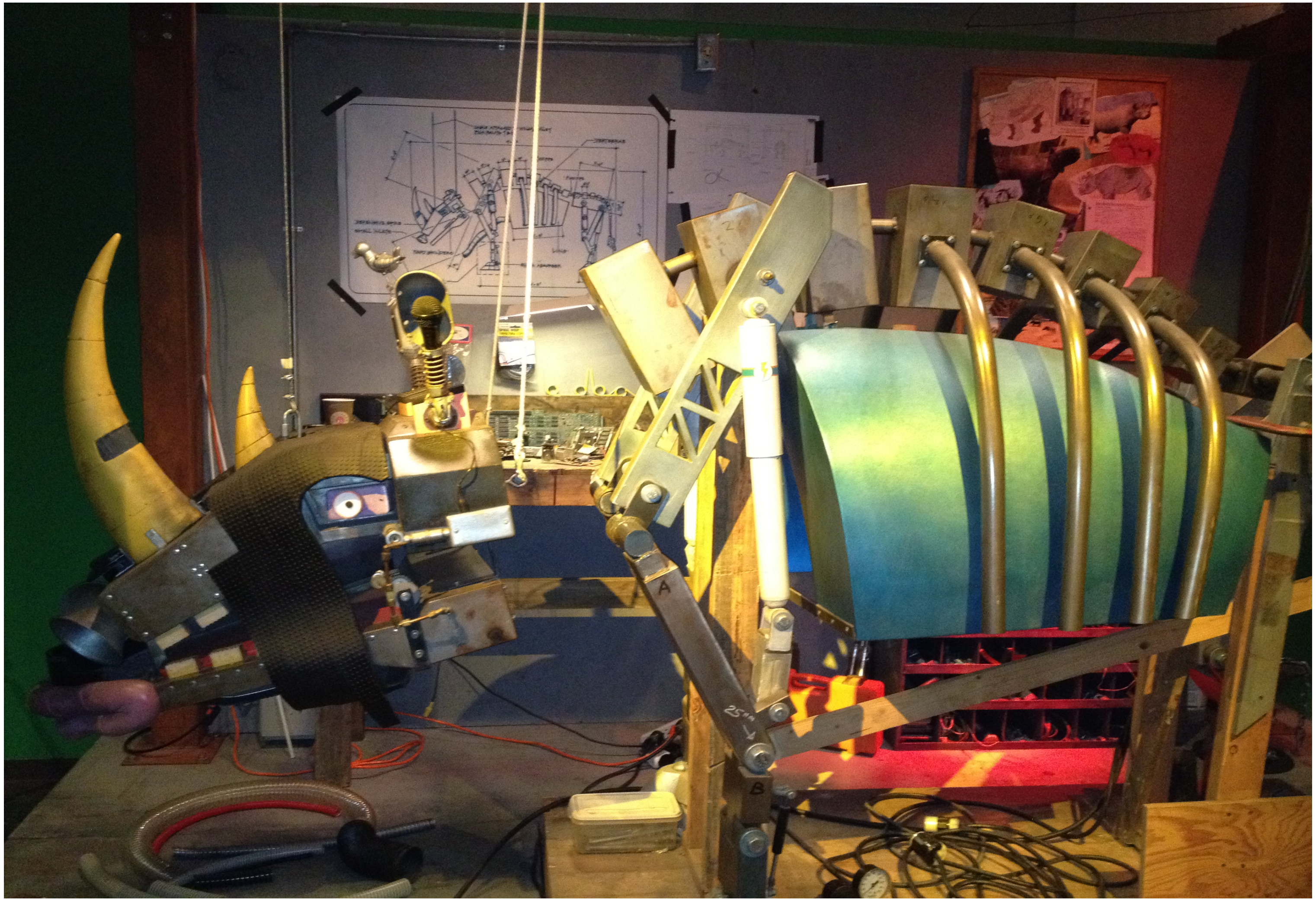
What is Nashorn and why?

What is Nashorn?

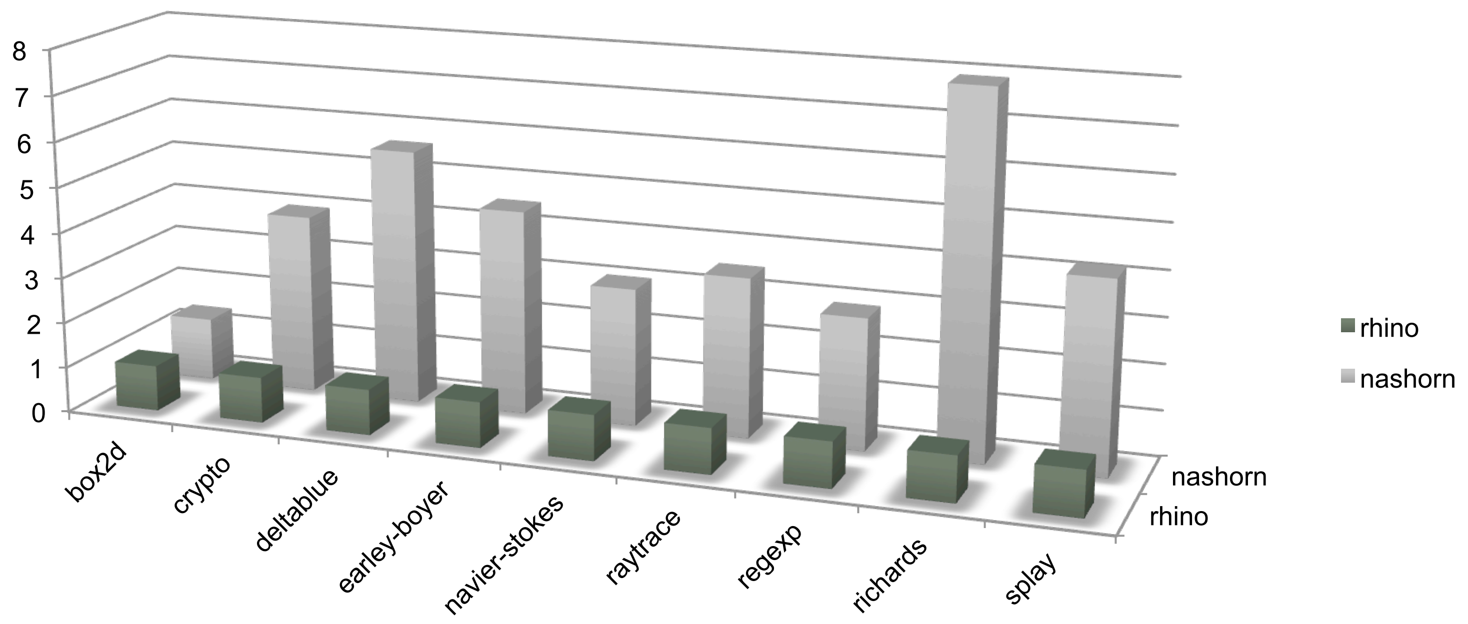
- Nashorn is a 100% pure Java runtime for JavaScript
- Nashorn generates bytecode
  - Invokedynamics are everywhere
- Nashorn currently performs somewhere on the order of ~2-10x better than Rhino
- Nashorn is in JDK 8
- Nashorn is 100% ECMAScript compliant
- Nashorn has a well thought through security model

Why Nashorn?

