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Ruby's C Extension Problem and How We're Solving It

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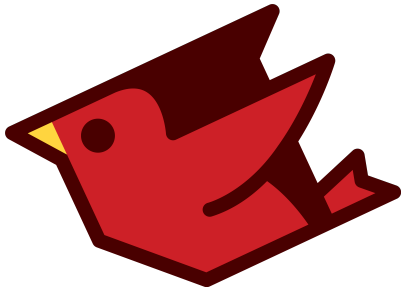
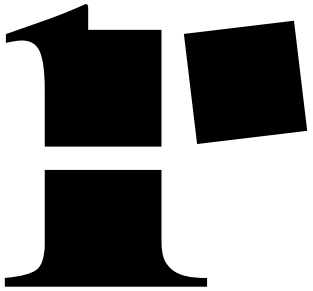
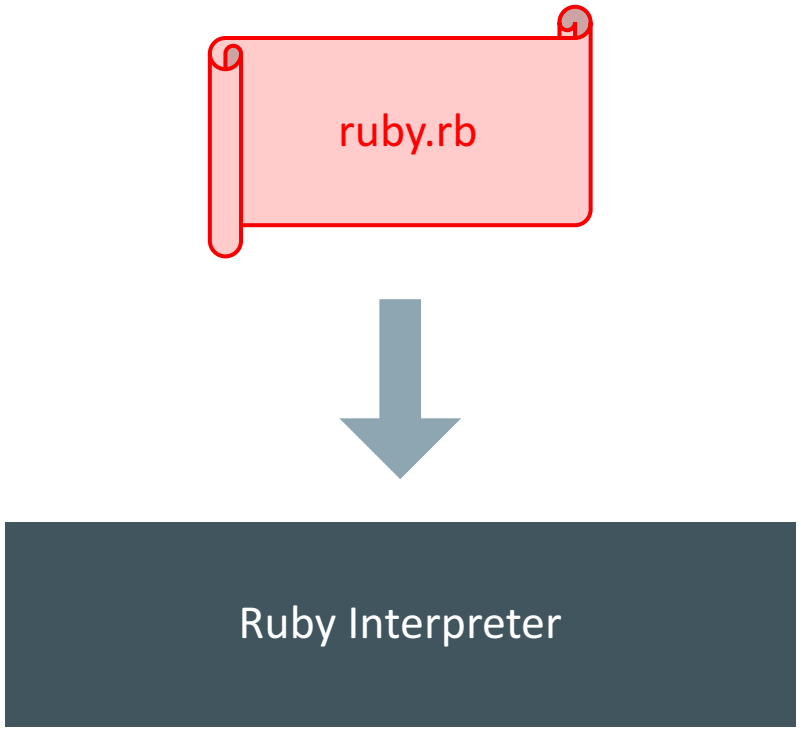
Lots of people want to make Ruby faster

