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Using LLVM and Sulong for Language C Extensions

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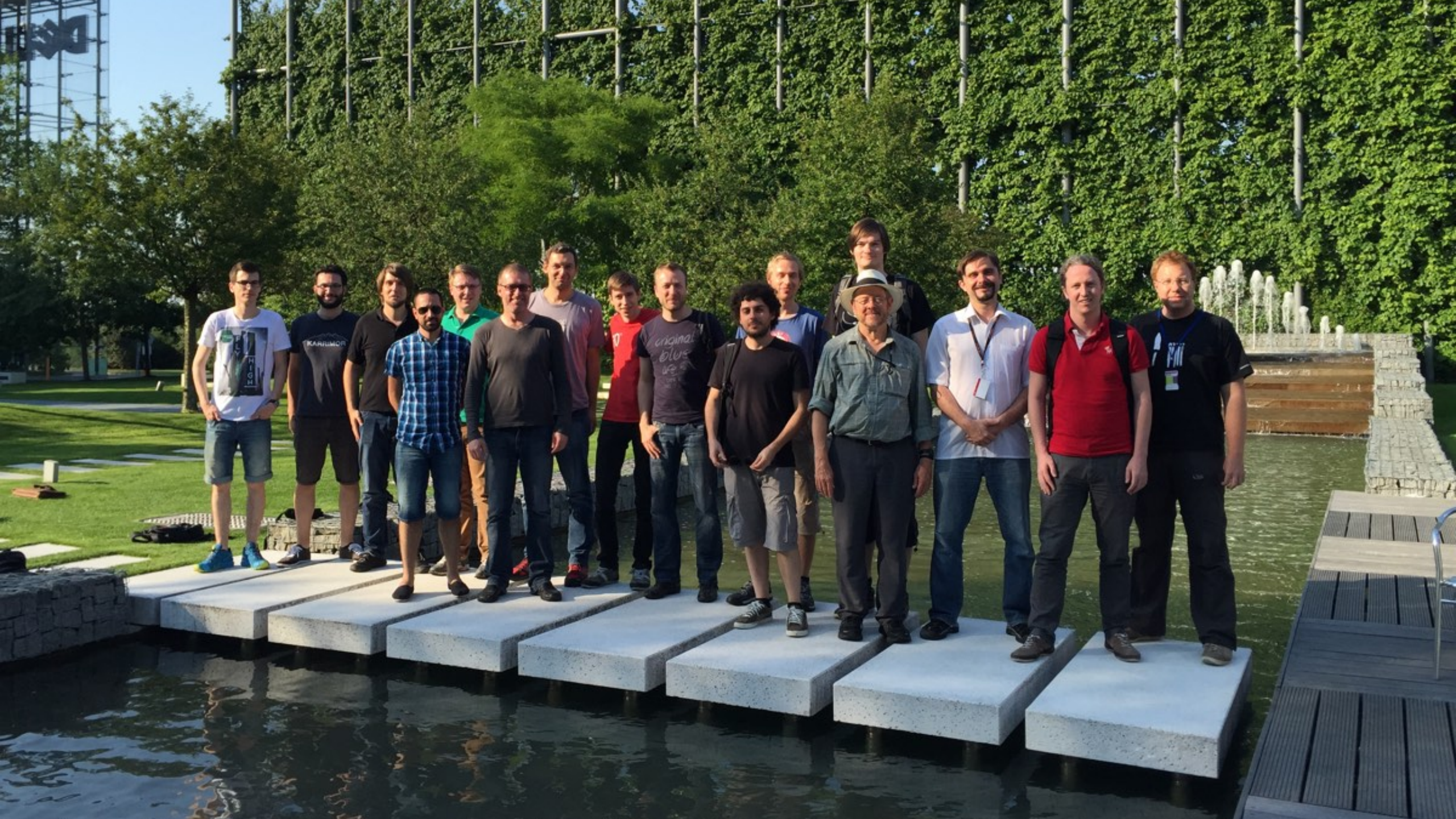
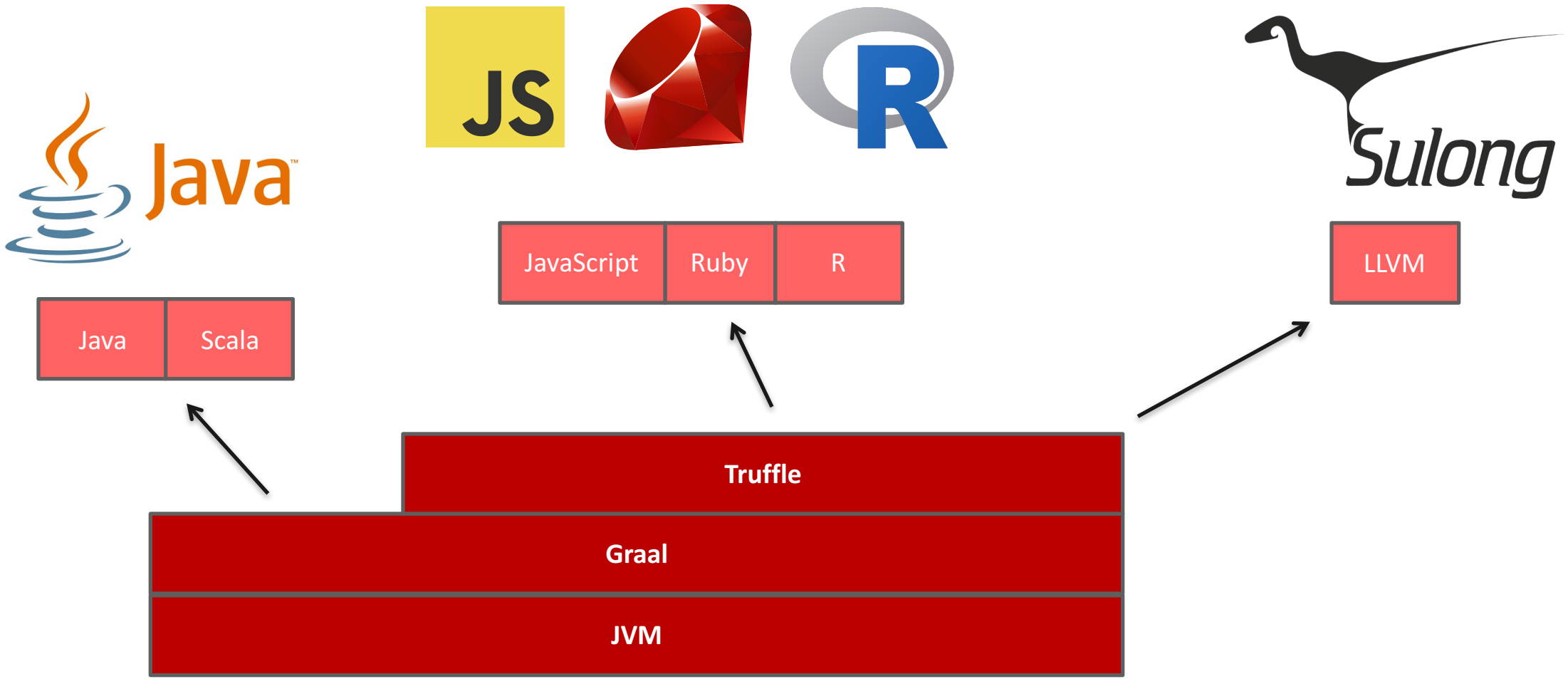
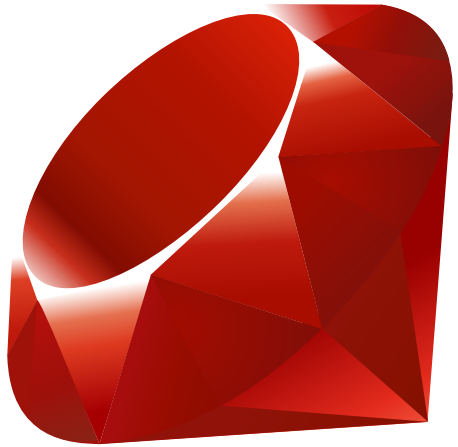
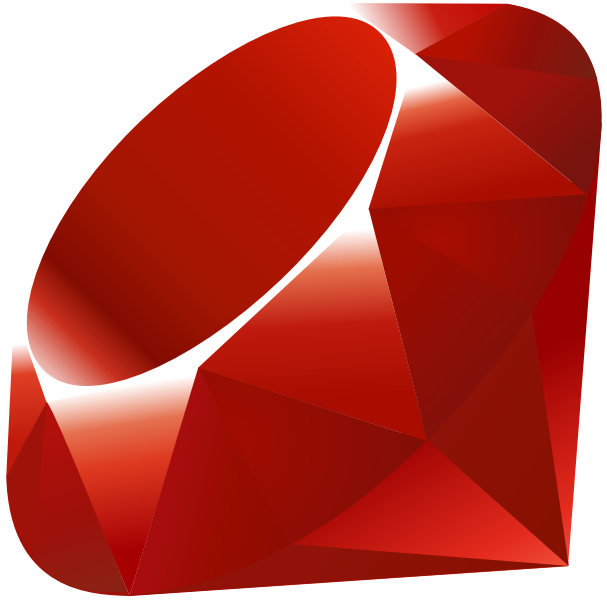
Who we are and what we're doing





Language C extensions



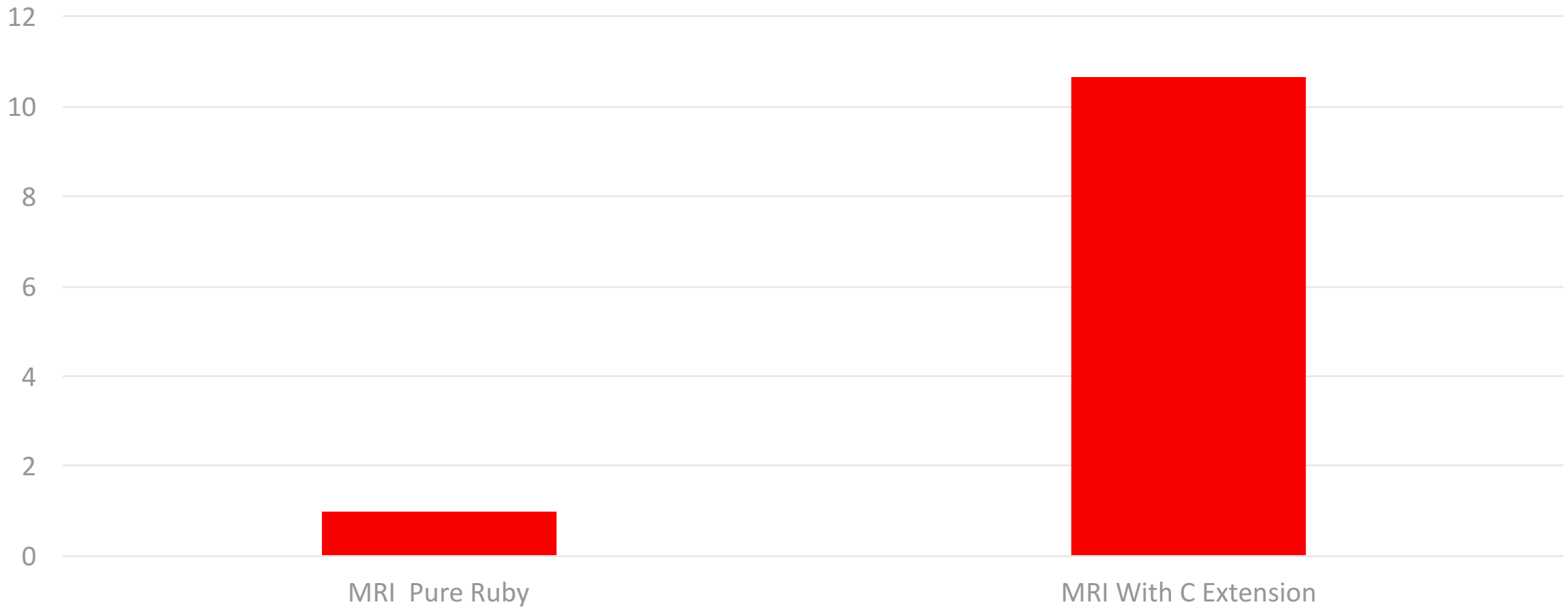


```ruby
def clamp(num, min, max)
  [min, num, max].sort[1]
end
```

```
VALUE psd_native_util_clamp(VALUE self,
      VALUE r_num, VALUE r_min, VALUE r_max) {
  int num = FIX2INT(r_num);
  int min = FIX2INT(r_min);
  int max = FIX2INT(r_max);

  return num > max ? r_max : (num < min ? r_min : r_num);
}
```

Performance on Ruby C Extensions Oily PNG and PSD Native



M. Grimmer, C. Seaton, T. Würthinger, H. Mössenböck. Dynamically Composing Languages in a Modular Way: Supporting C Extensions for Dynamic Languages. In Proceedings of the 14th International Conference on Modularity, 2015.