- Started as an `invokedynamic` POC.
- Rhino is still alive today after ~18 years. Why?
  - JSR-223
- Nashorn is now mature and replaces Rhino for Java 8



Performance



Performance

THIS IS JUST THE BEGINNING

When is Nashorn available?

- Nashorn is part of OpenJDK8
  - Already available in JDK 8 builds.

```
> jjs
jjs> var x = “hello”;
jjs> print(x);
hello
jjs>
```

Compiling an alien language to Java [sic] bytecode

Compiling an alien (non-Java language) to bytecode

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Compiling an alien (non-Java language) to bytecode

- Scala is fairly good fit
  - Yes I know: hard tail call optimization, interface injection etc.
- Ruby and JavaScript are pretty bad fits
  - No types
  - Things change at runtime. A lot.
  - Invokedynamic certainly alleviates a lot of the pain, but plenty of stuff remains to be solved

JavaScript!

Was it deliberately designed to make every efficient representation useless?

Let's talk about JavaScript

```
jjs> Array.prototype[1] = 17;
```

Let’s talk about JavaScript

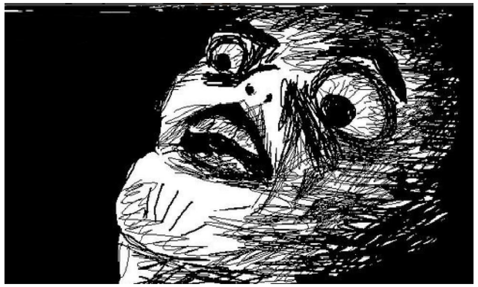
```
jjs> Array.prototype[1] = 17;
17
jjs>
```

Let's talk about JavaScript

```
jjs> Array.prototype[1] = 17;
17
jjs> print([,,,]);
```

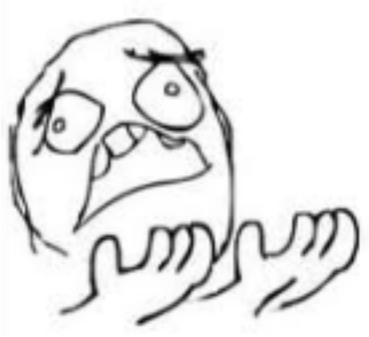
Let’s talk about JavaScript

```
jjs> Array.prototype[1] = 17;
17
jjs> print([,,,]);
,17,
jjs>
```



Let’s talk about JavaScript - Numbers

- Numbers in JavaScript have no fixed ranges
- “Intish”. “Doublish”.
- Not very nice for strongly typed bytecode
  - Overflows must be handled
- Conservative: At least they tend to fit in Java doubles.



Let’s talk about JavaScript - Numbers

- Double arithmetic is slower than integer arithmetic on modern HW
- But double arithmetic is sometimes *faster* than int arithmetic with the necessary overflow checks.
- WAT!
- (getting back to that)

Let’s talk about JavaScript – Types/Numbers

- HotSpot itself was originally tested and developed with bytecode that came from Java
- Representing everything as Objects to get the bytecode format type agnostic is nowhere near viable, performance wise.
- Boxing
- Go primitive

We should

- For bytecode performance we should
  - Use whatever static types we have
    - (mostly) done
  - Optimistically assume stuff about types
    - On it

Let's talk about JavaScript – Static type info

- JavaScript type coercion semantics and literals – uses and definitions
- That's all the static type info we're going to get from the compiler
  - Java `int`: statically enough for `~,&,|,^`
  - Java `double`: statically enough for: `*,/,-,%`
  - Object: binary `+` and pretty much everything else

Let’s talk about JavaScript – Static type info

- Callsites, though. How do we deal with parameter types?

```
int square(int x) {
   return x * x;
}
```

```
iload_0
dup
imul
ireturn
```

Let’s talk about JavaScript – Static type info

- But…

```
function square(x) {
   return x * x;
}
```

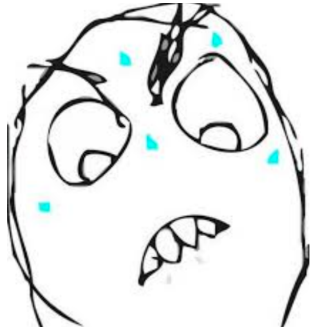
```
jjs> square(2)
4
jjs> square(2.1)
4.41
jjs> square(“a”)
NaN
```

Let’s talk about JavaScript – Static type info

- So conservatively…

```
square(Ljava/lang/Object;)D
  aload_0
  // hopefully just unbox:
  invokestatic coerce2Double(Ljava/lang/Object;)D
  dup
  dmul     // returns mul result, so always double
  dreturn
```

Let’s talk about JavaScript – Static type info



- Guess again

```
jjs> square({
       valueOf: function() {
              global++;
              return 2 + global; });


...
```

Let's talk about JavaScript – Static type info

- So conservatively…

```
square(Ljava/lang/Object;)D
  aload_0
  // hopefully just unbox:
  invokestatic coerce2Double(Ljava/lang/Object;)D
  dup
  dmul     // returns mul result, so always double
  dreturn
```

Let's talk about JavaScript – Static type info

sigh - well at least the return value HAS to be double

```
square(Ljava/lang/Object;)D
  aload_0
  invokestatic coerce2Double(Ljava/lang/Object;)D
  aload_0
  invokestatic coerce2Double(Ljava/lang/Object;)D
  dmul     // returns mul result, so always double
  dreturn
```

JavaScript has a lot of magic in its number coercion

```
var dict = Object.create(null);
var key  = 'valueOf';

//later
dict[key] = formatHarddriveFunction;

//much later
dict++;
```

… and this turns into “10”, of course

++[[]][+[]]+[+[]]

===

“10”

Brendan

Fibbonacci calculator

```
function fib(_) {
    for(_=[+[],++[[]][+[]],+[],_],_[++[++[++[[]][+[]]][+[]]]
        [+[]]][+[]]]=(((_[++[++[++[[]][+[]]][+[]]][+[]]]-
        (++[[]][+[]]))&(((--[[]][+[]])>>>(++[[]][+[]]))))
        ===(_[++[++[++[[]][+[]]][+[]]][+[]]]-
        (++[[]][+[]])))?(_[++[++[[]][+[]]][+[]]]=
        ++[[]][+[]],_[++[++[++[[]][+[]]][+[]]][+[]]]-
        (++[[]][+[]])):+[];_[++[++[++[[]][+[]]][+[]]]
        [+[]]]--;_[+[]]=(_[++[[]][+[]]]=
        _[++[++[[]][+[]]][+[]]]=_[+[]]+_[++[[]][+[]]])-
        _[+[]]);
    return _[++[++[[]][+[]]][+[]]];
}
```