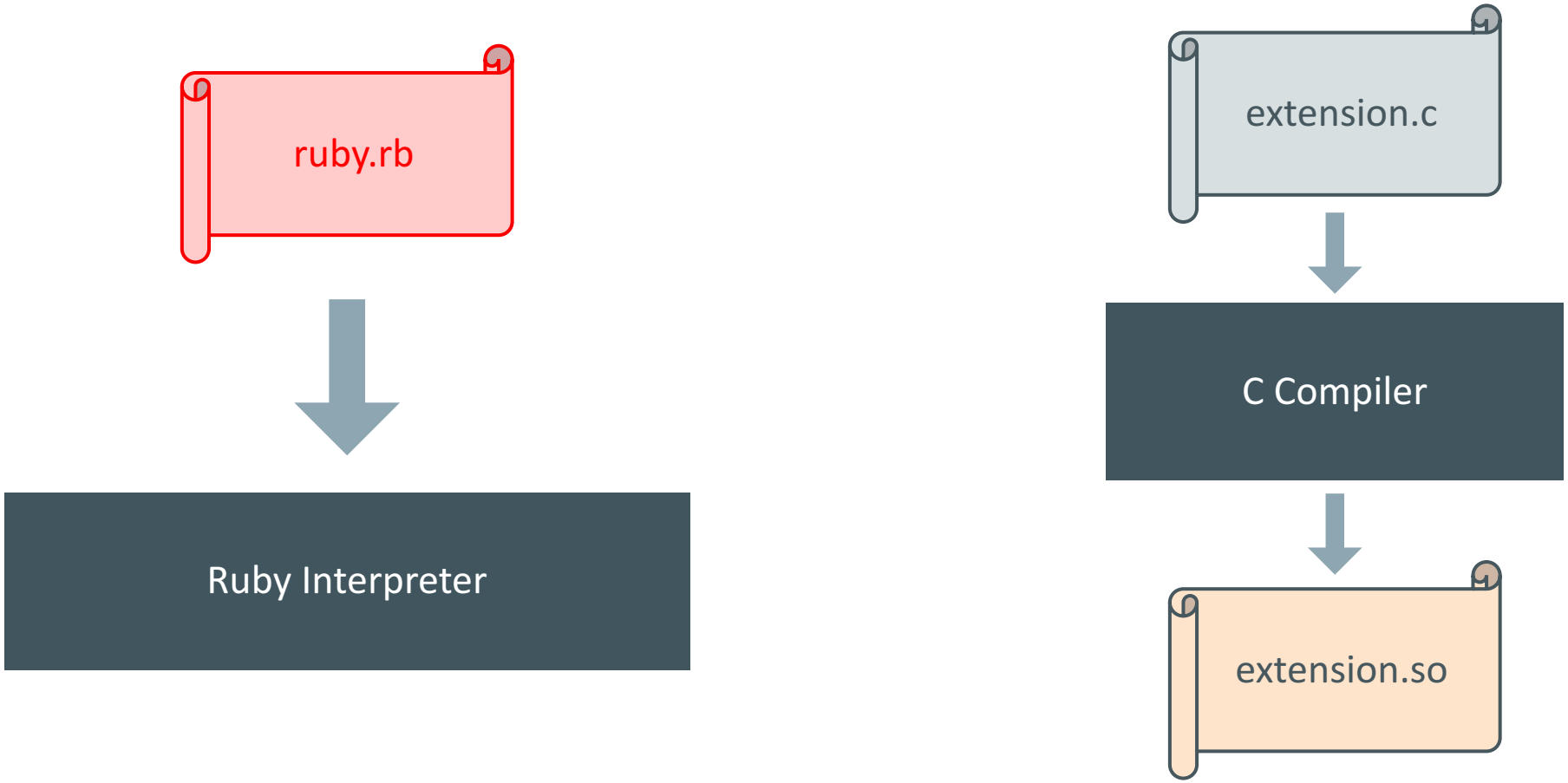




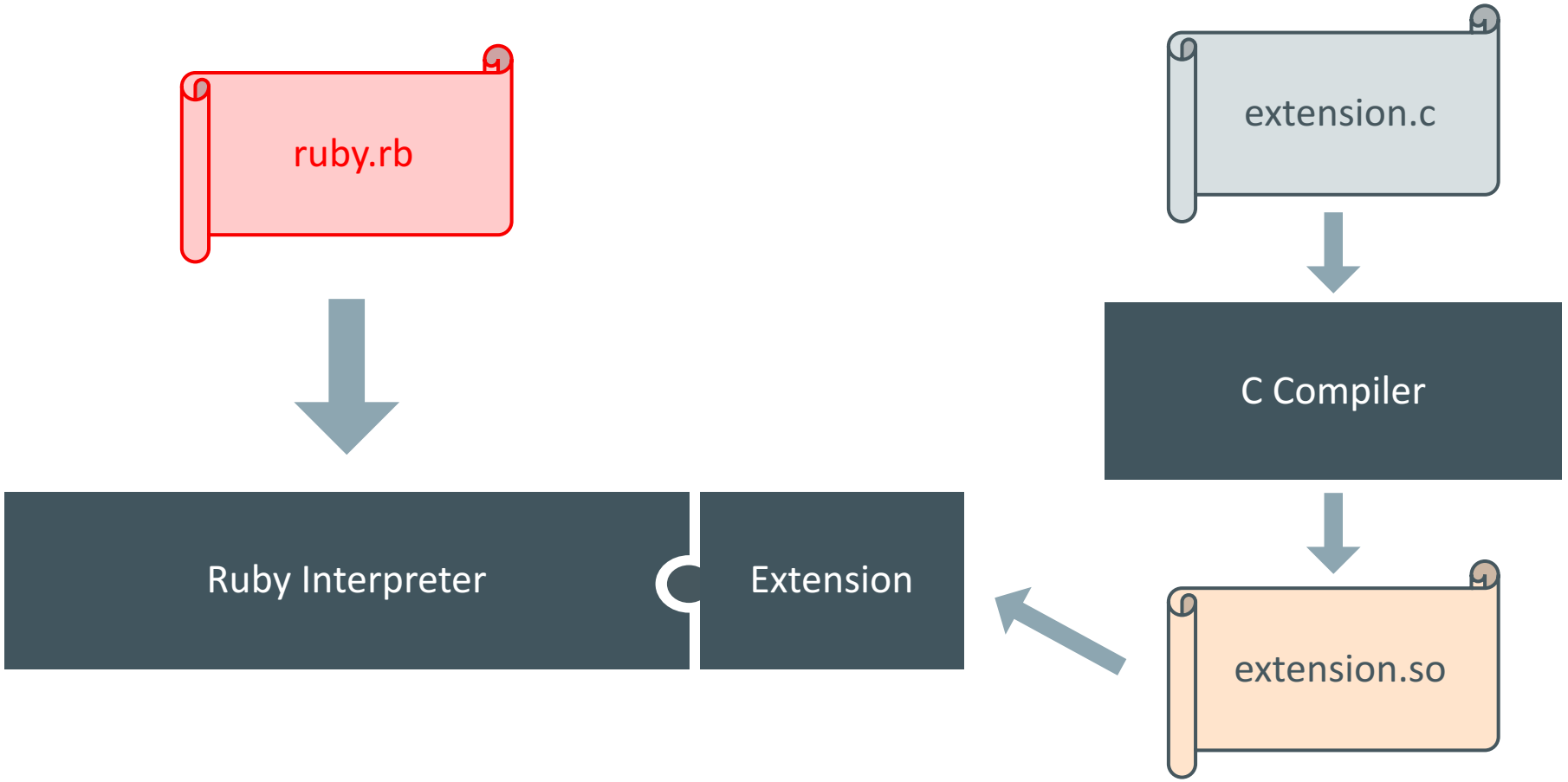
C extensions – the original solution for performance