The C extension problem

```
struct RString {
  struct RBasic basic;
  union {
    struct {
      long len;
      char *ptr;
      union {
        long capa;
        VALUE shared;
      } aux;
    } heap;
    char ary[RSTRING_EMBED_LEN_MAX + 1];
  } as;
};
```

Structs declared in the public API

Implementation details like embedded strings and sharing exposed

```c
static VALUE
ossl_rand_bytes(VALUE self, VALUE len)
{
    VALUE str;
    int n = NUM2INT(len);
    int ret;

    str = rb_str_new(0, n);
    ret = RAND_bytes((unsigned char *)RSTRING_PTR(str), n);
    if (ret == 0) {
       ossl_raise(eRandomError, "RAND_bytes");
    } else if (ret == -1) {
       ossl_raise(eRandomError, "RAND_bytes is not supported");
    }

    return str;
}
```

Ruby String object

Managed Ruby value on the C stack

Exposes inner char*

Call to arbitrary C code

String object with char* already exposed now returned to Ruby

```ruby
(0...@num_pixels).step(pixel_step) do |i|
  .....
  rgb = PSD::Color.cmyk_to_rgb(255 - c, 255 - m, 255 - y, 255 - k)
    .....
end
```

```ruby
def cmyk_to_rgb(c, m, y, k)
  Hash[{
    r: (65535 - (c * (255 - k) + (k << 8))) >> 8,
    g: (65535 - (m * (255 - k) + (k << 8))) >> 8,
    b: (65535 - (y * (255 - k) + (k << 8))) >> 8
  }.map { |k, v| [k, Util.clamp(v, 0, 255)] }]
end
```

Call from Ruby to native is extremely hot

Values need to be converted as they go from Ruby to native

```c
VALUE psd_native_util_clamp(VALUE self,
      VALUE r_num, VALUE r_min, VALUE r_max) {
  int num = FIX2INT(r_num);
  int min = FIX2INT(r_min);
  int max = FIX2INT(r_max);

  return num > max ? r_max : (num < min ? r_min : r_num);
}
```

Array implementation pointer taken and stored for later

```
VALUE* bg_pixels = RARRAY_PTR(rb_funcall(self, rb_intern("pixels"), 0));
VALUE* fg_pixels = RARRAY_PTR(rb_funcall(other, rb_intern("pixels"), 0));

long x = 0;
long y = 0;
for( y = 0; y < other_height; y++ ){
  for( x = 0; x < other_width; x++ ){
    bg_index = ( x + offset_x ) + ( y + offset_y ) * self_width;
    bg_pixels[bg_index] = UINT2NUM(
      oily_png_compose_color(
        NUM2UINT( fg_pixels[x+ y * other_width] ),
        NUM2UINT( bg_pixels[bg_index] ) ) );
  }
}
```

When they're used there's no indication someone else is managing them

Previous solutions

```
bool
RubyString::jsync(JNIEnv* env)
{
    if (rwdata.readonly && rwdata.rstring != NULL) {
        // Don't sync anything, just clear the cached data
        rwdata.rstring = NULL;
        rwdata.readonly = false;

        return false;
    }

    if (rwdata.rstring != NULL && rwdata.rstring->ptr != NULL) {
        jobject byteList = env->GetObjectField(obj, RubyString_value_field);
        jobject bytes = env->GetObjectField(byteList, ByteList_bytes_field);
        jint begin = env->GetIntField(byteList, ByteList_begin_field);
        checkExceptions(env);

        env->DeleteLocalRef(byteList);

        RString* rstring = rwdata.rstring;
        env->SetByteArrayRegion((jbyteArray) bytes, begin, rstring->len,
                (jbyte *) rstring->ptr);
        checkExceptions(env);
        env->SetIntField(byteList, ByteList_length_field, rstring->len);

        env->DeleteLocalRef(bytes);
    }

    return true;
}
```

Copy

```
bool
RubyString::nsync(JNIEnv* env)
{
    jobject byteList = env->GetObjectField(obj, RubyString_value_field);
    checkExceptions(env);
    jobject bytes = env->GetObjectField(byteList, ByteList_bytes_field);
    checkExceptions(env);
    jint begin = env->GetIntField(byteList, ByteList_begin_field);
    checkExceptions(env);
    long length = env->GetIntField(byteList, ByteList_length_field);
    checkExceptions(env);
    jint capacity = env->GetArrayLength((jarray) bytes) - begin;
    checkExceptions(env);
    env->DeleteLocalRef(byteList);

    RString* rstring = rwdata.rstring;

    if ((capacity > rstring->capa) || (rstring->capa == 0)) {
        rstring->capa = capacity;
        rstring->ptr = (char *) realloc(rstring->ptr, rstring->capa + 1);
    }

    env->GetByteArrayRegion((jbyteArray) bytes, begin, length,
            (jbyte *) rstring->ptr);
    checkExceptions(env);
    env->DeleteLocalRef(bytes);

    rstring->ptr[rstring->len = length] = 0;

    return true;
}
```

Copy

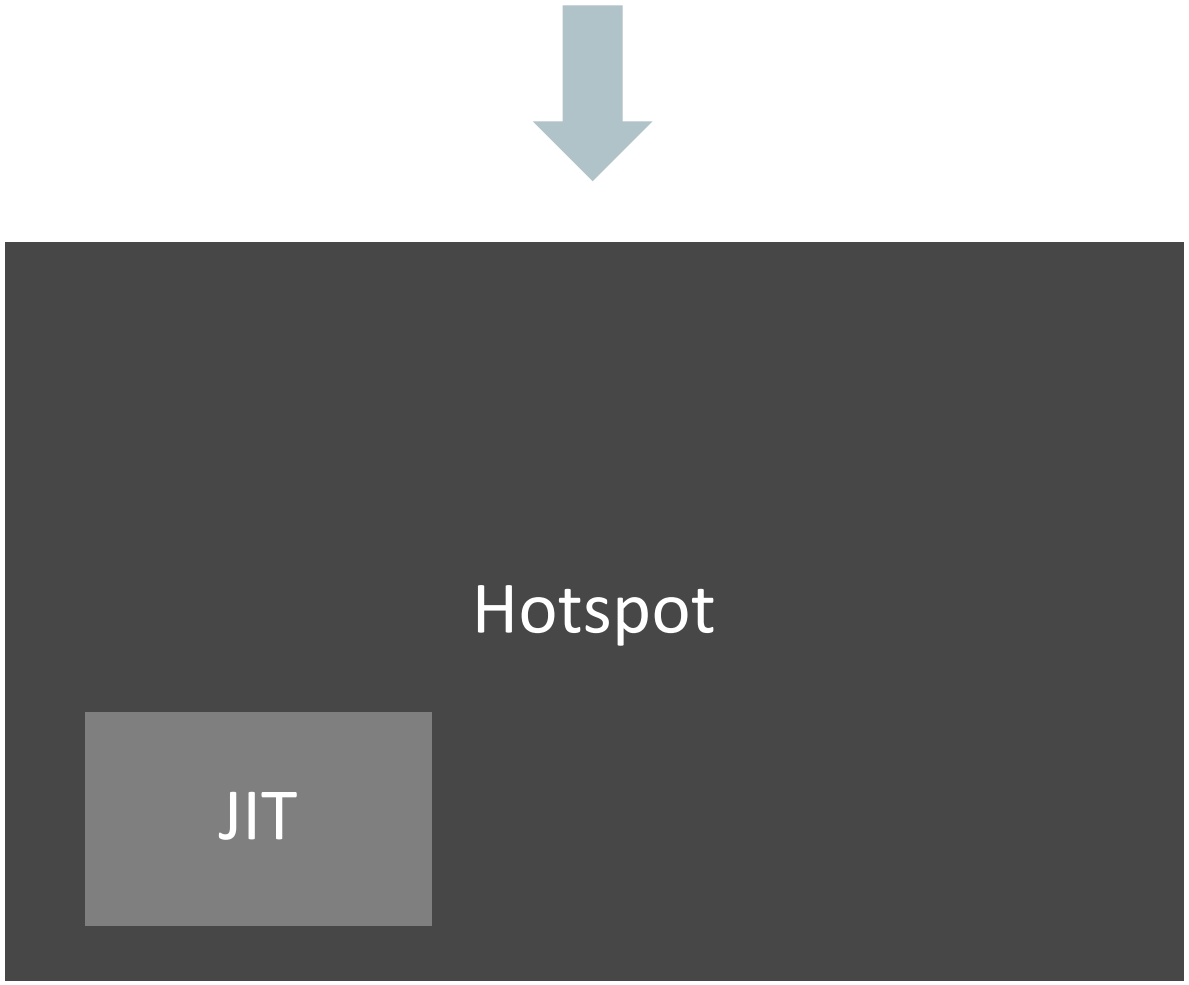
Our new solution

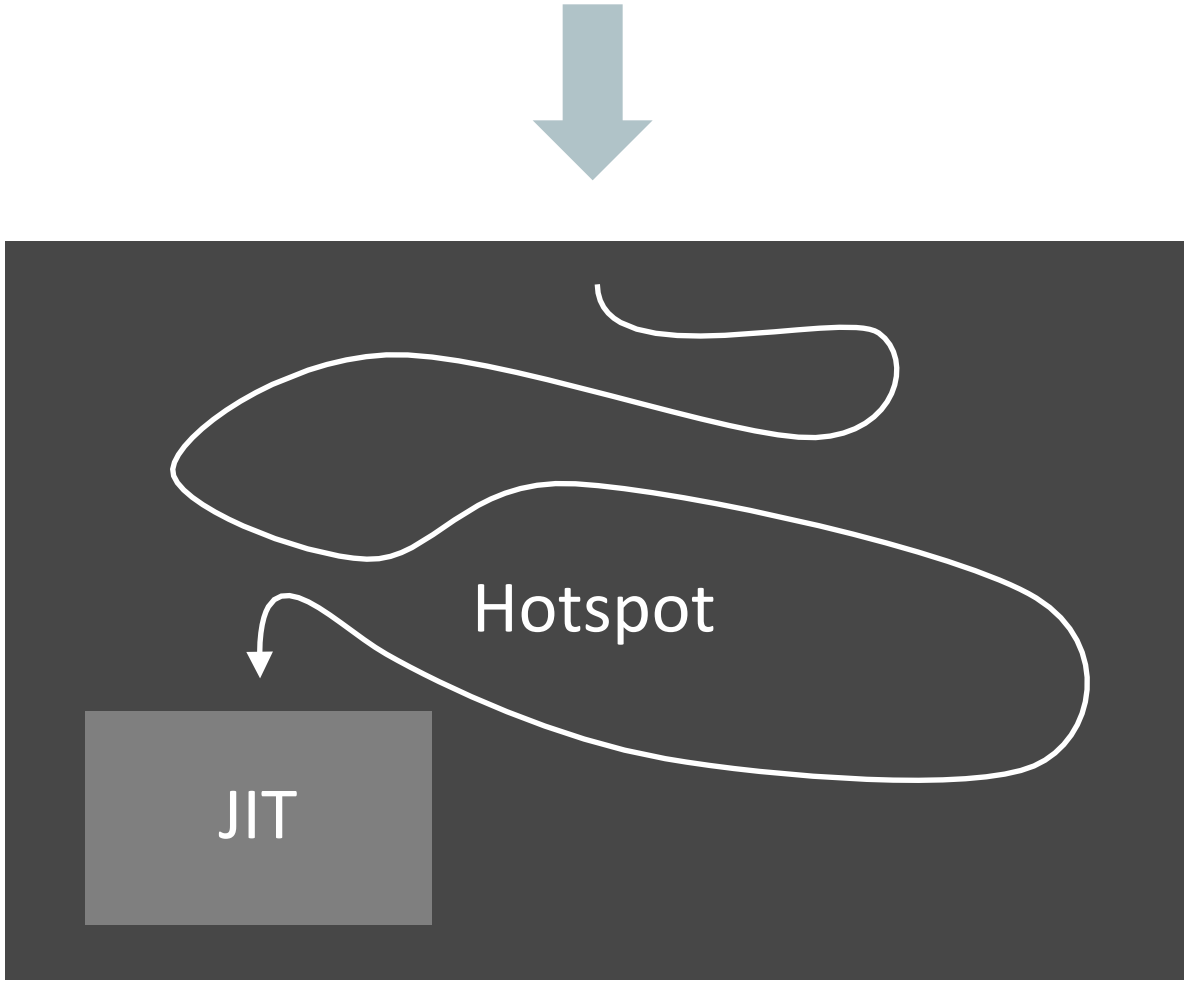
- Interpret both the Ruby and the C
- Actually, interpret the LLVM IR of the C to simplify
- JIT compile the Ruby and the C
- Use a single high and low level IR for both
- Forget which language the IR came from and optimise them together
- Give virtualised pointers to the C program