Callsite specialization

- We can, and do, use static callsite types though.
- (ignore `int` overflows for a bit)

```
// Even if square is replaced, callsite type is not
// It always takes a number, always returns a number
var a = b * square(17.0);
```

Callsite specialization

- We can, and do, use static callsite types though.
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```
// Even if square is replaced, callsite type is not
// It always takes a number, always returns a number
var a = b * square(17.0);
```

```
square(D)D
  dload 0
  dup
  dmul
  dreturn
```

Callsite specialization

- We can, and do, use static callsite types though.
- (ignore `int` overflows for a bit)

```
// Even if square is replaced, callsite type is not
// It always takes a number, always returns a number
var a = b * square(17.0);
square = function(x) { return x + "string"; }
```

```
square(D)D
  dload 0
  dup
  dmul
  dreturn
```

Callsite specialization

```
square(Ljava/lang/Object;)Ljava/lang/Object;
  aload 0
  ldc “string”
  JS_ADD(Ljava/lang/Object;Ljava/lang/Object);Ljava/lang/Object;
  areturn
```

Callsite specialization

```
square(Ljava/lang/Object;)Ljava/lang/Object;
  aload 0
  ldc "string"
  JS_ADD(Ljava/lang/Object;Ljava/lang/Object);Ljava/lang/Object;
  areturn
```

```
revert_square(D)D
  dload 0
  coerceToJSObject(D)Ljava/lang/Object; # param filter
  invokedynamic square(Ljava/lang/Object;)Ljava/lang/Object;
  coerceToDouble(Ljava/lang/Object;)D
  dreturn
```

Callsite specialization

```
square(Ljava/lang/Object;)Ljava/lang/Object;
  aload 0
  ldc "string"
  JS_ADD(Ljava/lang/Object;Ljava/lang/Object);Ljava/lang/Object;
  areturn
```

```
revert_square(D)D
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  invokedynamic square(Ljava/lang/Object;)Ljava/lang/Object;
  coerceToDouble(Ljava/lang/Object;)D
  dreturn
```

NO EXPLICIT BYTECODE

Static compile time types bring us performance,
[But they are too rare to take us all the way]

Type Specialization

```
function am3(i,x,w,j,c,n) {
  var this_array = this.array;
  var w_array    = w.array;

  var xl = x&0x3fff, xh = x>>14;
  while(--n >= 0) {
    var l = this_array[i]&0x3fff;
    var h = this_array[i++]>>14;
    var m = xh*l+h*xl;
    l = xl*l+((m&0x3fff)<<14)+w_array[j]+c;
    c = (l>>28)+(m>>14)+xh*h;
    w_array[j++] = l&0xfffffff;
  }
  return c;
}
```

Type Specialization – Prove ints

```
function am3(i,x,w,j,c,n) {
  var this_array = this.array;
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    var h = this_array[i++]>>14;
    var m = xh*l+h*xl;
    l = xl*l+((m&0x3fff)<<14)+w_array[j]+c;
    c = (l>>28)+(m>>14)+xh*h;
    w_array[j++] = l&0xfffffff;
  }
  return c;
}
```

Type Specialization – Prove doubles

```
function am3(i,x,w,j,c,n) {
  var this_array = this.array;
  var w_array    = w.array;

  var xl = x&0x3fff, xh = x>>14;
  while(--n >= 0) {
    var l = this_array[i]&0x3fff;
    var h = this_array[i++]>>14;
    var m = xh*l+h*xl;
    l = xl*l+((m&0x3fff)<<14)+w_array[j]+c;
    c = (l>>28)+(m>>14)+xh*h;
    w_array[j++] = l&0xfffffff;
  }
  return c;
}
```

Static range analysis – fold doubles to ints

```
function am3(i,x,w,j,c,n) {
  var this_array = this.array;
  var w_array    = w.array;

  var xl = x&0x3fff, xh = x>>14;  // xl = max 32 bits, xh: 18 bits
  while(--n >= 0) {
    var l = this_array[i]&0x3fff; // l max 12 bits
    var h = this_array[i++]>>14;  // h max (32-14) = 18 bits
    var m = xh*l+h*xl;            // will never overflow
    l = xl*l+((m&0x3fff)<<14)+w_array[j]+c;
    c = (l>>28)+(m>>14)+xh*h;
    w_array[j++] = l&0xfffffff;
  }
  return c;
}
```

Static range analysis

```
function am3(i,x,w,j,c,n) {
  var this_array = this.array;
  var w_array    = w.array;

  var xl = x&0x3fff, xh = x>>14;  // xl = max 32 bits, xh: 18 bits
  while(--n >= 0) {
    var l = this_array[i]&0x3fff; // l max 12 bits
    var h = this_array[i++]>>14;  // h max (32-14) = 18 bits
    var m = xh*l+h*xl;            // will never overflow
    l = xl*l+((m&0x3fff)<<14)+w_array[j]+c;
    c = (l>>28)+(m>>14)+xh*h;
    w_array[j++] = l&0xffffff;
  }
  return c;
}
```

PARAMETERS CAUSE TROUBLE

Do we need our own inlining as well?

Do we need our own inlining as well?

We can statically prove a few primitive numbers from callsites to `am3`.

Not from all of them.

Runtime callsite is really:

`(Ljava/lang/Object;IILjava/lang/Object;III)I`

Statically unprovable, though

Summary – Static analysis

- Just ignore all primitive types – use boxing everywhere and `axxx` instructions
  - Way too slow. The JVM is nowhere near being able to cope with that amount of boxing, and probably never will

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  - Way too slow. The JVM is nowhere near being able to cope with that amount of boxing, and probably never will
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- Add static range checking
  - Gives us another 30% or so

Summary – Static analysis

- Just ignore all primitive types – use boxing everywhere and `axxx` instructions
  - Way too slow. The JVM is nowhere near being able to cope with that amount of boxing, and probably never will
- Use what primitives we can
  - Definitely gives us performance, depending on the amount of statically provable primitives
- Add static range checking
  - Gives us another 30% or so
- Augment CFG with usedef chains to establish param types

But soon… static analysis won't get us further unless we build our own native JavaScript runtime

But soon… static analysis won't get us further unless we build our own native JavaScript runtime

Become adaptive/dynamic/optimistic

Statically provable callsites for am3

- `(Object, int, Object, Object, double, int, Object)Object`
- `(Object, Object, Object, Object, double, int, int)Object`
- `(Object, Object, double, Object, double, Object, double)Object`
- `(Object, Object, Object, Object, double, int, int)Object`
- `(Object, int, int, Object, double, int, Object)Object`
- `(Object, int, Object, Object, Object, int, Object)Object`

In fact they are…

- `(Object, int, int, Object, int, int, int)Object`
- `(Object, int, int, Object, int, int, int)Object`
- `(Object, int, int, Object, int, int, int)Object`
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- `(Object, int, int, Object, int, int, int)Object`
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- We know this when linking at runtime
- Use this signature to generate an optimistic version of `am3`, guard the types
- Just because it's `int` right now, doesn't mean it's not undefined later. Guard required.

In fact they are…

- `(Object, int, int, Object, int, int, int)Object`
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- We know this when linking at runtime
- Use this signature to generate an optimistic version of `am3`, guard the types
- Just because it's `int` right now, doesn't mean it's not undefined later. Guard required.
- x2 Performance

We really want to use ints where we can

- `x++` pessimistic: `x` is double (if no static range analysis can prove otherwise)
- Having a double as a loop counter is slow
  - Loop unrolling doesn't work for non integer strides
  - Factor ~50 in improvement if replacing with ints