C extensions – the original solution for performance



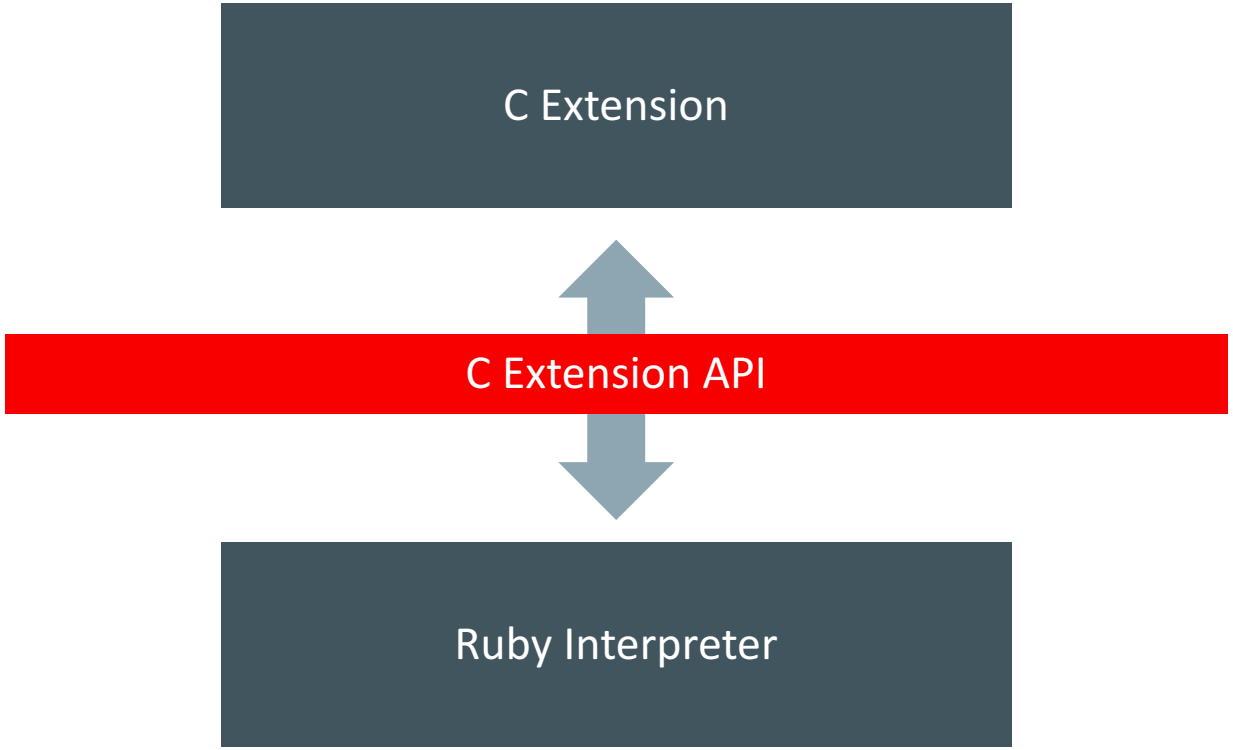
C extensions – the original solution for performance