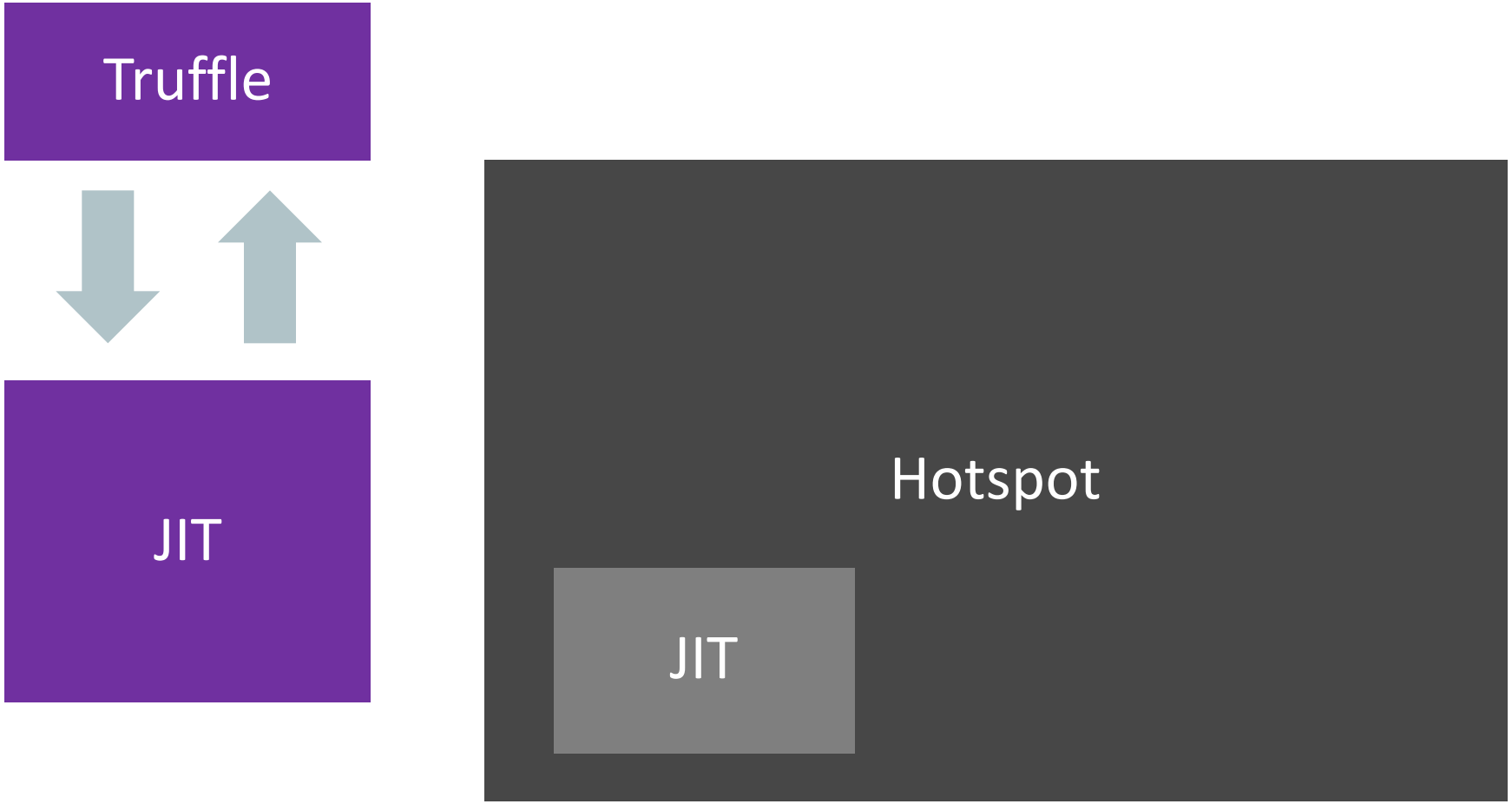
How Sulong and JRuby+Truffle work

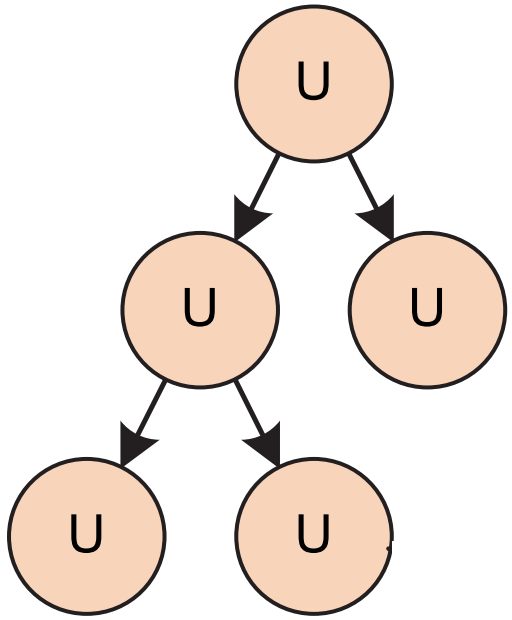
Hotspot

Hotspot



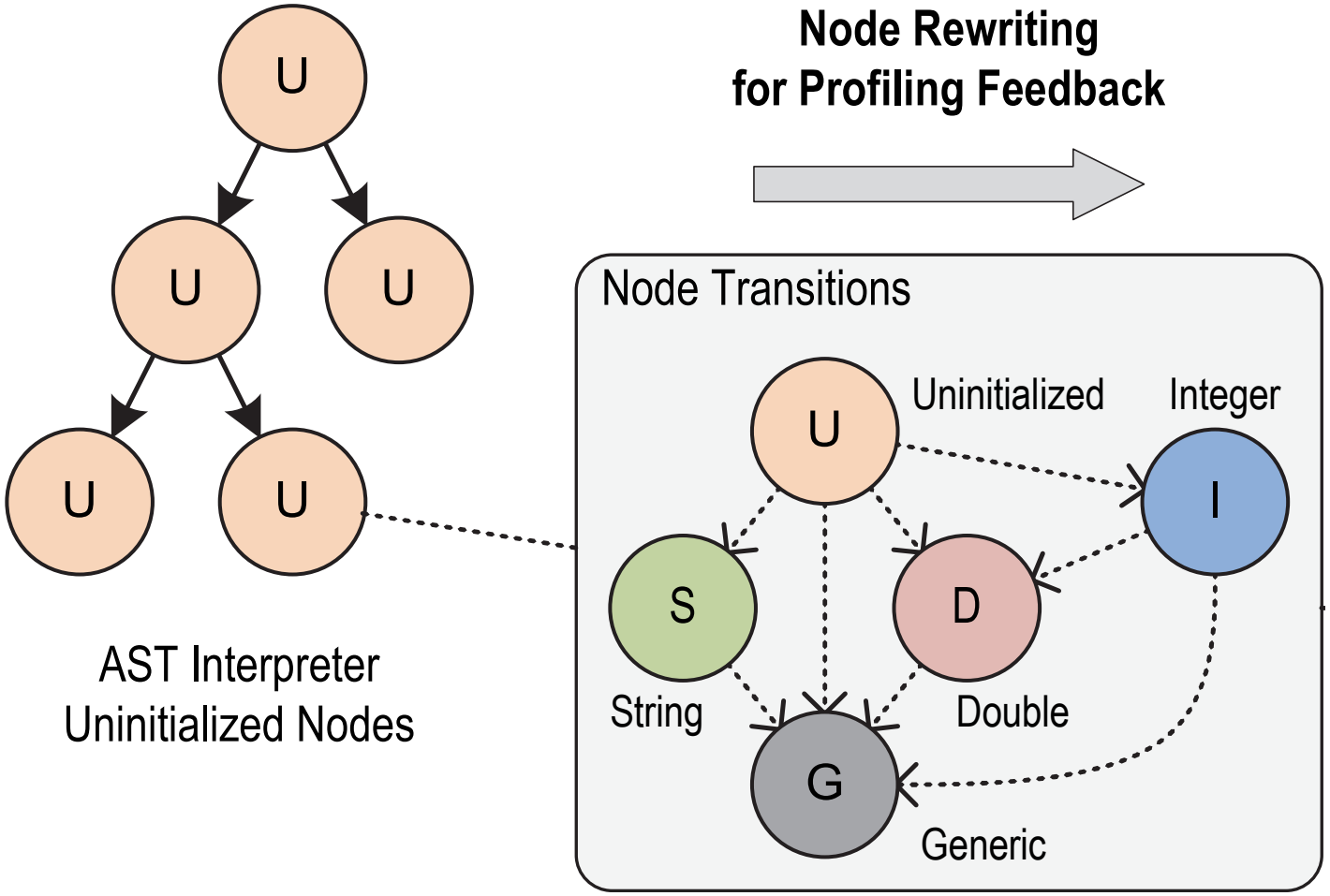






AST Interpreter
Uninitialized Nodes

T. Würthinger, C. Wimmer, A. Wöß, L. Stadler, G. Duboscq, C. Humer, G. Richards, D. Simon, and M. Wolczko. One VM to rule them all. In Proceedings of Onward!, 2013.



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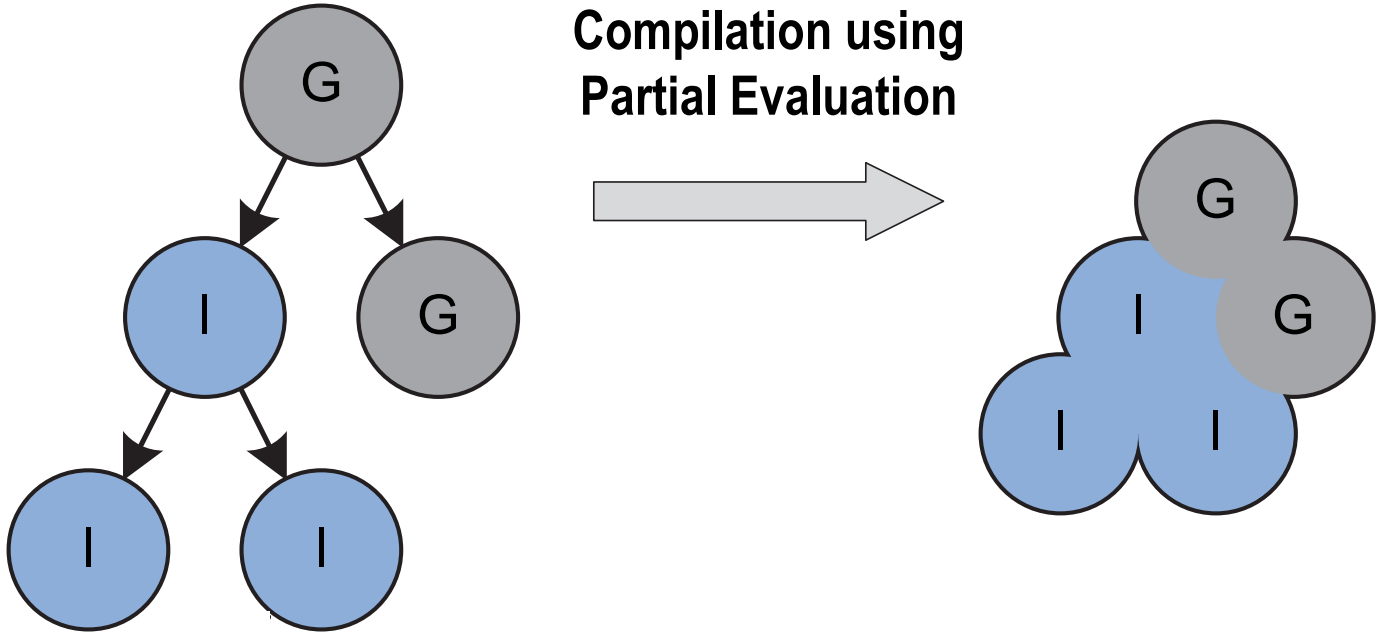

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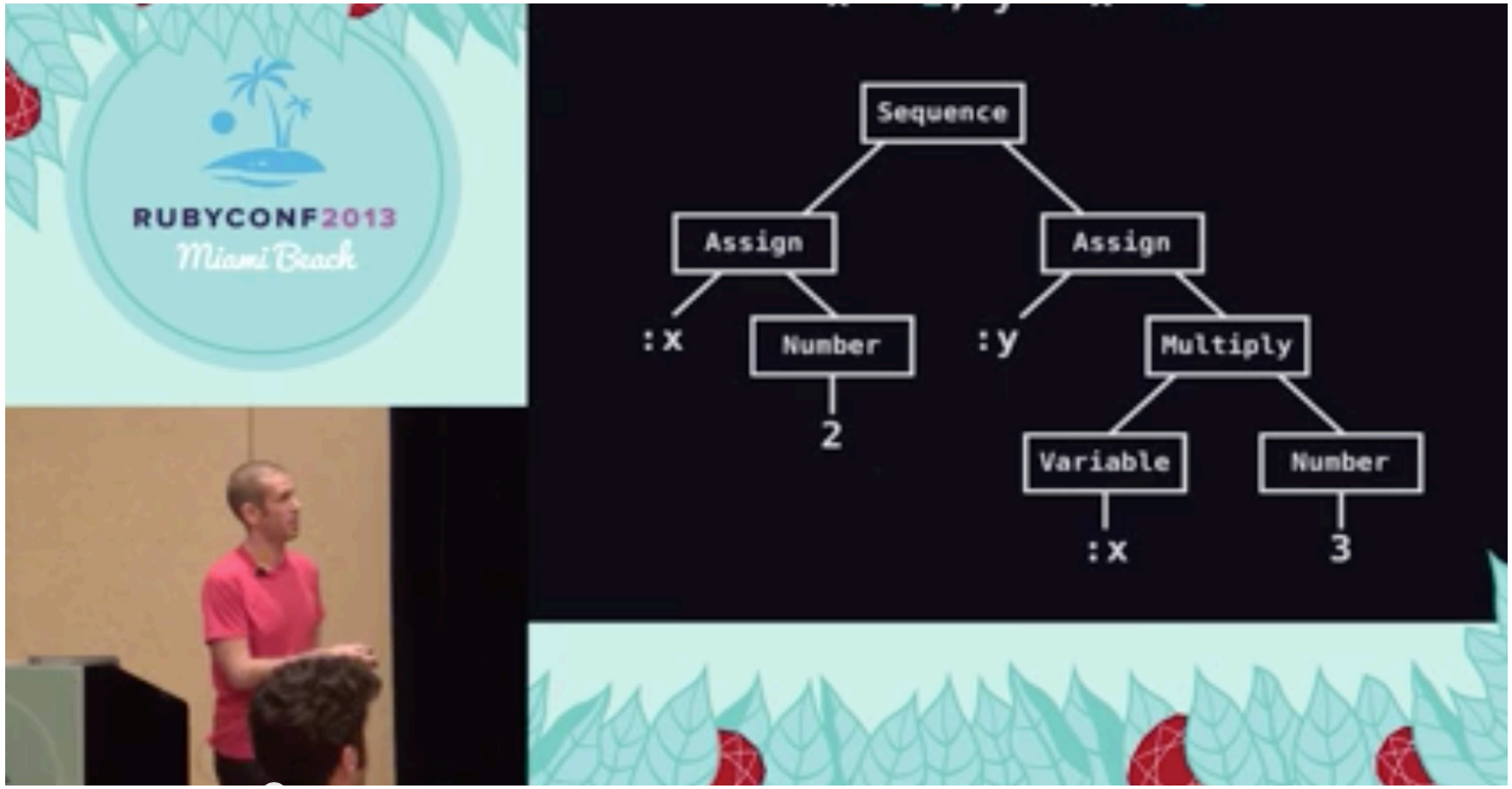
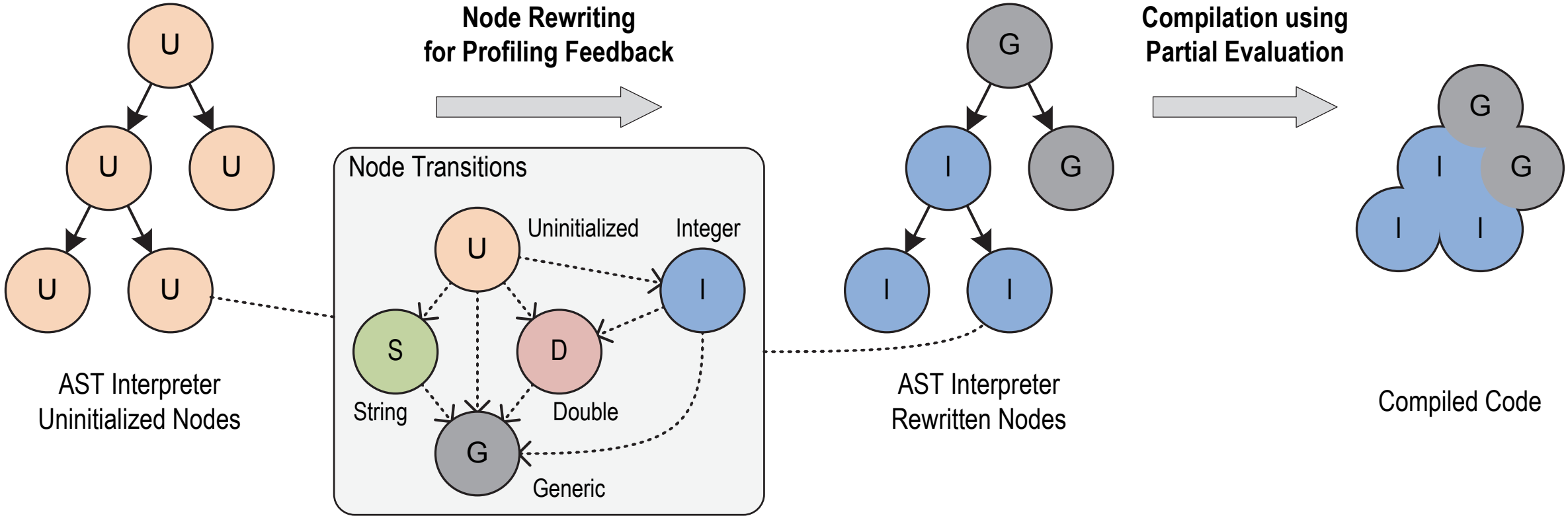