```
function f() {
   var x = 0;
   while (x < y) {
      x++;
   }
   return x;
}
```

We really want to use ints where we can

- All non-bitwise arithmetic can potentially overflow
- The + operator is the worst, as it can take any object
- Experiment: TypeScript frontend
  - A lot more performance with no further mods
  - Nashorn performs well with known primitive int types

```
function f() {
   var x = 0;
   while (x < y) {
      x++; // dadd? iadd with overflow check?
   }
   return x;
}
```

Using ints, problem 1 of 2 – Overflow check overhead

```
static int addExact(int x, int y) {
   int result = x + y;
   if ((x ^ result) & (y ^ result) < 0) {
      throw new ArithmeticException(“int overflow”)
   }
   return result;
}
```

```
function f() {
   var x = 0;
   while (x < y) {
      x = addExact(x, 1);
   }
   return x;
}
```

This is actually pretty much as slow as the `dadd` alone

Not sometimes, but often.

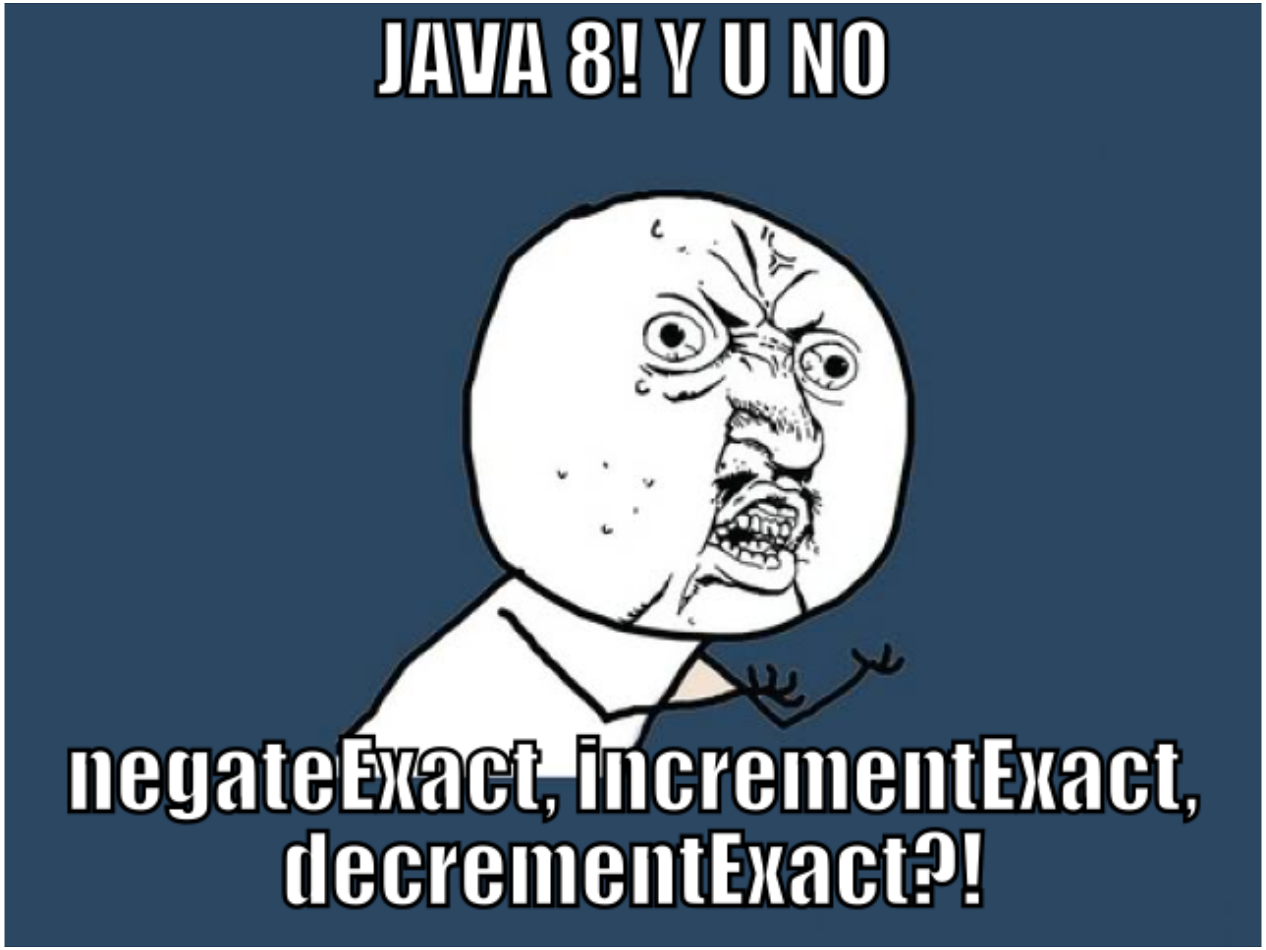
Solution: Intrinsify math operations

- Java 8: `addExact/subExact/mulExact`
- Intrinsify them
- Basically and `addExact` is just

```
   add eax, edx
   jo fail
   ret
 fail:
   //slow stuff
```

- < 10-15% slower than just the `iadd` when it doesn't fault
- Twice the speed of the non-intrinsified version with `xor`s
- Only slightly faster than `dadd`, but enables everything

Solution: Intrinsify math operations



```
function f() {
   var x = 0;
   while (x < y) {
      x = addExact(x, 1);
   }
   return x;
}
```

```
iconst_0
istore_0
while:
iload_0
invokedynamic get y()I
if_icmpge exit
iload_0
iconst_1
invokestatic addExact //intrinsic
goto while
exit:
istore_0
ireturn
```

This is almost native-fast with add intrinsic and the int specialization.