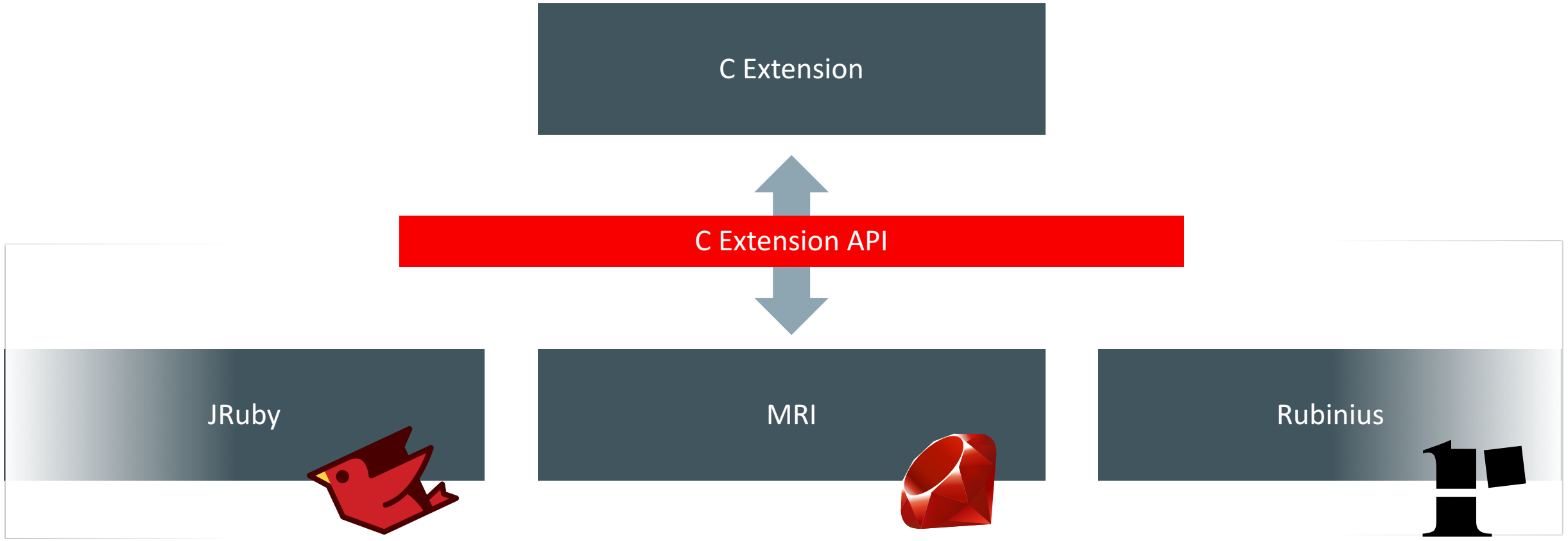


```ruby
def clamp(num, min, max)
  [min, num, max].sort[1]
end
```