codon.com/compilers-for-free



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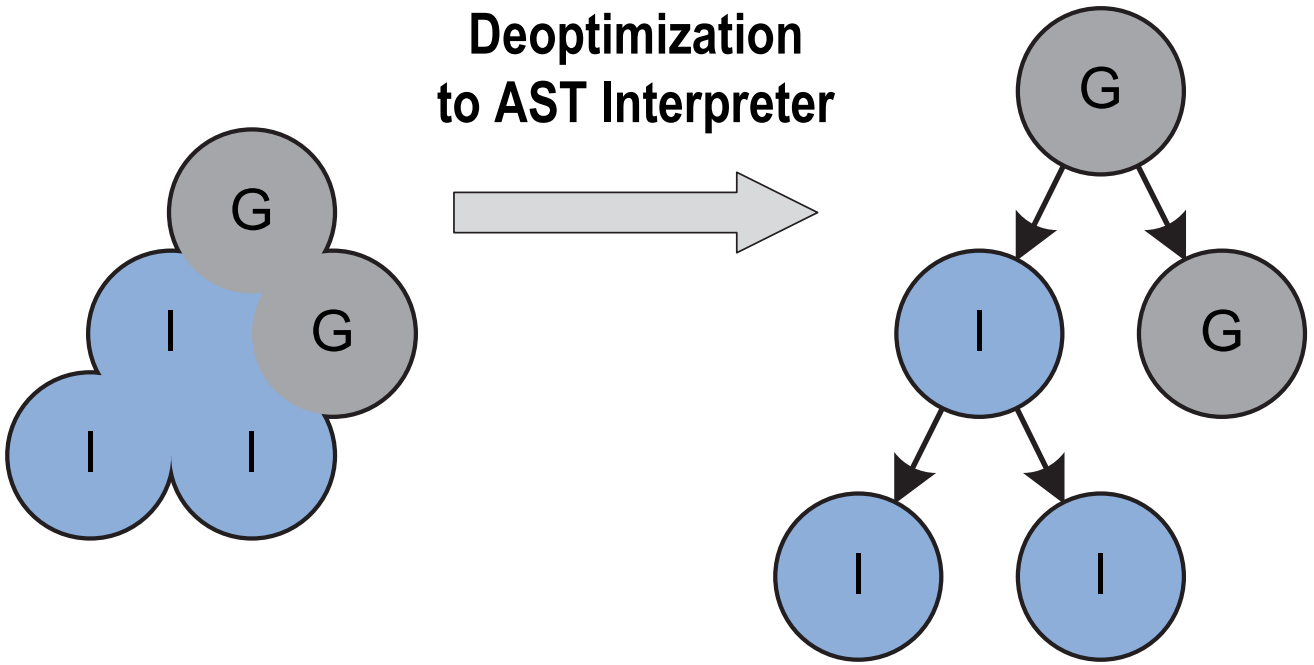

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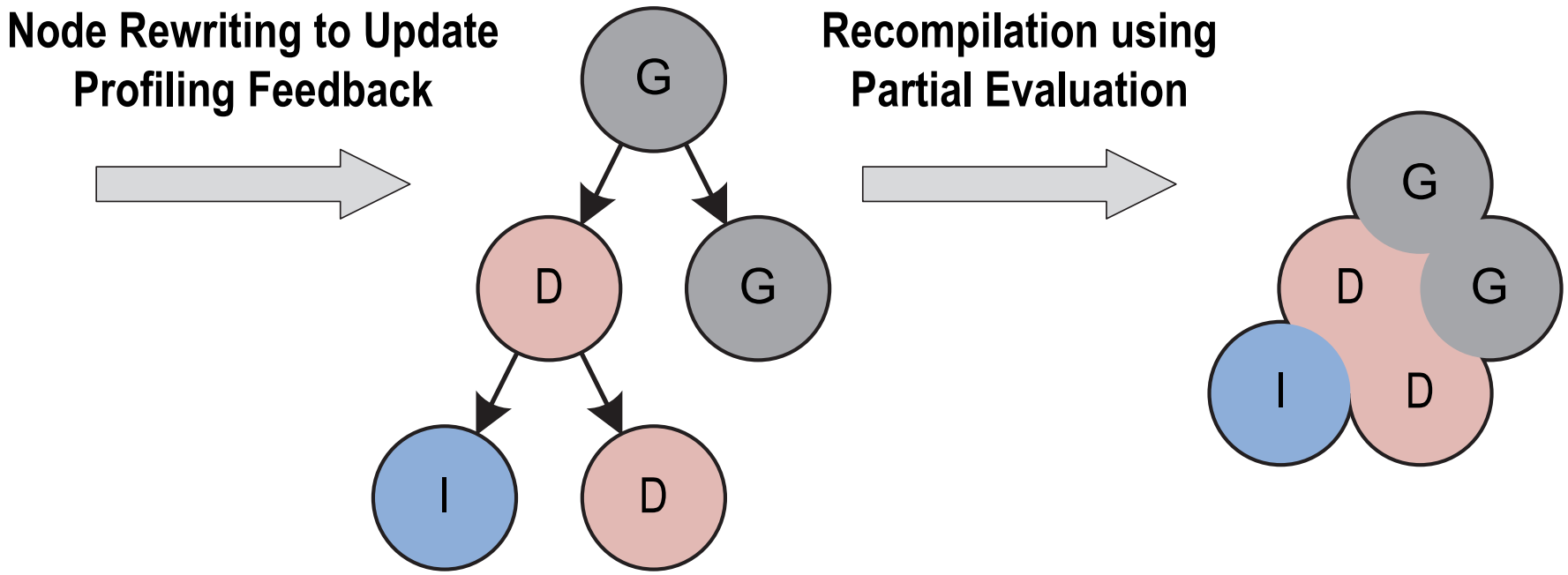

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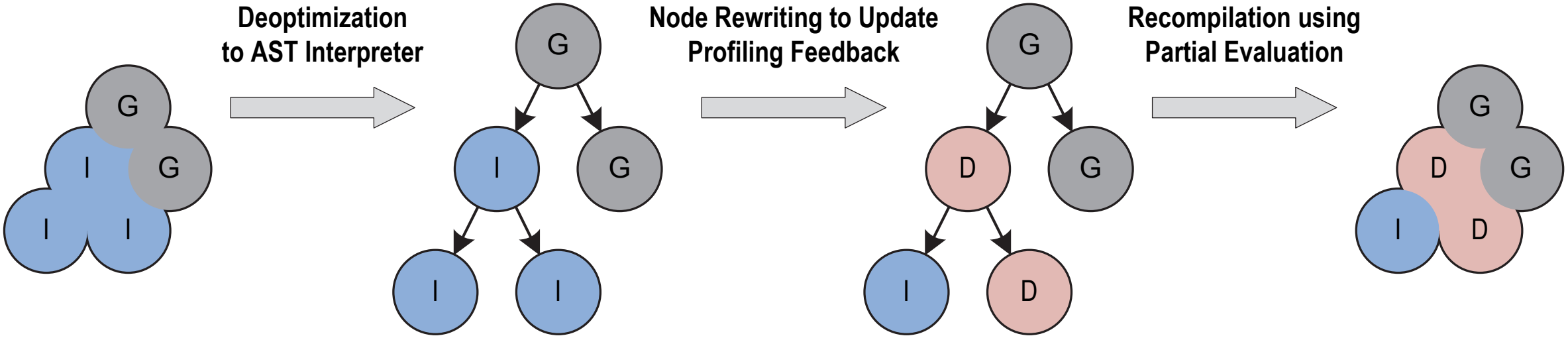