```
function f() {
   var x = 0;
   while (x < y) {
      x = addExact(x, 1);
   }
   return x;
}
```

```
iconst_0
istore_0
invokedynamic get y()I //check primitive
istore_1
while:
iload_0
iload_1   // y
if_icmpge exit
iload_0
iconst_1
invokestatic addExact //intrinsic
goto while
exit:
istore_0
ireturn
```

(One more optimization: is `y` loop invariant? It may be a getter with side effects or anything as this is JavaScript hell… Hotspot won't be able to tell with the indy)

```
iconst_0
istore_0
invokedynamic get y()I //check primitive
istore_1
while:
iload_0
iload_1   // y
if_icmpge exit
iload_0
iconst_1
invokestatic addExact //intrinsic
goto while
exit:
istore_0
ireturn
```

Native-fast

We really want to use ints where we can

Very common instance of same problem.

```
function f() {
   return 17 + array[3];
}
 ...
 bipush 17
 aload 2 //scope
 invokedynamic get:array(Ljava/lang/Object;)Ljava/lang/Object;
 aload 2
 iconst_3
 invokedynamic getElem(Ljava/lang/Object;I)Ljava/lang/Object;
 invokedynamic ADD:OIO_I(ILjava/lang/Object;)Ljava/lang/Object;
 areturn
```

We really want to use ints where we can

Very common instance of same problem.

```
function f() {
   return 17 + array[3];
}
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 iconst_3
 invokedynamic getElem(Ljava/lang/Object;I)I
 invokestatic Math.addExact
 ireturn
```

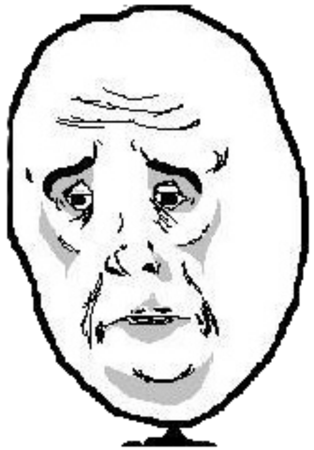
Using ints problem 2 of 2 – erroneous assumptions

- So what do we do if we overflow or miss an assumption?
- Bytecode is strongly typed, so we can’t reuse the same code
- Throw errors or add guards/version code

Using ints problem 2 of 2 – erroneous assumptions

- So what do we do if we overflow or miss an assumption?
- Bytecode is strongly typed, so we can’t reuse the same code
- Throw errors ~~or add guards/version code~~

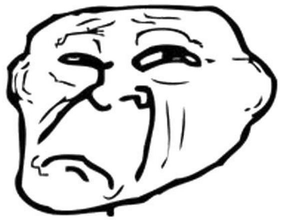
```
if (x < y) {
  x &= 1;
  if (x < 2) {
     x *= 2;
     if (k) {
        x += "string"
        //keep branching
     }
  }
}
return x; //hope this is an int
```



So add a catch block, take a continuation and jump to a less specialized version of the code

So add a catch block, take a continuation and jump to a less specialized version of the code

Uh-oh…



Continuations, you say?

Start out with

```
...
ALOAD w_array
ILOAD j

INVOKEDYNAMIC dyn:getElem(I)I
...
IADD
...
```

Continuations, you say?

Mark callsite optimistic, tag it with a program point

```
...
ALOAD w_array
ILOAD j

INVOKEDYNAMIC dyn:getElem(I)I [optimistic | pp 17]
...
IADD
...
```

Continuations, you say?

Add a return value filter throwing an Exception
if we return a non-int type

```
public class UnwarrantedOptimismException extends Exception {
  ...
  public int getProgramRestartPointId() { ... };
  public Object getReturnedValue() { ... };
}
```

Continuations, you say?

Send a message to the caller to regenerate the method

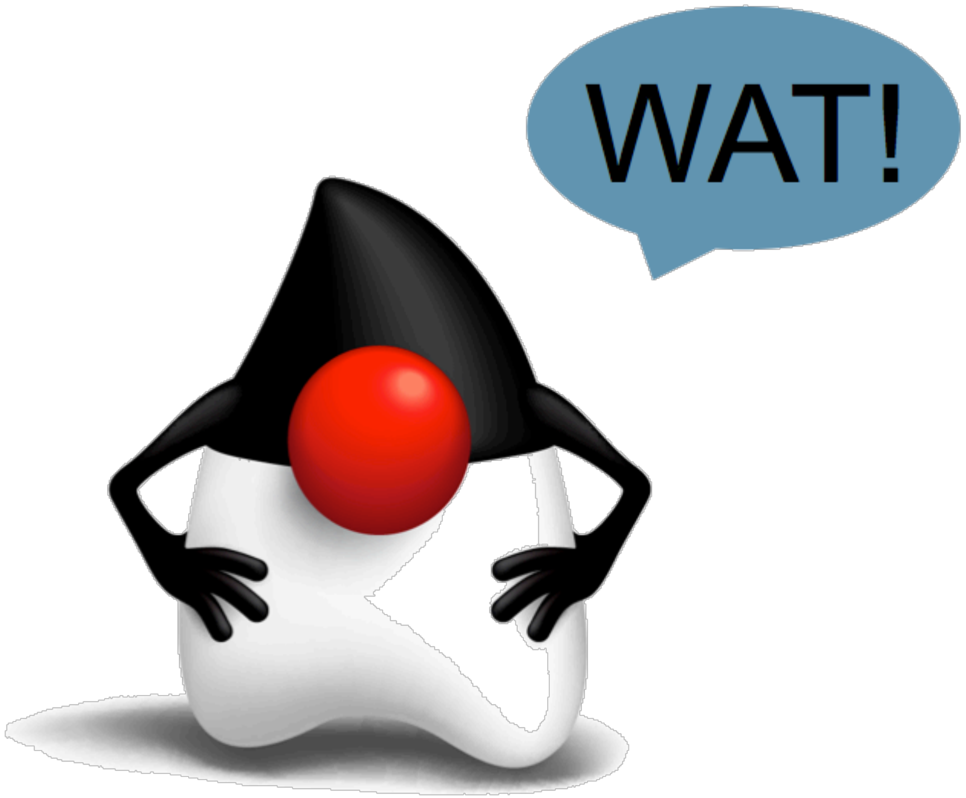
```
try {
  ...
  ALOAD w_array
  ILOAD j
  // make sure bc stack is written to locals
  INVOKEDYNAMIC dyn:getElem(I)I [optimistic | pp 17]
  ...
  IADD
  ...
} catch (UnwarrantedOptimismException e) {
  // ask linker to regenerate method
  throw new RewriteException(e.getId(), e.getReturnValue(), locals);
}
```

Continuations, you say?

- We know when we are relinking a rewritable method
- Add a `MethodHandles.catchException` for `RewriteException`
- Catch triggers recompilation, with the failed callsite made more pessimistic.
- Also generates and invokes a “rest of” method

```
restOfMethod(RewriteException e) {
   // store to locals e.getLocals();
   // ...
   // all code after invokedynamic that failed with
   // maximum pessimism
   // (can never throw UnwarrantedOptimismException)
   return pessimisticReturnValue;
}
```

The JVM situation



JVM issues

- Java 7
  - Pretty quickly started giving us the infamous `NoClassDefFoundError` bug
  - Circumvented by running with everything in bootclasspath (Eww…)
- Java 8
  - A lot of C++ was reimplemented as LambdaForms
  - Initially, 10% of Java 7 performance. ☹

```
print(Math.round(0.5));
```

WTF?