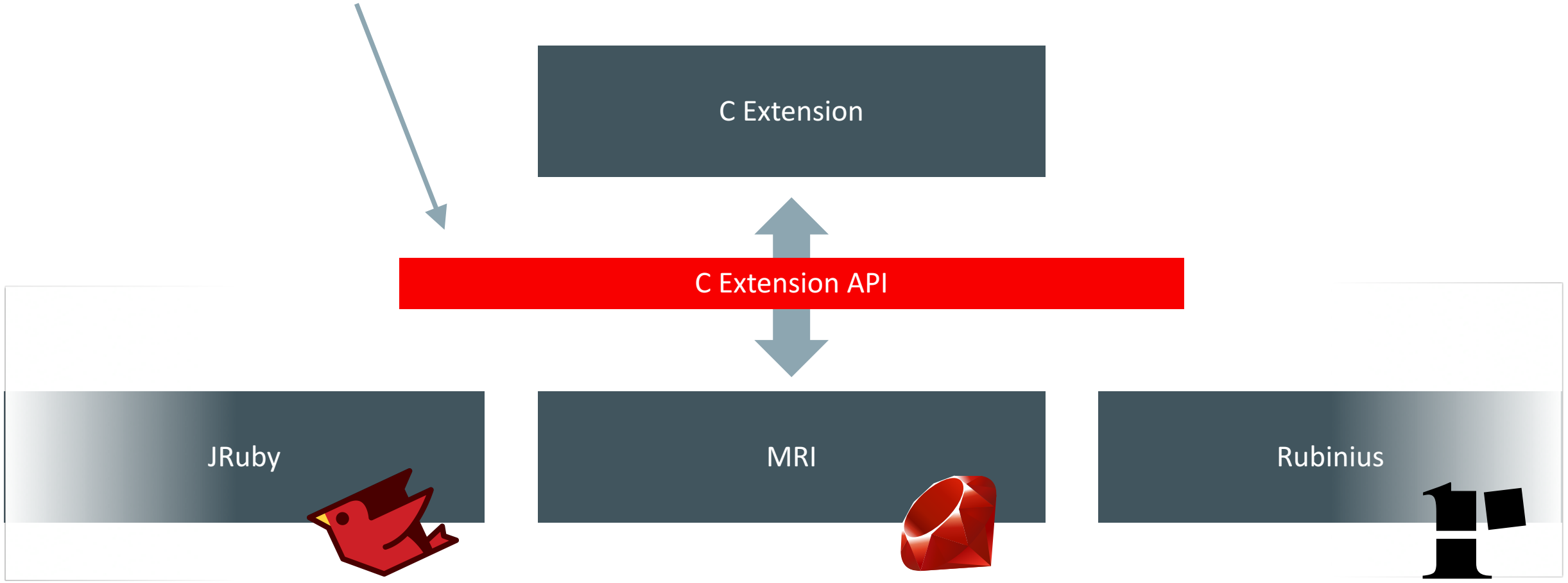
```c
VALUE psd_native_util_clamp(VALUE self,
    VALUE r_num, VALUE r_min, VALUE r_max) {
  int num = FIX2INT(r_num);
  int min = FIX2INT(r_min);
  int max = FIX2INT(r_max);

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