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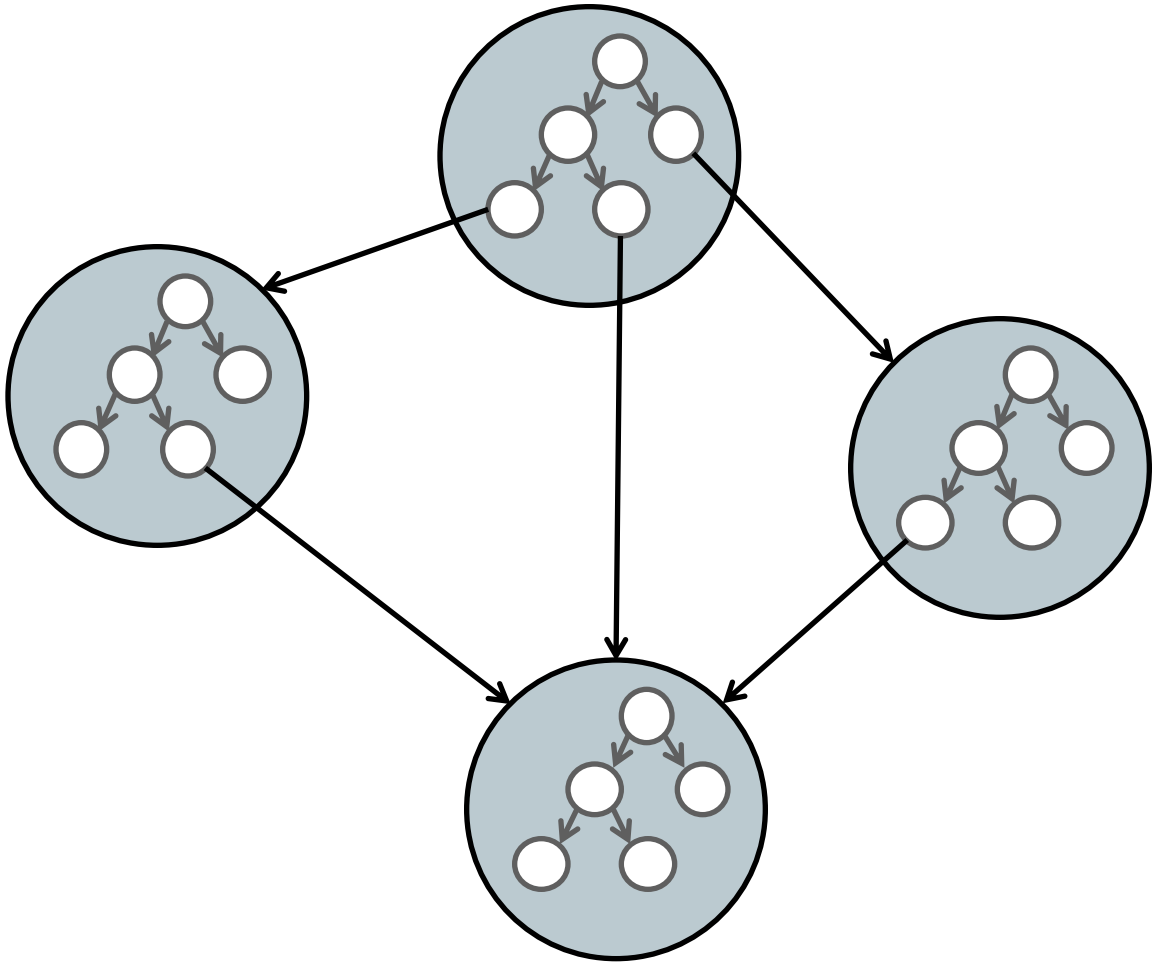
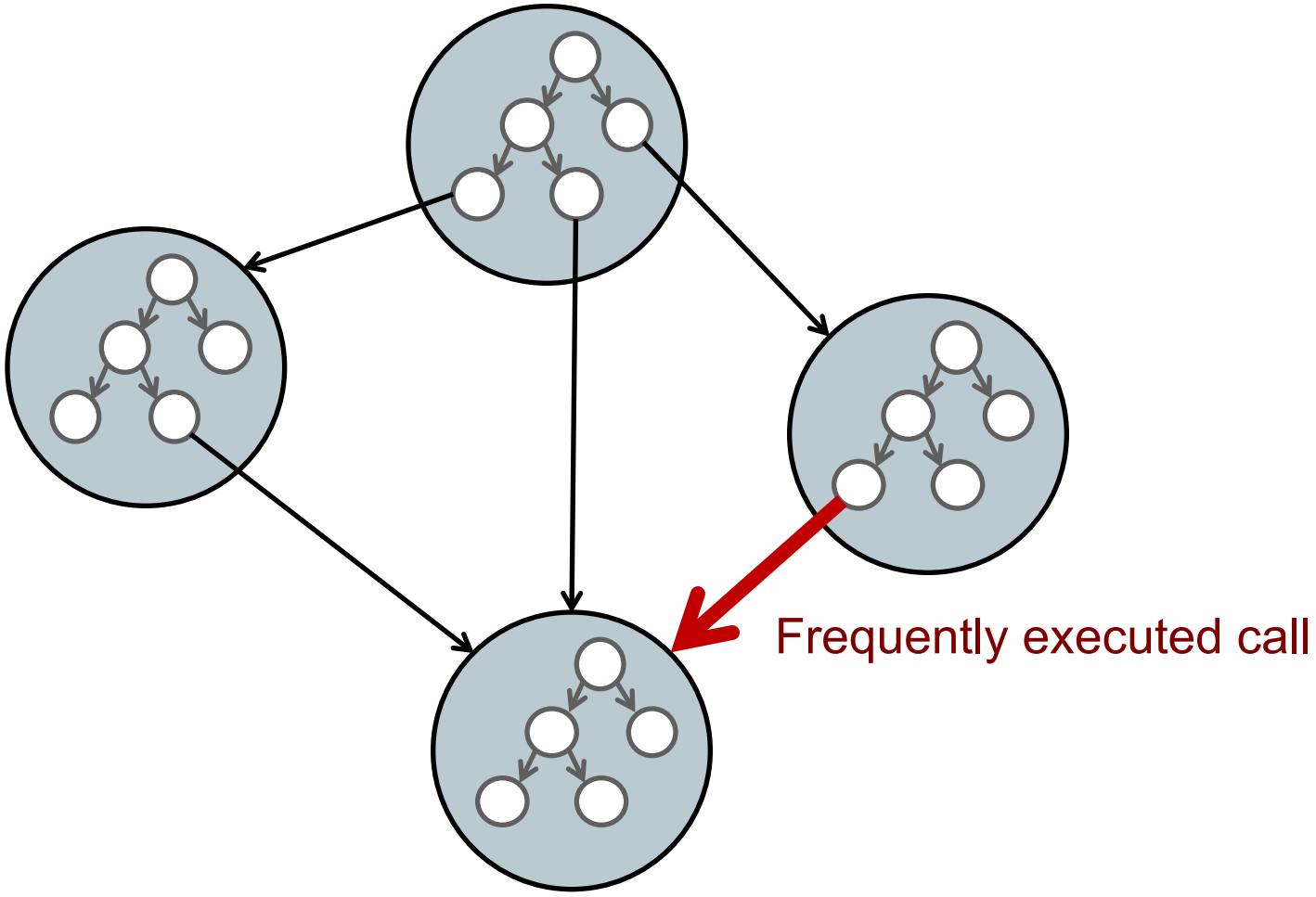
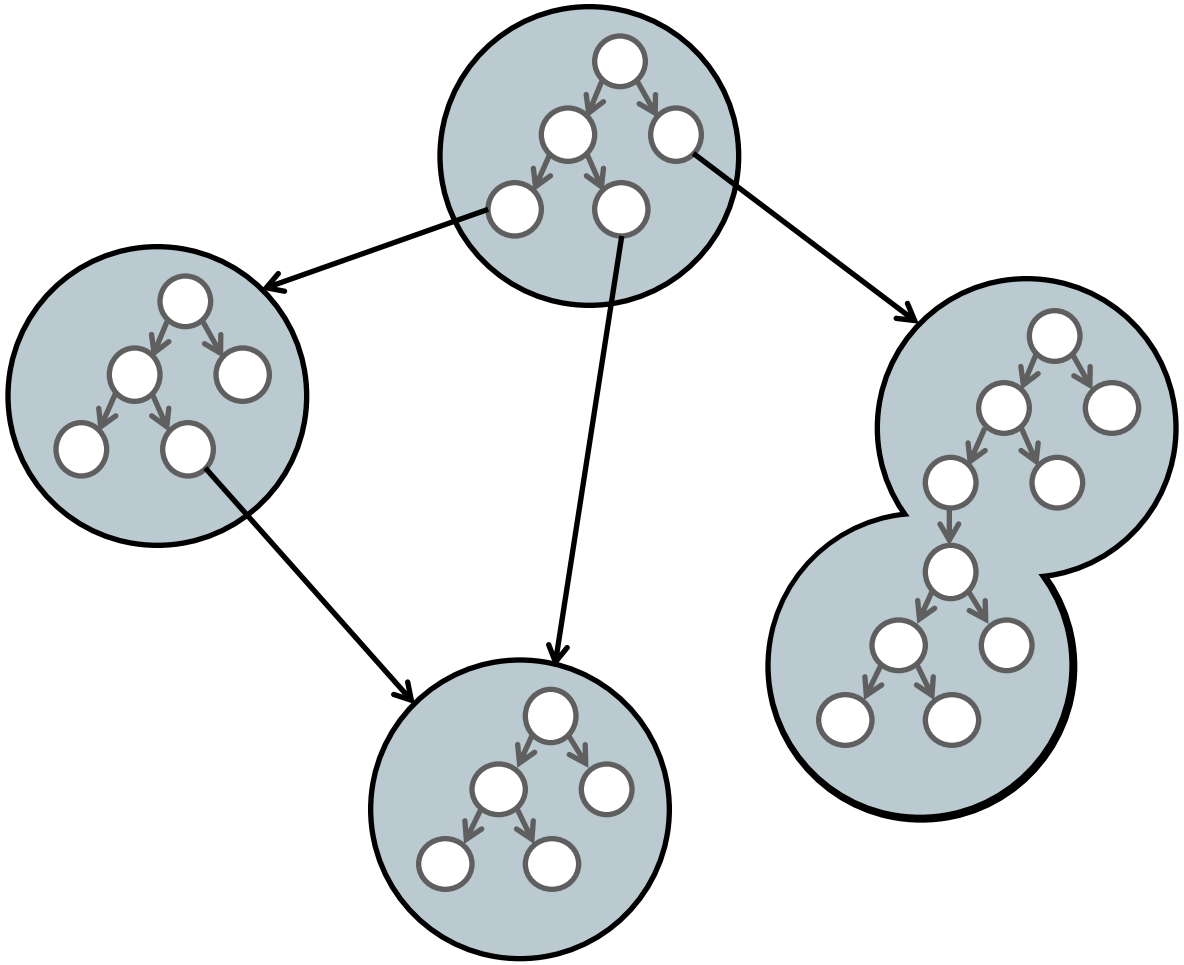
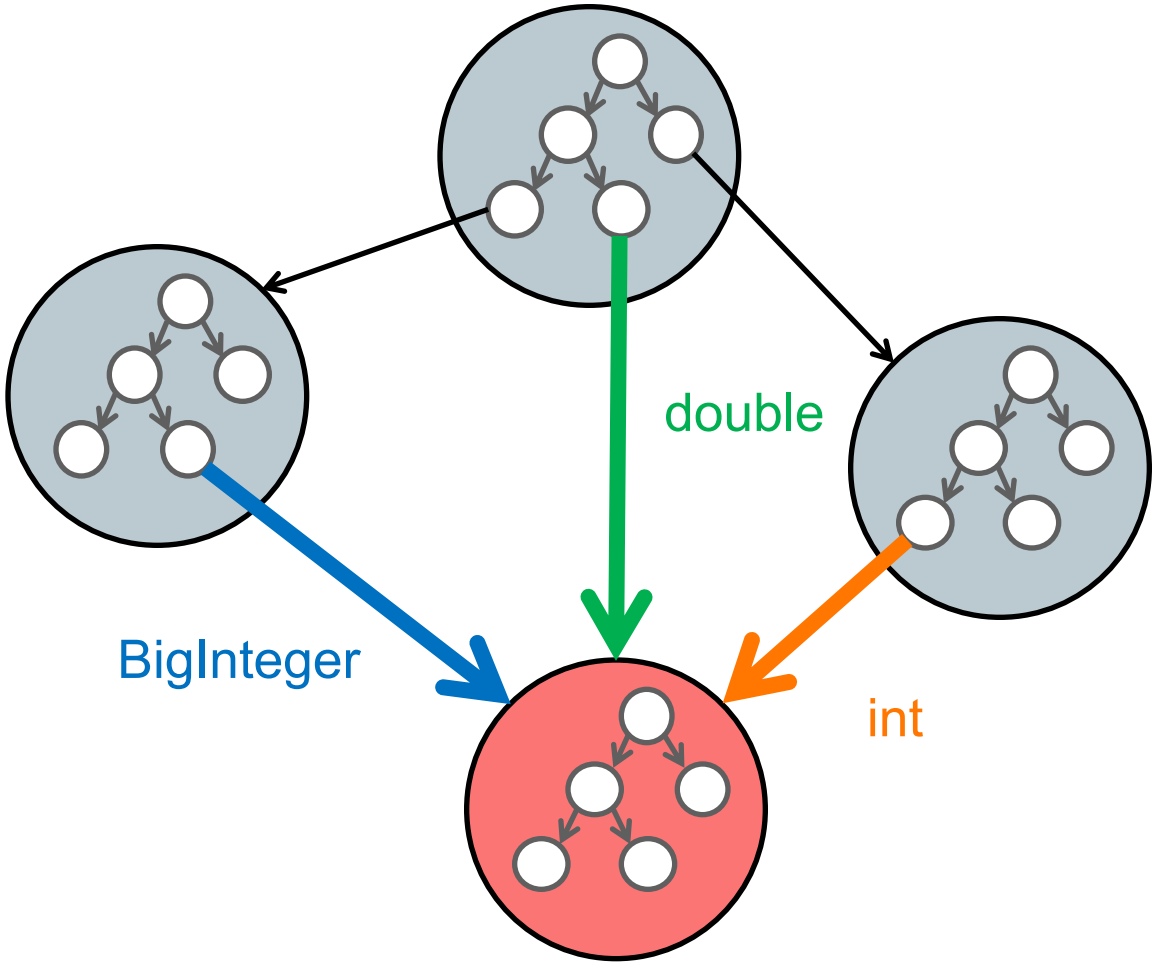
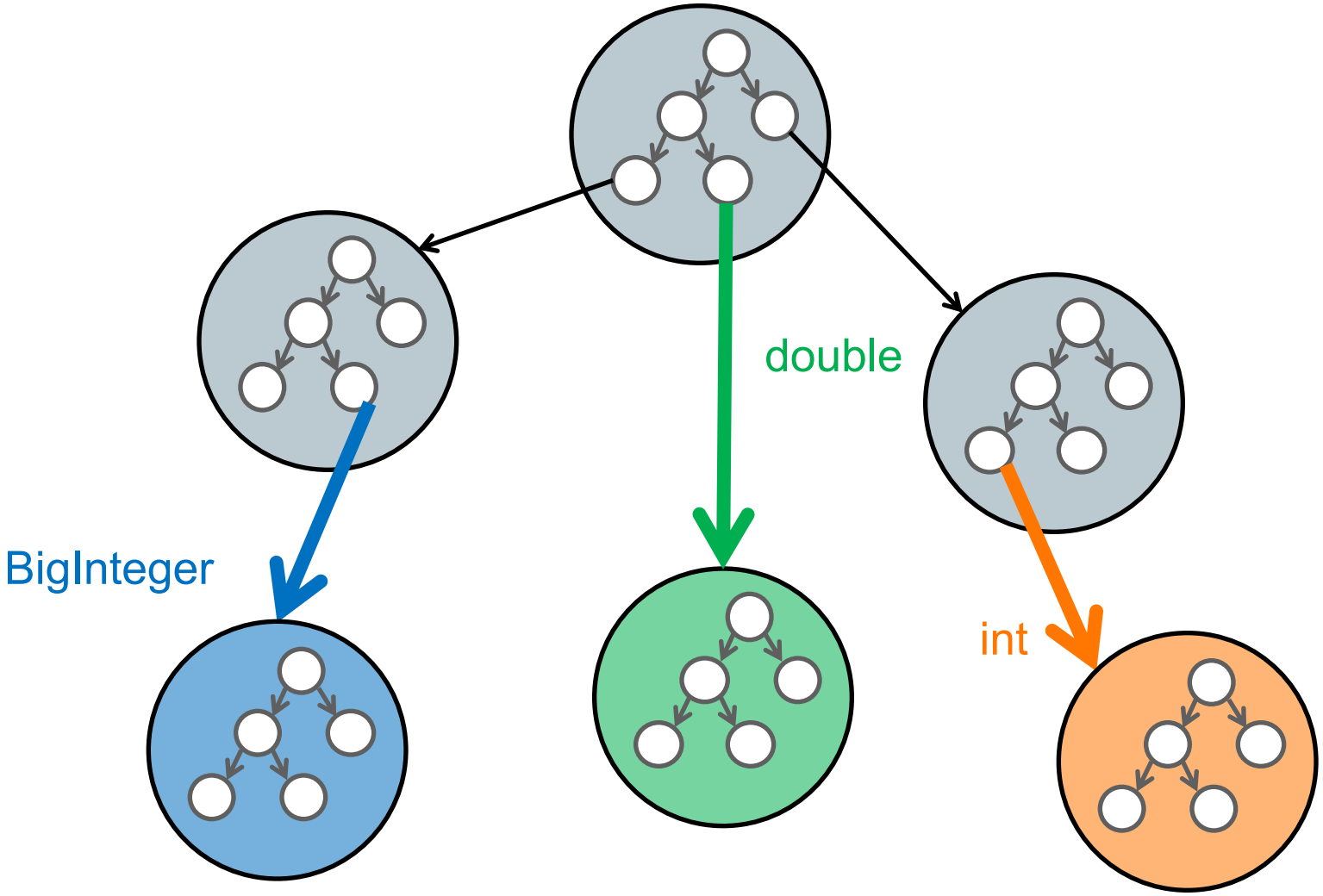
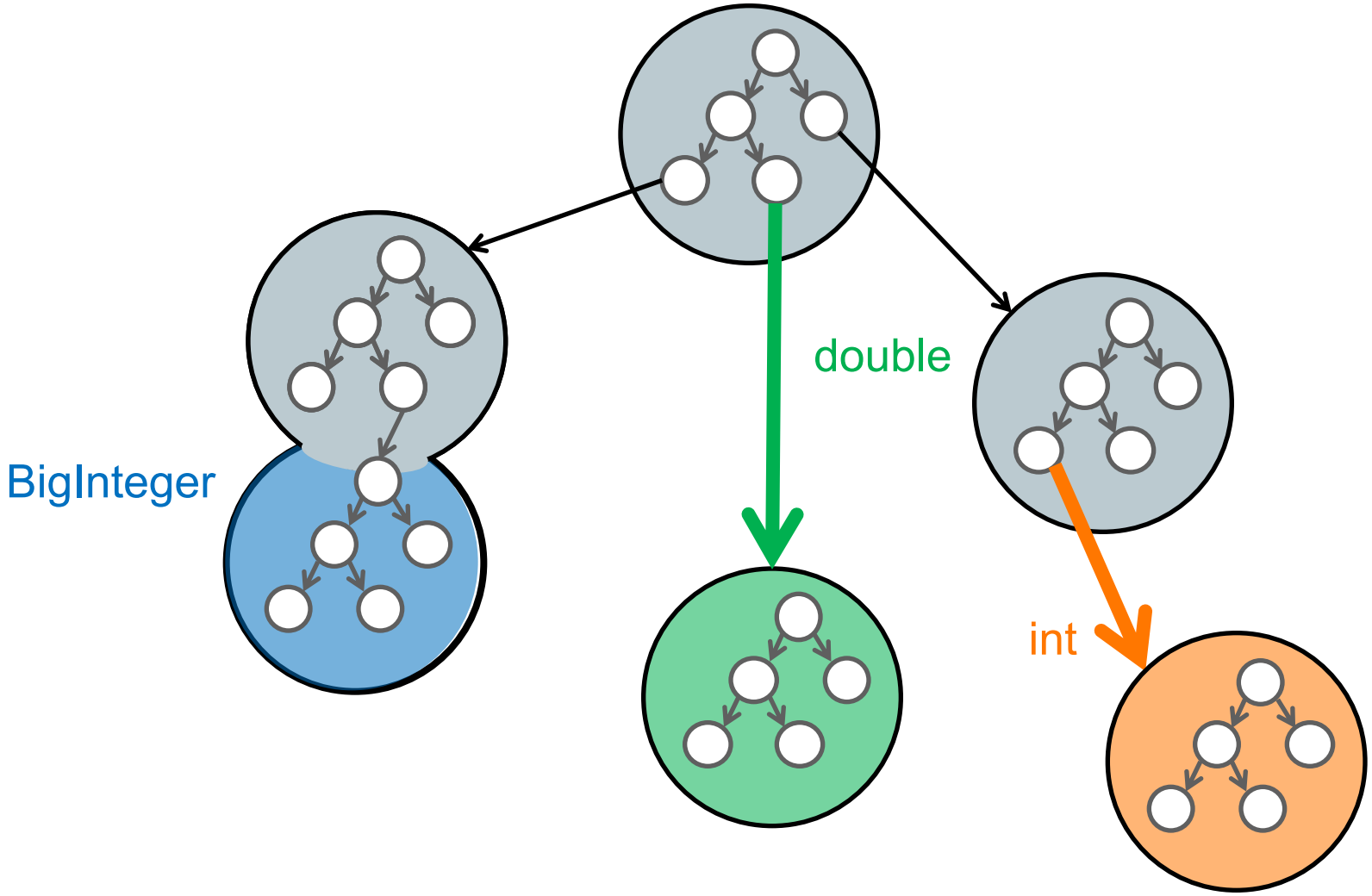