```
New_configuration [Java Application]
  jdk.nashorn.tools.Shell at localhost:54014
    Thread [main] (Suspended (breakpoint at line 618 in NativeMath))
      NativeMath.round(Object, Object) line: 618
      LambdaForm$DMH.invokeStaticInit_LL_L(Object, Object, Object) line: not available
      LambdaForm$DMH.invokeSpecial_LLL_L(Object, Object, Object, Object) line: not available
      LambdaForm$NamedFunction.invoke_LLL_L(MethodHandle, Object[]) line: 1102
      LambdaForm$DMH.invokeStatic_LL_L(Object, Object, Object) line: not available
      LambdaForm$NamedFunction.invokeWithArguments(Object...) line: 1136
      LambdaForm.interpretName(LambdaForm$Name, Object[]) line: 625
      LambdaForm.interpretWithArguments(Object...) line: 604
      LambdaForm$LFI.interpret_L(MethodHandle, Object, Object, Object) line: not available
      LambdaForm$NamedFunction.invoke_LLL_L(MethodHandle, Object[]) line: 1102
      LambdaForm$DMH.invokeStatic_LL_L(Object, Object, Object) line: not available
      LambdaForm$NamedFunction.invokeWithArguments(Object...) line: 1136
      LambdaForm.interpretName(LambdaForm$Name, Object[]) line: 625
      LambdaForm.interpretWithArguments(Object...) line: 604
      LambdaForm$LFI.interpret_L(MethodHandle, Object, Object, double) line: not available
      LambdaForm$DMH.invokeSpecial_LLLD_L(Object, Object, Object, Object, double) line: not available
      LambdaForm$NFI.invoke_LLLD_L(MethodHandle, Object[]) line: not available
      LambdaForm$DMH.invokeStatic_LL_L(Object, Object, Object) line: not available
      LambdaForm$NamedFunction.invokeWithArguments(Object...) line: 1136
      LambdaForm.interpretName(LambdaForm$Name, Object[]) line: 625
      LambdaForm.interpretWithArguments(Object...) line: 604
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      LambdaForm$NamedFunction.invokeWithArguments(Object...) line: 1136
      LambdaForm.interpretName(LambdaForm$Name, Object[]) line: 625
      LambdaForm.interpretWithArguments(Object...) line: 604