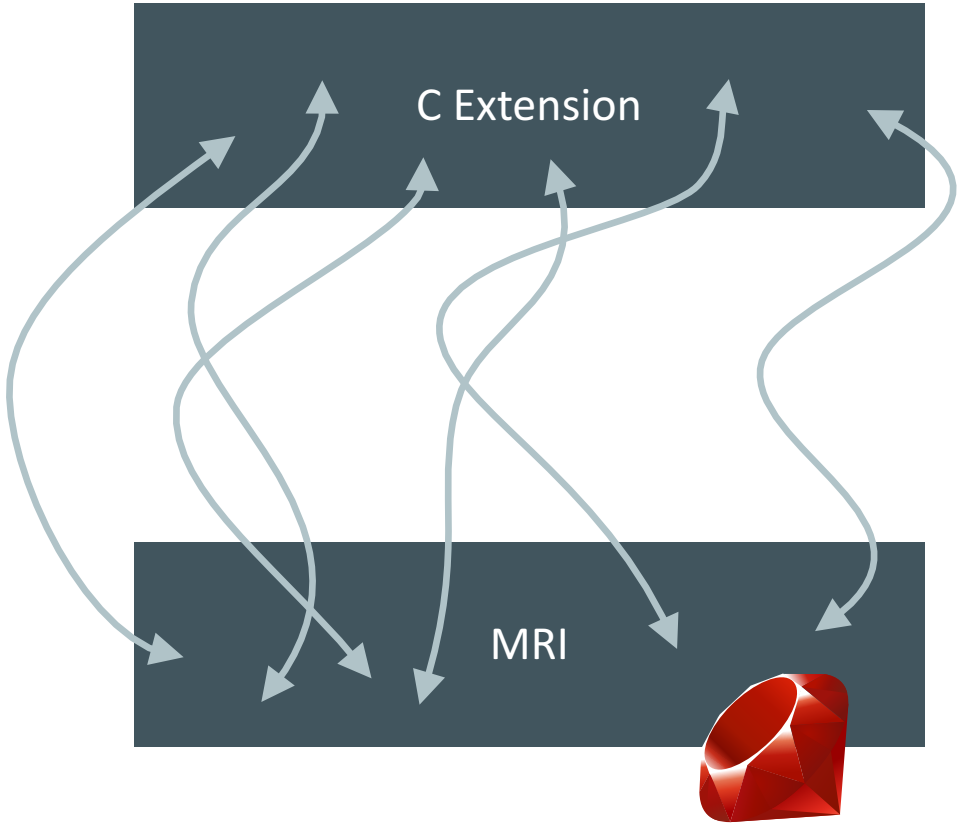
Why C extensions hold us back

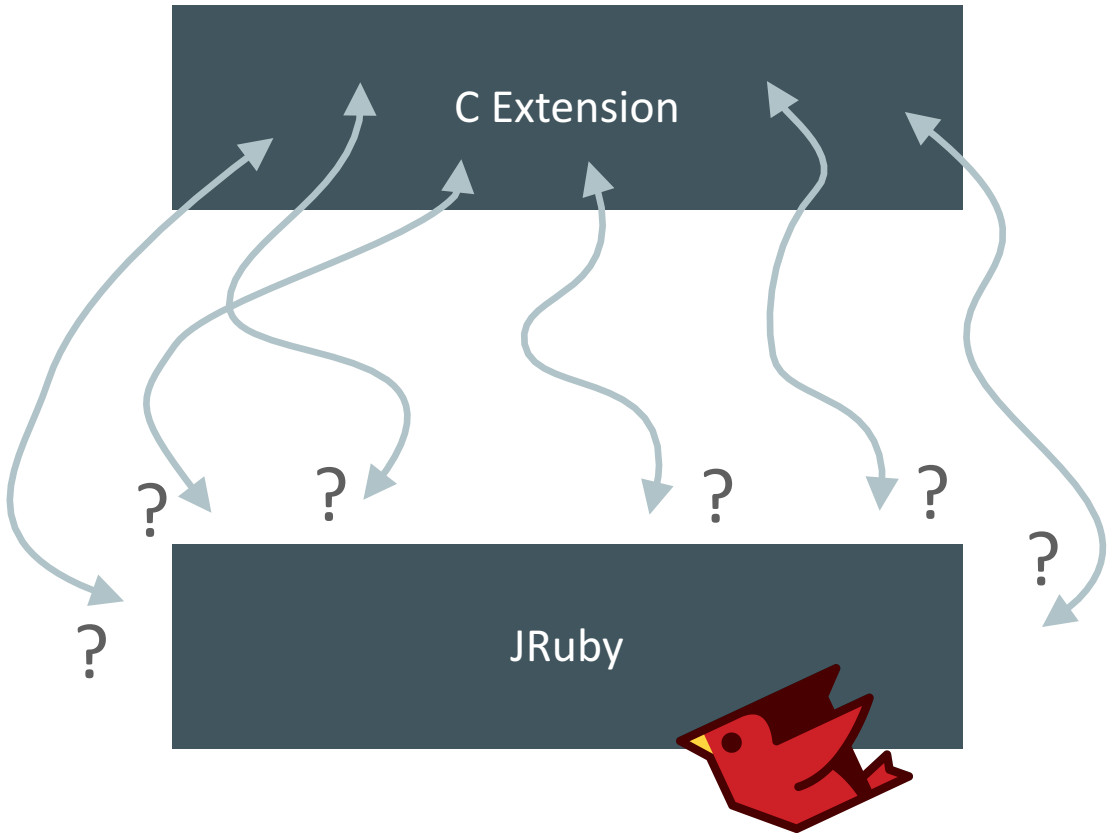


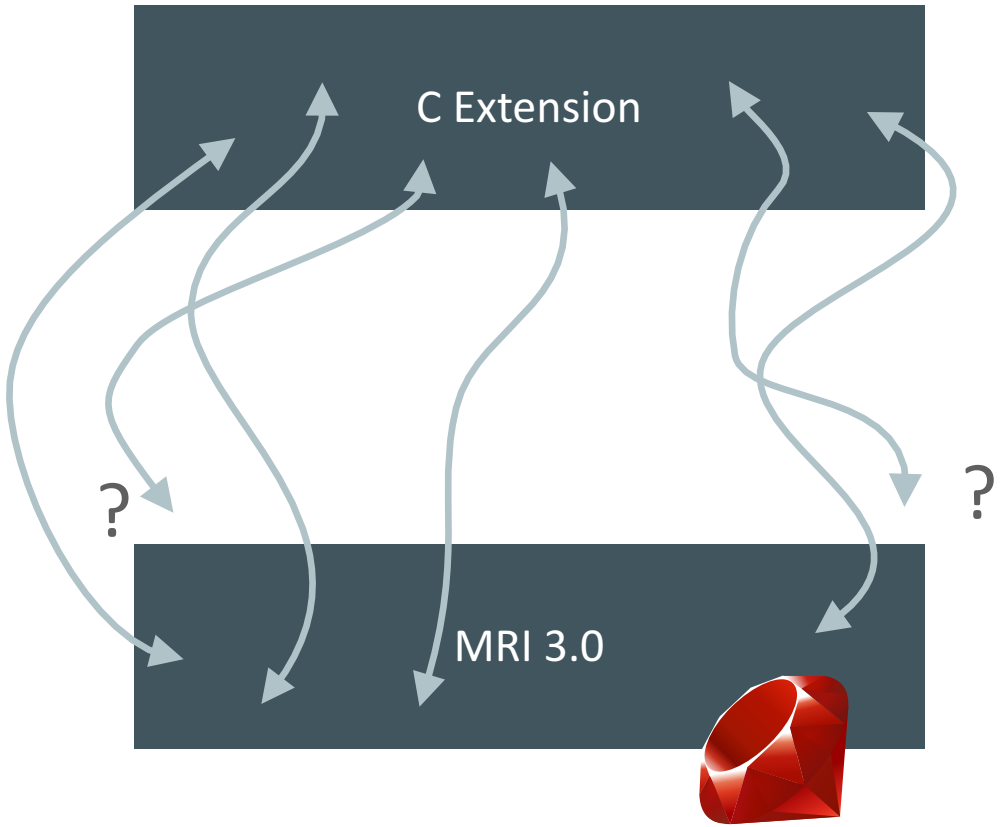


Bad news – this isn't really a thing in practice









String pointers