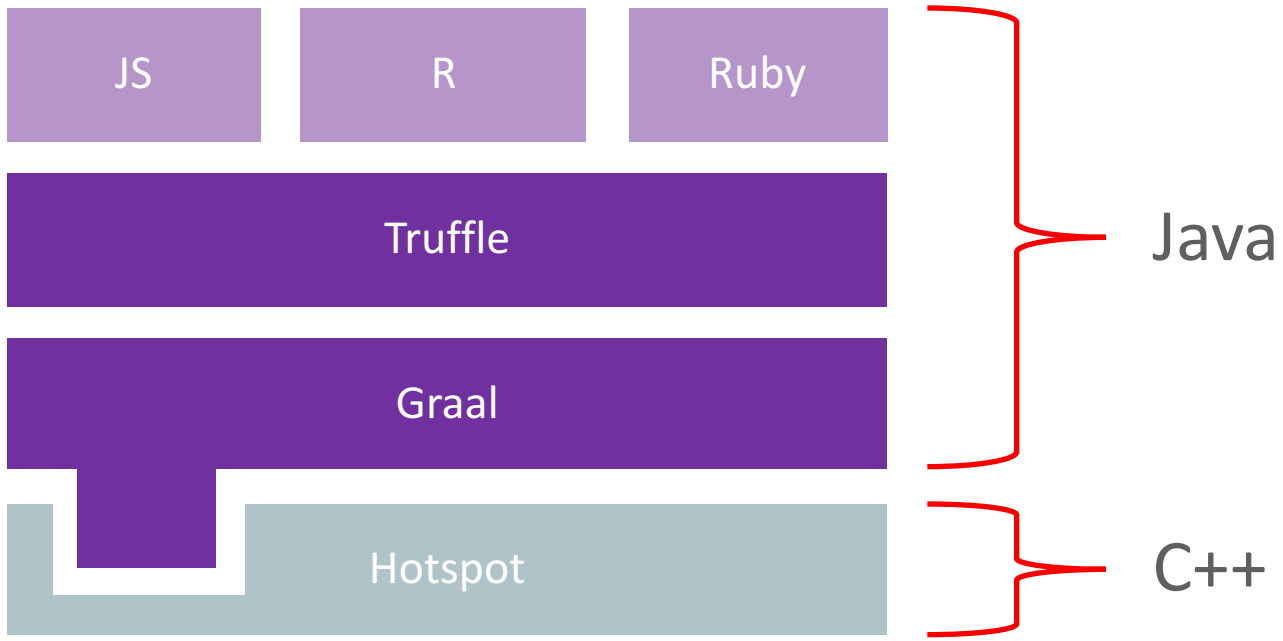


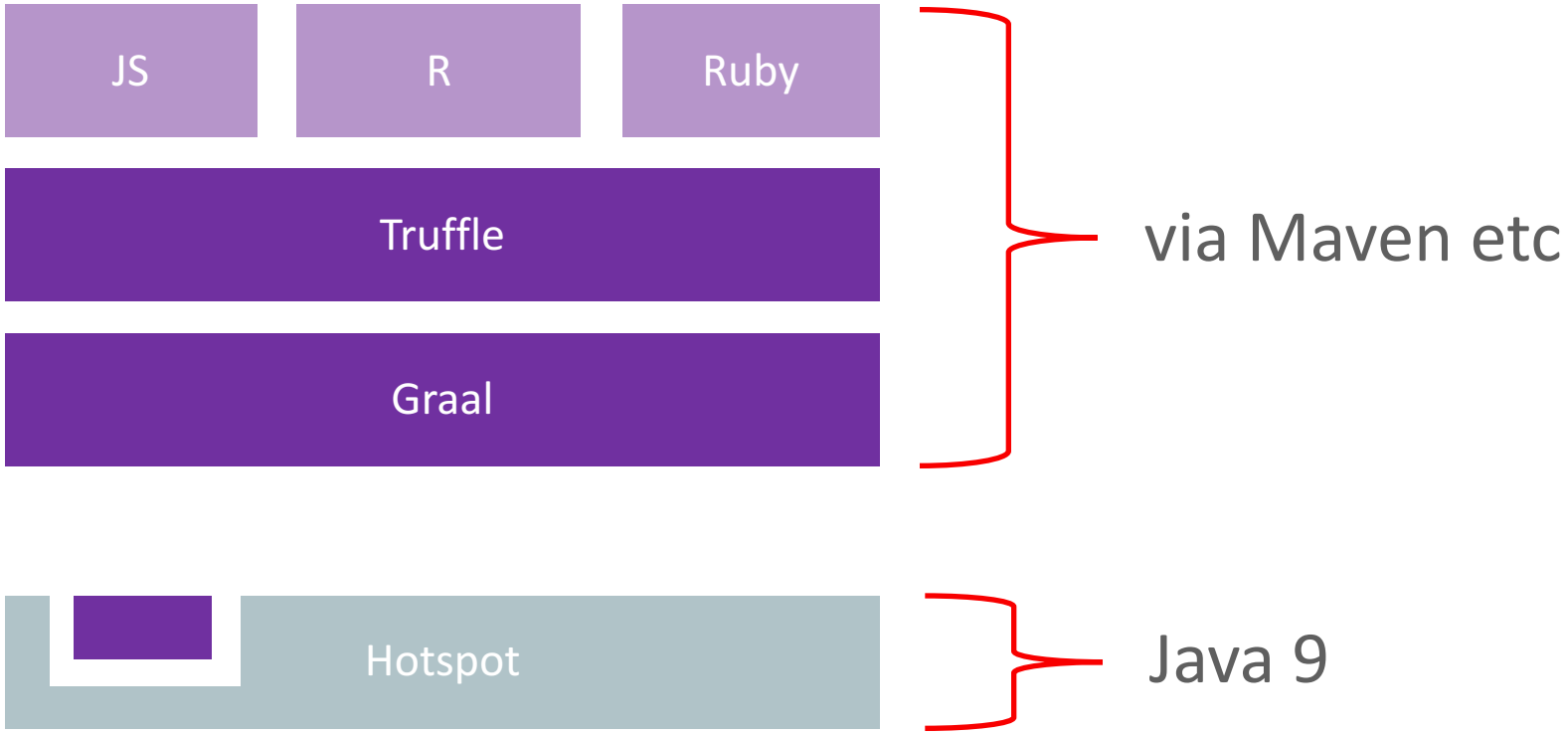


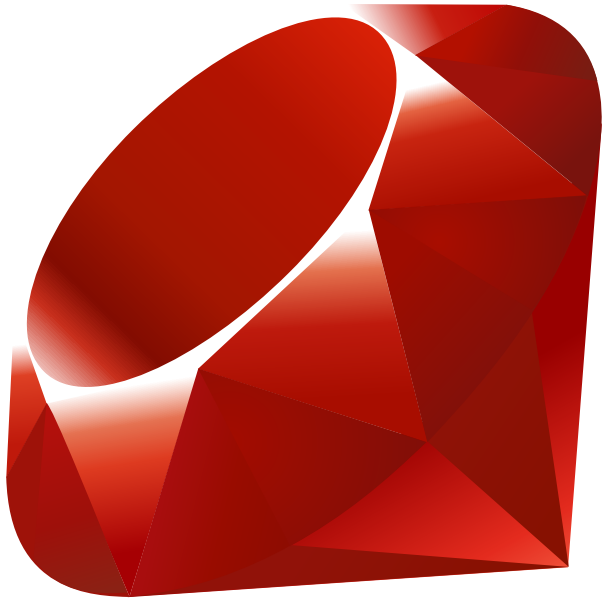




JVMCI
(JVM Compiler Interface)