      LambdaForm$LFI.interpret_L(MethodHandle, Object, Object, double) line: not available
      LambdaForm$MH.linkToCallSite(Object, Object, double, Object) line: not available
      Script$b.runScript(ScriptFunction, Object) line: 1
      LambdaForm$DMH.invokeStatic_LL_L(Object, Object, Object) line: not available
      LambdaForm$MH.invokeExact_MT(Object, Object, Object, Object) line: not available
      FinalScriptFunctionData(ScriptFunctionData).invoke(ScriptFunction, Object, Object...) line: 512
      ScriptFunctionImpl(ScriptFunction).invoke(Object, Object...) line: 202
      ScriptRuntime.apply(ScriptFunction, Object, Object...) line: 346
      Shell.apply(ScriptFunction, Object) line: 385
      Shell.runScripts(Context, ScriptObject, List<String>) line: 314
      Shell.run(InputStream, OutputStream, OutputStream, String[]) line: 178
      Shell.main(InputStream, OutputStream, OutputStream, String[]) line: 142
      Shell.main(String[]) line: 121
```
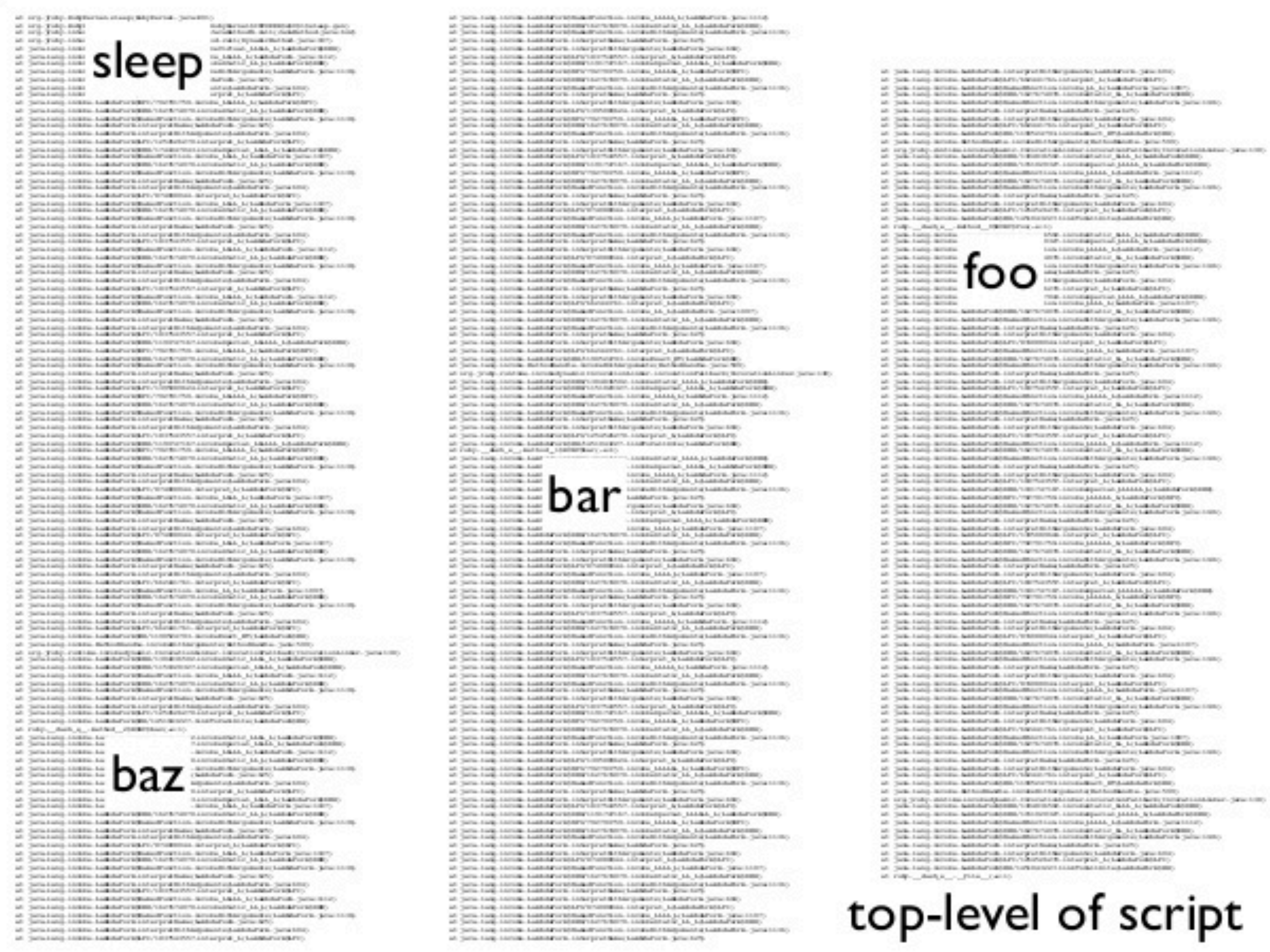



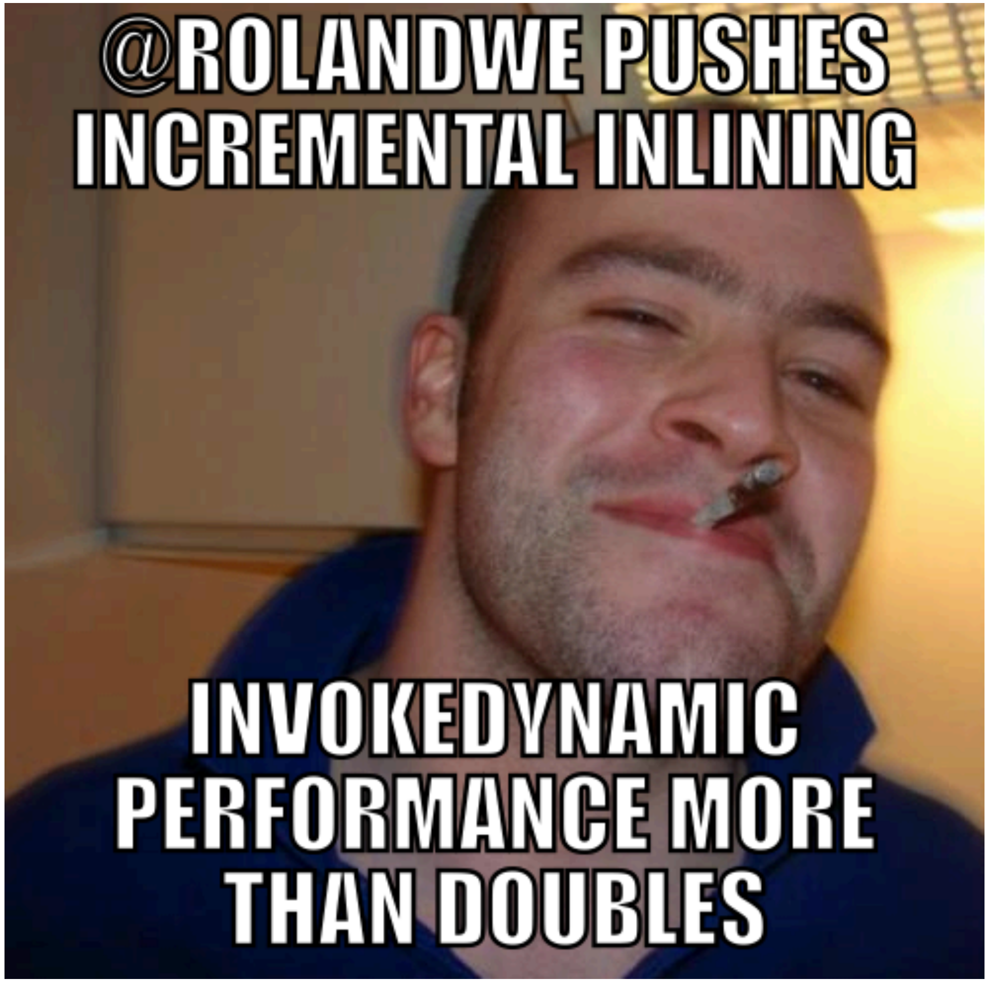
top-level of script

JVM issues

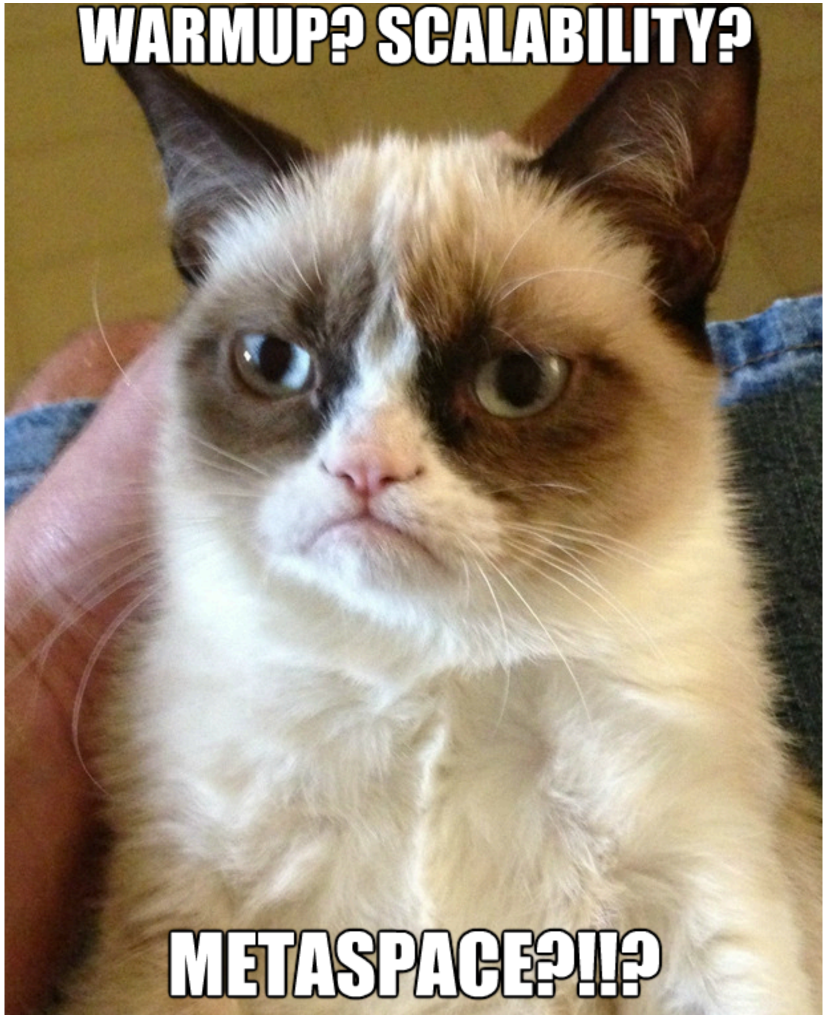
JVM issues

- Many inlining problems
  - Even, traditionally, for normal Java code – add a code line, 50% of performance disappears
  - Seen that from time to time with HotSpot
  - Relevant in our quick paths in Nashorn too
- LambdaForms & MethodHandles
  - Tremendous pressure on inlining, lambda form classes also on metaspace
- Discovered a few very old bugs in C2 inliner
  - E.g: dead nodes counted as size.

JVM issues


@ROLANDWE PUSHES INCREMENTAL INLINING
INVOKEDYNAMIC PERFORMANCE MORE THAN DOUBLES

JVM issues



JVM issues

- LambdaForms compile a lot of code, generate a lot of metaspace stress
- If we have to have LambdaForms, they might not be able to remain in bytecode land?
- Inlining, despite tweaking has a lot of problems that remain to be solved
- Boxing removal boxing removal boxing removal
  - (probably enabled by local escape analysis)

JVM issues

- MethodHandle.invoke (not exact) is slow