```
char *RSTRING_PTR(VALUE string);

static VALUE
ossl_dsa_export(int argc, VALUE *argv, VALUE self)
{
    char *passwd;
    ...
    passwd = RSTRING_PTR(pass);
    ...
    PEM_write_bio_DSAPrivateKey(out, pkey->pkey.dsa, ciph,
            NULL, 0, ossl_pem_passwd_cb, passwd)
    ...
}
```

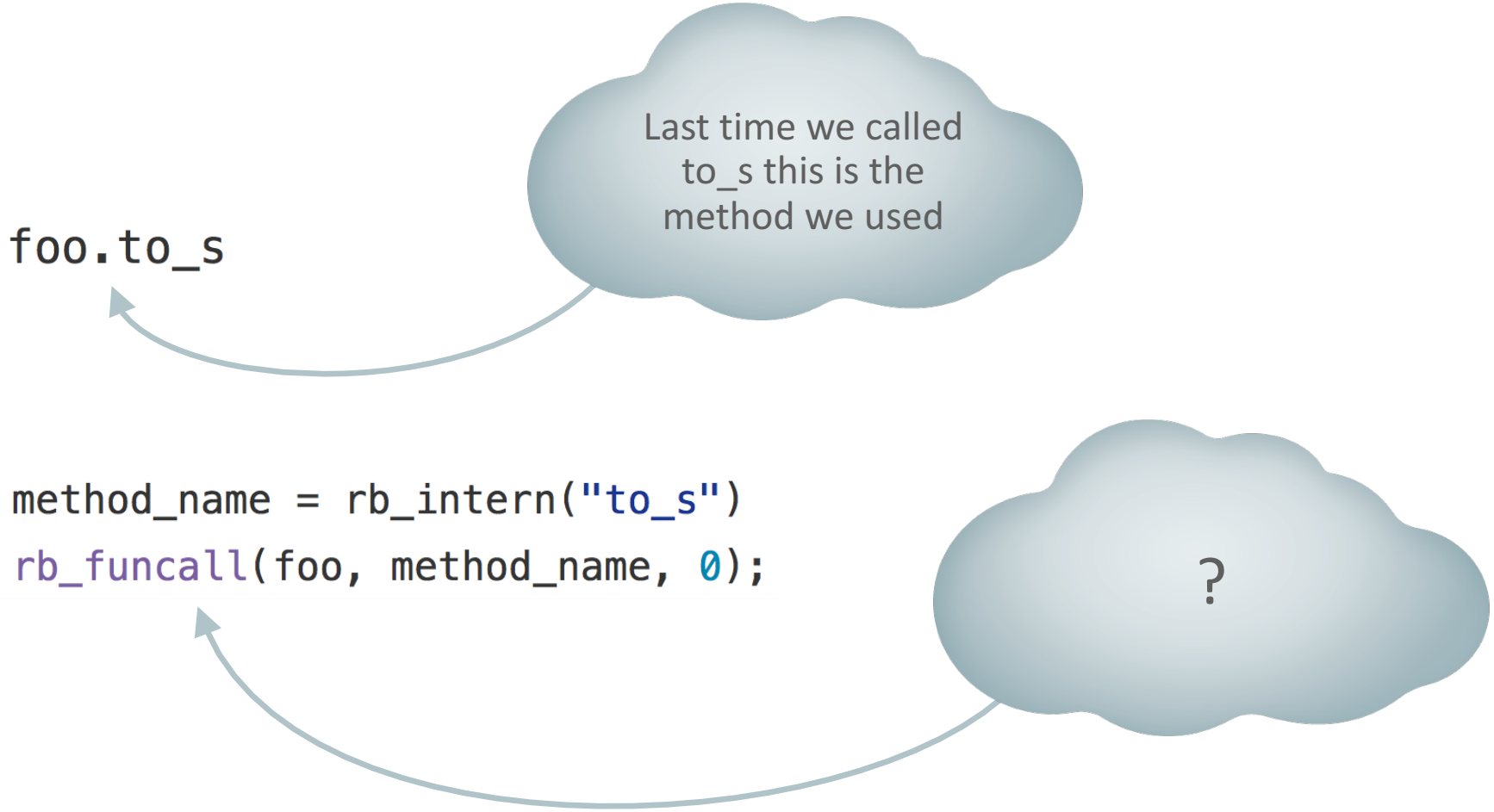
Array pointers