Completeness – language and core library

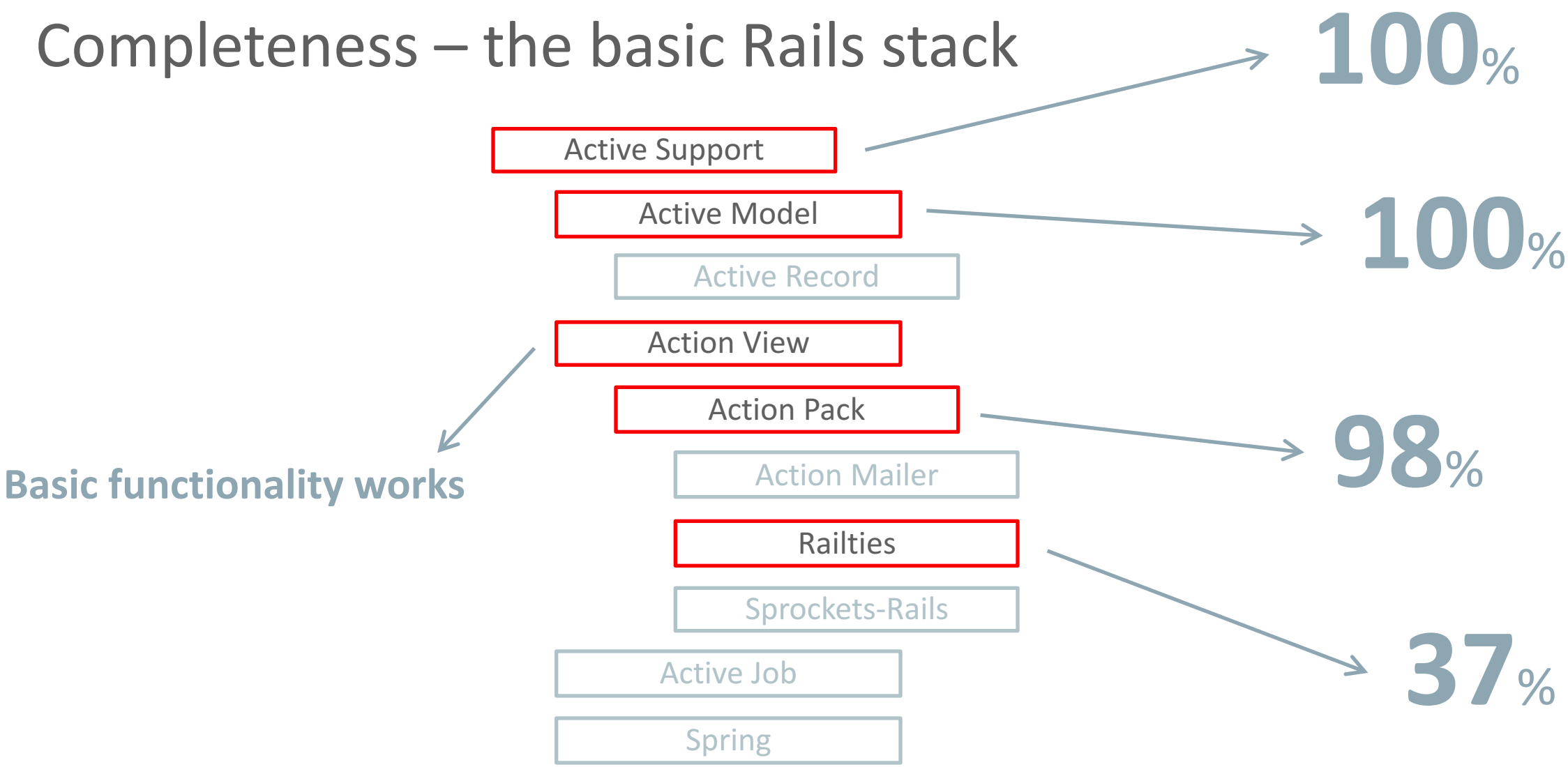
99% Ruby language

JRuby passes 94%

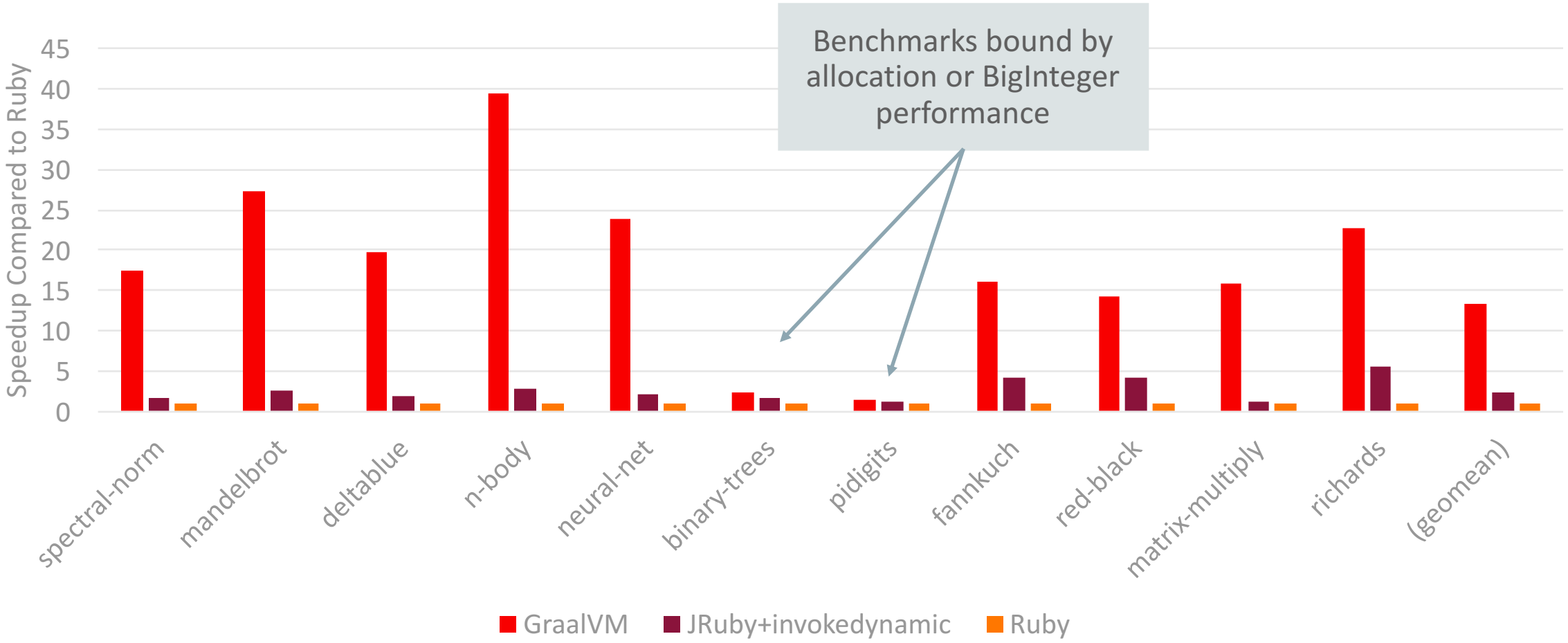
95% Ruby core library

JRuby passes 95%

Completeness – the basic Rails stack



Classic research benchmarks – 10-20x faster

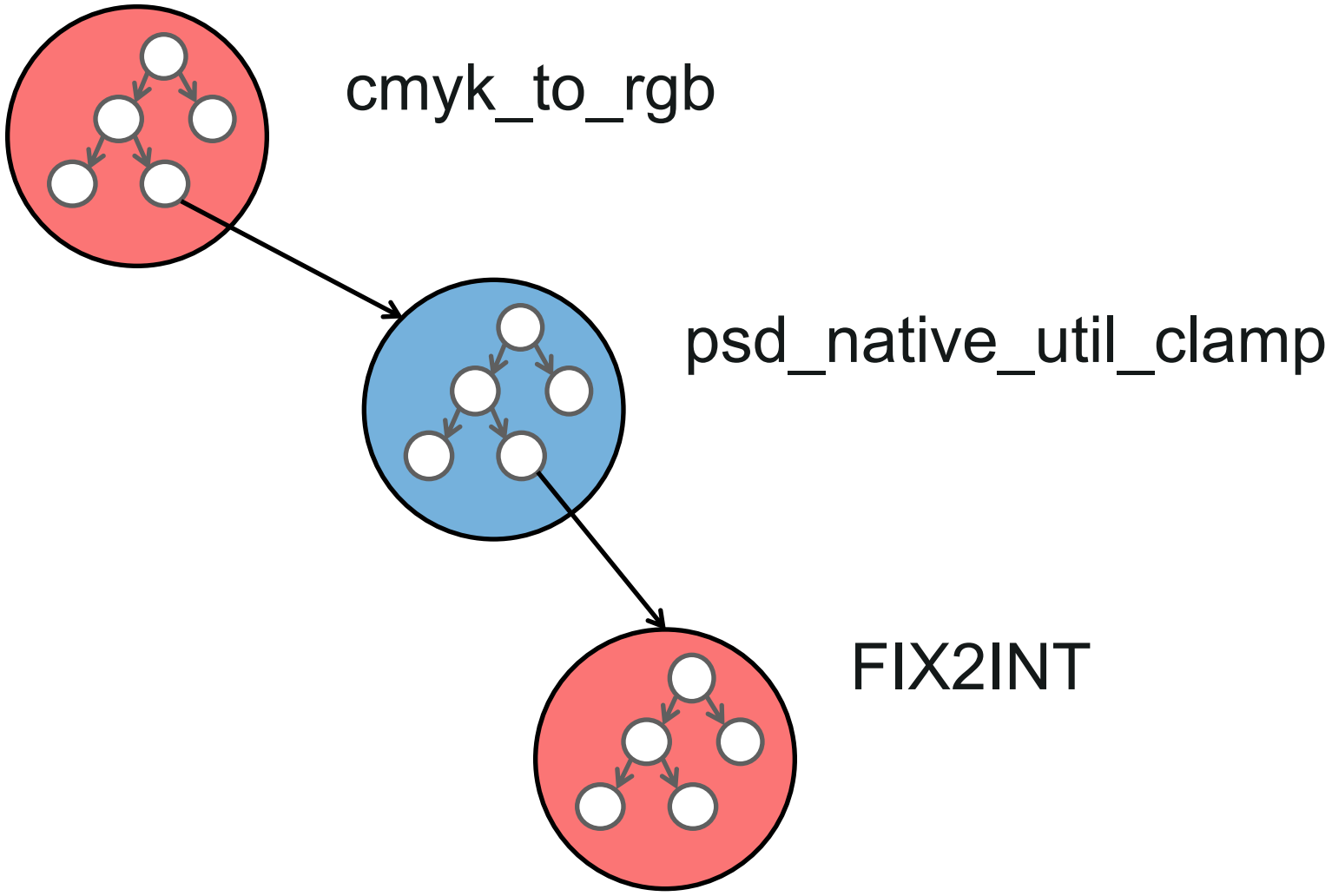


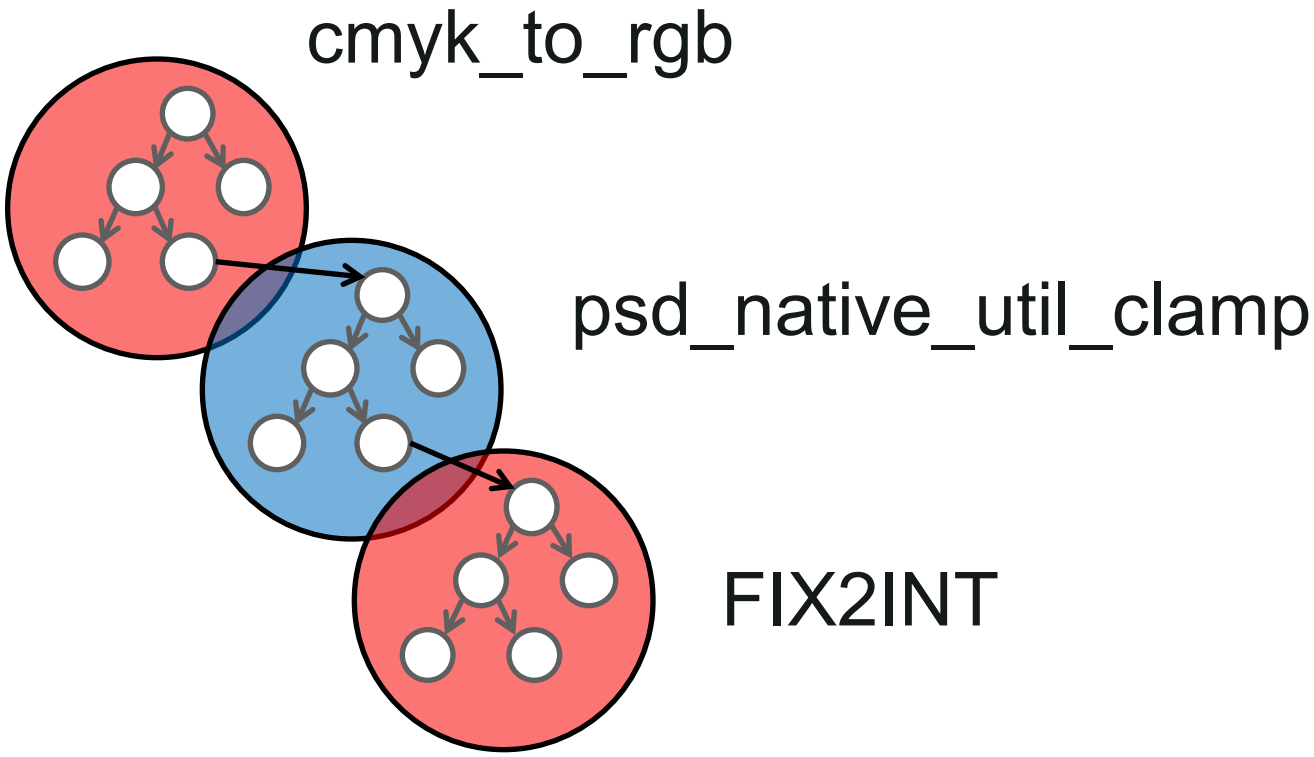
```
VALUE psd_native_util_clamp(VALUE self,
      VALUE r_num, VALUE r_min, VALUE r_max) {
  int num = FIX2INT(r_num);
  int min = FIX2INT(r_min);
  int max = FIX2INT(r_max);

  return num > max ? r_max : (num < min ? r_min : r_num);
}
```

```
define i8* @psd_native_util_clamp(i8* %self, i8* %r_num, i8* %r_min, i8* %r_max)
  %1 = call i32 @FIX2INT(i8* %r_num)
  %2 = call i32 @FIX2INT(i8* %r_min)
  %3 = call i32 @FIX2INT(i8* %r_max)
  %4 = icmp sgt i32 %1, %3
  br i1 %4, label %5, label %6
; <label>:5                                       ; preds = %0
  br label %12
; <label>:6                                       ; preds = %0
  %7 = icmp slt i32 %1, %2
  br i1 %7, label %8, label %9
; <label>:8                                       ; preds = %6
  br label %10
; <label>:9                                       ; preds = %6
  br label %10
; <label>:10                                      ; preds = %9, %8
  %11 = phi i8* [ %r_min, %8 ], [ %r_num, %9 ]
  br label %12
; <label>:12                                      ; preds = %10, %5
  %13 = phi i8* [ %r_max, %5 ], [ %11, %10 ]
  ret i8* %13
}
```

How we implement C extensions





```
VALUE* bg_pixels = RARRAY_PTR(rb_funcall(self, rb_intern("pixels"), 0));
VALUE* fg_pixels = RARRAY_PTR(rb_funcall(other, rb_intern("pixels"), 0));

long x = 0;
long y = 0;
for( y = 0; y < other_height; y++ ){
  for( x = 0; x < other_width; x++ ){
    bg_index = ( x + offset_x ) + ( y + offset_y ) * self_width;
    bg_pixels[bg_index] = UINT2NUM(
      oily_png_compose_color(
        NUM2UINT( fg_pixels[x+ y * other_width] ),
        NUM2UINT( bg_pixels[bg_index] ) ) );
  }
}
```

Instead of RARRAY_PTR returning a pointer (a number), return a proper Java object

```
.....
%42 = call i8** @RARRAY_PTR(i8* %41)
.....
%55 = getelementptr inbounds i8** %42, i64 %54
%56 = load i8** %55, align 8
.....
```

Operations like getelementptr can return a new Java object that remembers the original object, and what offset to use

Let SSA names store Java objects as well as numbers

The load can then use whatever logic we want to actually read a value from the Java object – reuse normal Ruby array logic

```
void*
```

```
public final class LLVMTruffleObject {
    private final TruffleObject object;
    private final long offset;
}
```

The C program has no way of knowing it's not a real char *

Virtualised pointer – really points to a Java object which represents our Ruby string

```
char *virtualised_string;
virtualised_string[n] = 'x';
```

```
virtualised_string.read_at_offset(n)
```

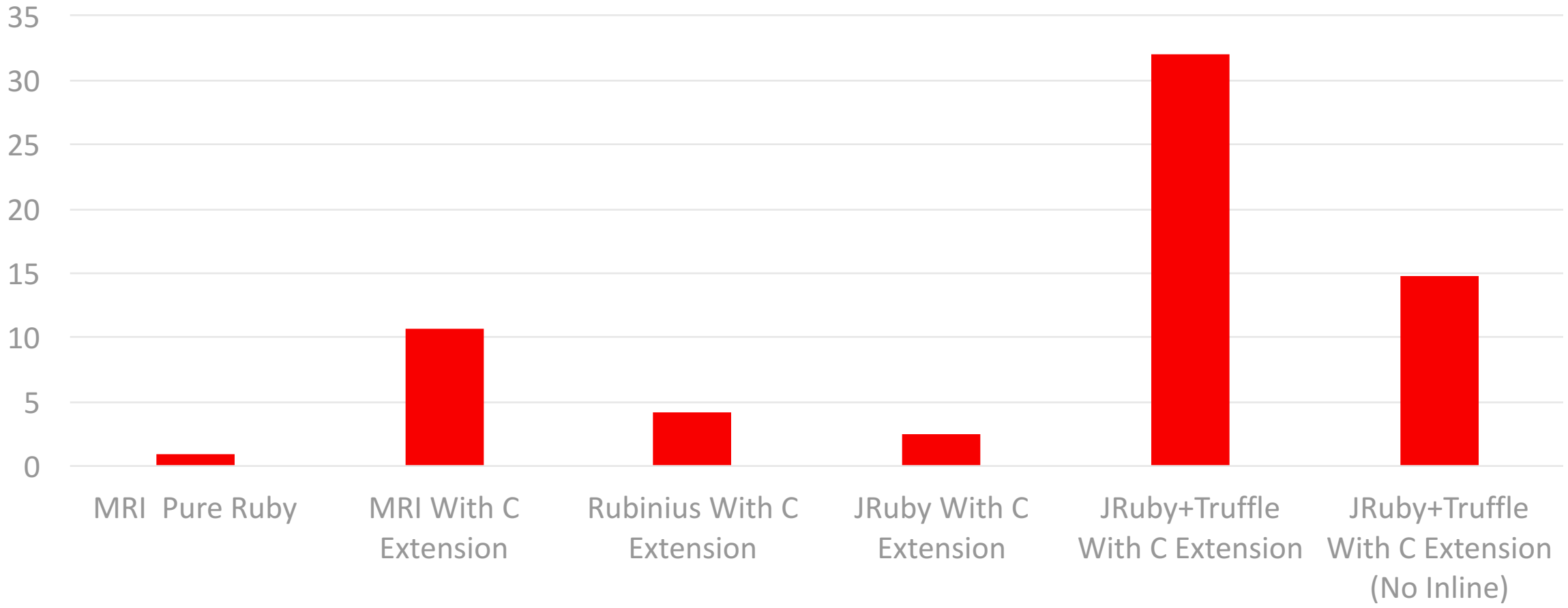
Intrinsic operations on the pointer are redirected to be method calls