```
public class Test {
      private final static MethodHandle CALC =
            MethodHandles.publicLookup().findStatic(
                        Test.class, "calc", int.class, int.class, Object.class);

      static int test() throws Throwable {
          MethodHandle mh = CALC;
          Object aString = "A";
          int a = mh.invoke(1, aString);
          int b = mh.invoke(2, "B");
          Integer c = mh.invoke((Integer)3, 3);
          return a+b+c;
      }

      static int calc(int x, Object o) {
           return x + o.hashCode();
      }
}
```

JVM issues

- MethodHandle.invoke (not exact) is slow

```
public class Test {
      private final static MethodHandle CALC =
            MethodHandles.publicLookup().findStatic(
                        Test.class, "calc", int.class, int.class, Object.class);

      static int test() throws Throwable {
          return 140;






      }

      static int calc(int x, Object o) {
           return x + o.hashCode();
      }
}
```

JVM issues

- Still artifacts here. We do ugly stuff in Java like

```
@Override
public long getLong(final long key) {
    final int index = ArrayIndex.getArrayIndex(key);
    final ArrayData array = getArray();

    if (array.has(index)) {
        return array.getLong(index);
    }

    return getLong(index, convertKey(key));
}
```

JVM issues

- Still artifacts here. We do ugly stuff in Java like

```
@Override
public long getLong(final double key) {
    final int index = ArrayIndex.getArrayIndex(key);
    final ArrayData array = getArray();

    if (array.has(index)) {
        return array.getLong(index);
    }

    return getLong(index, convertKey(key));
}
```

JVM issues

- Still artifacts here. We do ugly stuff in Java like

```
@Override
public long getLong(final Object key) {
    final int index = ArrayIndex.getArrayIndex(key);
    final ArrayData array = getArray();

    if (array.has(index)) {
        return array.getLong(index);
    }

    return getLong(index, convertKey(key));
}
```

JVM issues

- Still artifacts here. We do ugly stuff in Java like

```
@Override
public long getLong(final int key) {

   final ArrayData array = getArray();

   if (array.has(key)) {
       return array.getLong(key);
   }

   return getLong(key, convertKey(key));
}
```

War story: warmup

- Indy intrinsically needs bootstrapping
- Every call site contributes to warmup
- LambdaForms contribute to warmup
- Tiered compilation has gone back and forth.
    - Peak performance is reached sooner, even without C2 compiling all the methods
    - Added deviation has been very large
    - C2 is slow

Another war story: Metaspace

- Runtime didn't know about anonymous classes
- Build b58-b74 were broken ☹
- Compressed klass pointers gave us a fixed size 100 MB default klass pointer chunk ☹
- Metaspace allocated from metaspace pool subject to fragmentation. Chunks went 5% full to different classloaders
- HotSpot did not hand back dealloced Metaspace memory to the OS

Future work – Nashorn

- Optimistic code everywhere
- Static analysis/IR
- Field representations
  - Objects only, dual fields, `sun.misc.TaggedArray` `(TaggedObject?)`
- Parallelism

Future work - JVM

- Boxing removal (probably requires Local EA)
- `sun.misc.TaggedArray`?
- Intrinsify `Math.addExact` and friends
  - Done!
- `MethodHandle.invoke` must be fast
- LambdaForms
  - Caching for footprint?
  - Replacing LambdaForms with something else?
    - Get them out of class/bytecode land

Future work - JVM

- Is bytecode even the correct format to do this entire in
  - Pluggable frontends?
  - More magic: I probably really need to talk to my compiler
  - Or have my compiler talk to me

Nashorn current performance status

- (Very) initial POC after 2.5 weeks of work:
  - Broke out `octane.crypto.am3` – the hotspot in the Crypto benchmark in octane.
  - Turned it into microbenchmark

```
function am3(i, x, w, j, c, n) {
  var this_array = this.array;
  var w_array    = w.array;
  var xl = x & 0x3fff, xh = x >> 14;

  while(--n >= 0) {
    var l = this_array[i] & 0x3fff;
    var h = this_array[i++] >> 14;
    var m = xh * l + h * xl;
    l = xl * l+ ((m & 0x3fff) << 14) + w_array[j] + c;
    c = (l >> 28) + (m >> 14) + xh * h;
    w_array[j++] = l & 0xfffffff;
  }

  return c;
}
```

Nashorn current performance status

- Runtime
  - Rhino (with –opt 9): 34.6 s
  - Nashorn tip: 10.8 s
  - V8 1.3 s

Nashorn with optimistic types

- Runtime
  - Rhino (with –opt 9): 34.6 s
  - Nashorn tip: 5.8 s
  - V8 1.3 s

Add JVM math intrinsics…

- Runtime
  - Rhino (with –opt 9): 34.6 s
  - Nashorn tip: 4.4 s
  - V8 1.3 s

Patch JVM to keep more type info while inlining…

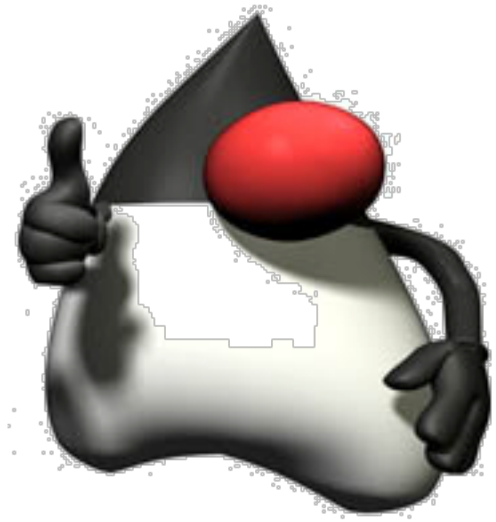
- Runtime
  - Rhino (with –opt 9): 34.6 s
  - Nashorn tip: 2.5 s
  - V8 1.3 s

Talk to us

- Tweet us: @lagergren, @wickund, @asz, @hannesw, @sundararajan_a
- http://blogs.oracle.com/nashorn
- nashorn-dev@openjdk.java.net
- mlvm-dev@openjdk.java.net

Thank you!

Q&A?



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