Evaluation

Evaluation is based on earlier work

- We used to have a C interpreter – TruffleC
- We've moved on from this, because we want to support more languages
- But we aren't able to run all the same benchmarks yet
- So we've showing results from our old implementation in the mean time
- We're pretty sure results will be similar, as the compiled code is similar

Performance on Ruby C Extensions Oily PNG and PSD Native



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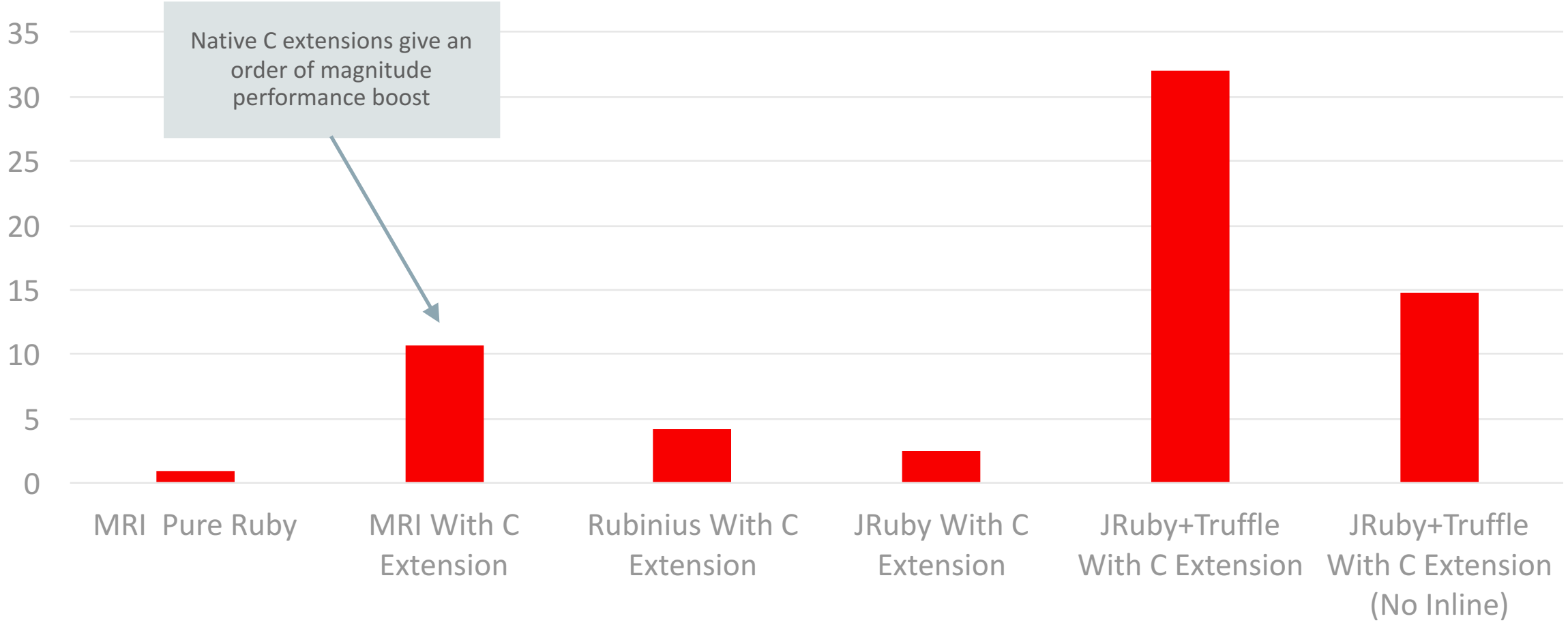

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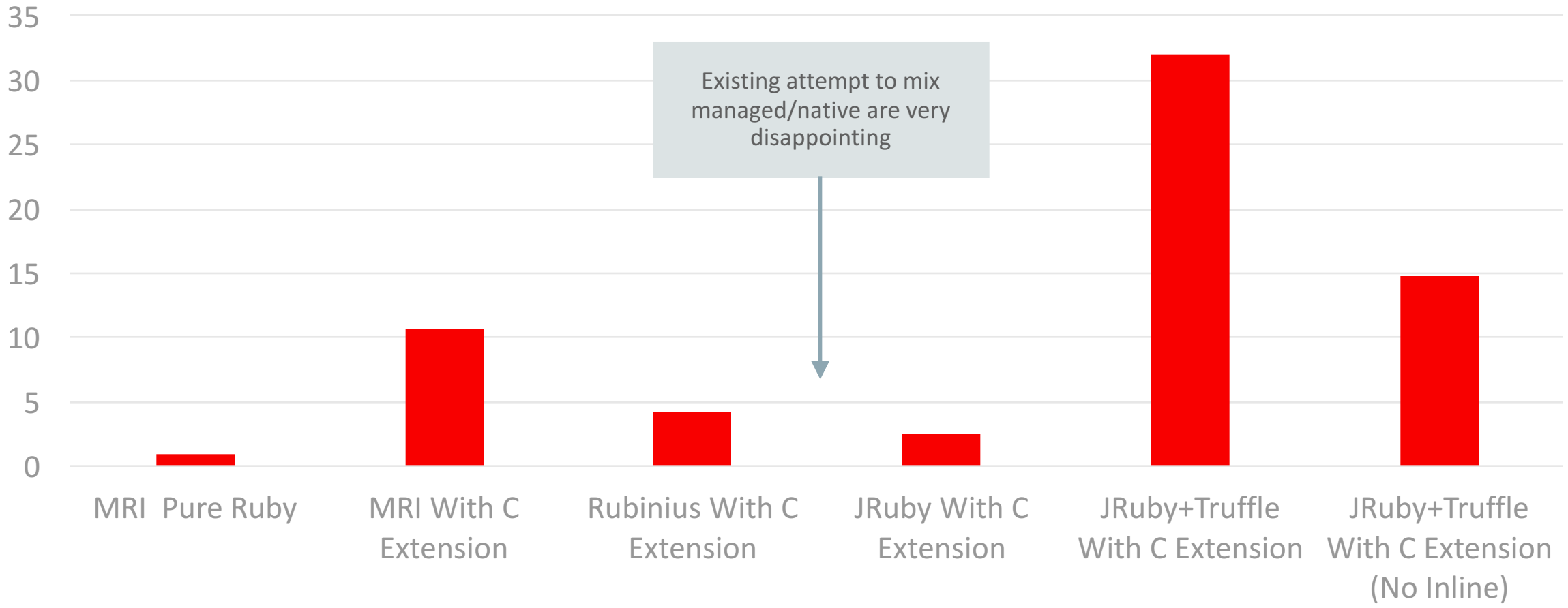

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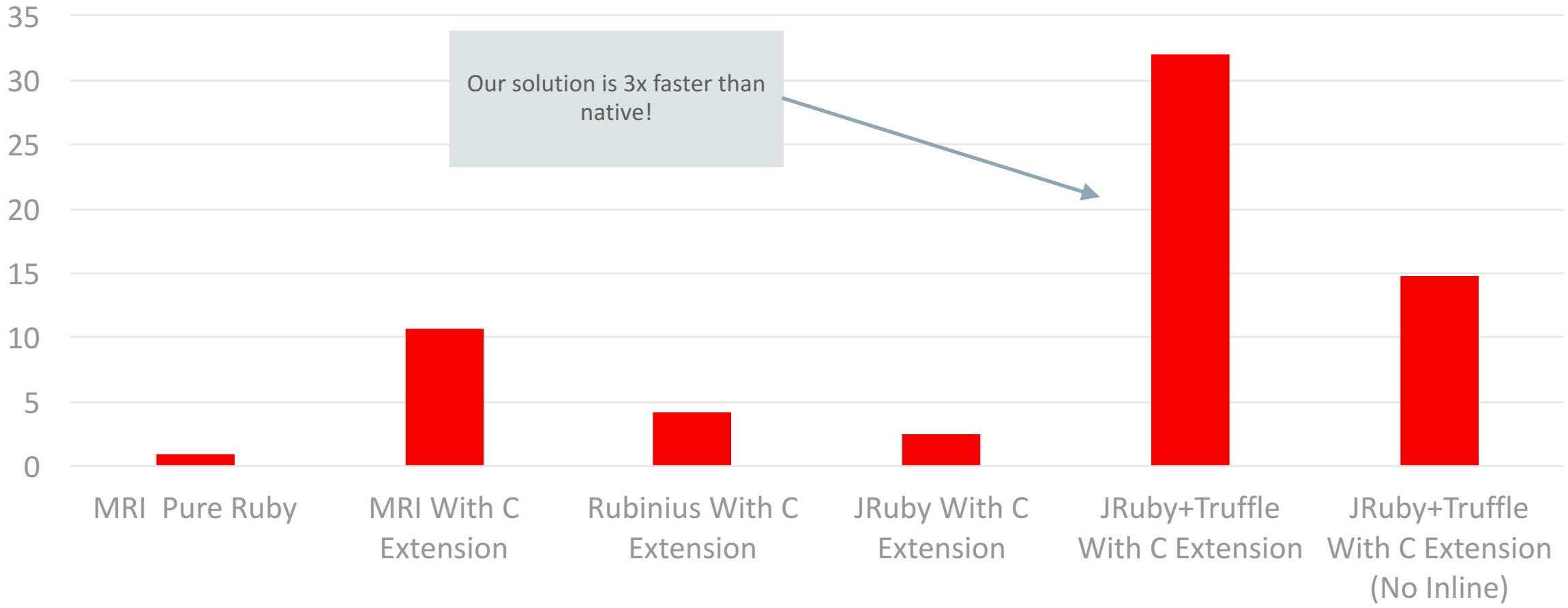
Performance on Ruby C Extensions Oily PNG and PSD Native



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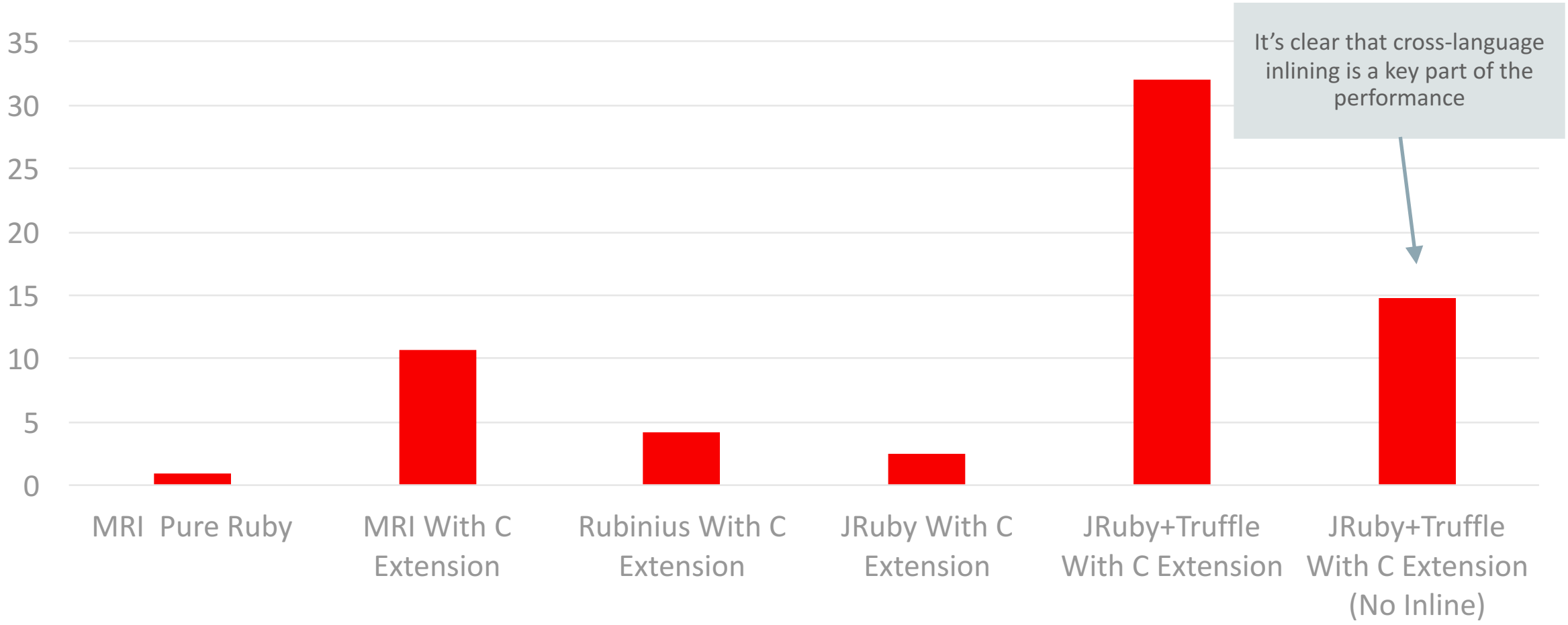

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Conclusions

Parallel Graph Analytics
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Souffle
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Thank you for downloading this release of the Oracle Labs GraalVM. With this release, one can execute Java applications with Graal, as well as applications written in JavaScript, Ruby, and R, with our Polyglot language engines.

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GraalVM preview for Linux (v0.15), Development Kit
GraalVM preview for Linux (v0.15), Runtime Environment
GraalVM preview for Mac OS X (v0.15), Development Kit
GraalVM preview for Mac OS X (v0.15), Runtime Environment

labsjdk-8u92-jvmci-0.20-darwin-amd64.tar.gz
labsjdk-8u92-jvmci-0.20-linux-amd64.tar.gz
labsjdk-8u92-jvmci-0.20-solaris-sparcv9.tar.gz

How to install GraalVM

Unpack the downloaded *.tar.gz file on your machine. You can then use the java executable to

Open Source

- https://github.com/graalvm/graal-core
  - Graal compiler
- https://github.com/graalvm/truffle
  - Truffle language implementation framework
- https://github.com/graalvm/fastr
  - Fast R runtime
- https://github.com/graalvm/sulong
  - Dynamic runtime for LLVM bitcode
- https://github.com/jruby/jruby/wiki/Truffle
  - Fast Ruby runtime

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