```
VALUE *RARRAY_PTR(VALUE array);

VALUE psd_native_blender_compose_bang(VALUE self) {
  ...
  VALUE bg_pixels = rb_funcall(bg_canvas, rb_intern("pixels"), 0);
  VALUE *bg_pixels_ptr = RARRAY_PTR(bg_pixels);
  ...
  for (i = 0, len = RARRAY_LEN(bg_pixels); i < len; i++) {
    ... bg_pixels_ptr[i] ...
  }
  ...
}
```

Data fields

```
struct RData {
  struct RBasic basic;
  void (*dmark)(void *data);
  void (*dfree)(void *data);
  void *data;
};

#define RDATA(value)    ((struct RData *)value)

#define DATA_PTR(value) (RDATA(value)->data)

static VALUE
ossl_x509req_copy(VALUE self, VALUE other)
{
    ...
    DATA_PTR(self) = X509_REQ_dup(b);
    ...
}
```

Lack of caching when you are in C



The black box

```ruby
def add(a, b)
  a + b
end

add(14, 2)
```

```c
VALUE add(VALUE self, VALUE a, VALUE b) {
  return INT2FIX(FIX2INT(a) + FIX2INT(b));
}

add(14, 2)
```

The black box

```
def add(a, b)
  a + b
end

add(14, 2)
```

= 16

```
VALUE add(VALUE self, VALUE a, VALUE b) {
  return INT2FIX(FIX2INT(a) + FIX2INT(b));
}

add(14, 2)
```

The black box

```
def add(a, b)
  a + b
end

add(14, 2)
```

= ?

```
VALUE add(VALUE self, VALUE a, VALUE b) {
  return INT2FIX(FIX2INT(a) + FIX2INT(b));
}

add(14, 2)
```

Previous solutions to the C extension problem

Denial

- Everyone should use the FFI or Fiddle
  - FFI and Fiddle are two ways to call C functions directly from Ruby
  - 2.1 billion lines of code in RubyGems, 0.5 billion of it is C extension code
  - It might be nice if people used FFI instead of C extensions… but they don't… so little point in continuing to argue about it

```ruby
module MyLib
  extend FFI::Library
  ffi_lib 'c'
  attach_function :sqrt, [ :double ], :double
end
```

Bargaining

- Attempt to implement the C extension API as best as possible, alongside optimisations
- Generally involves a lot of copying
- JRuby used this approach in the past, Rubinius still uses it
  - JRuby only ran 60% of C extensions I tried
  - Rubinius ran 90%
  - Worse: when they didn't work they just ground to a halt, no clear failure point

Bargaining

- Try to improve the C extension API over time
  - The JavaScript (V8) and Java C extension APIs don't have these problems because they have better designed APIs that don't expose internals
  - Steady progress in this direction, has helped
  - But even OpenSSL doesn't use these new methods!

> **Don't touch pointers directly**
>
> In MRI (include/ruby/ruby.h), some macros to acquire pointers to the internal data structures are supported such as RARRAY_PTR(), RSTRUCT_PTR() and so on.
>
> DO NOT USE THESE MACROS and instead use the corresponding C-APIs such as rb_ary_aref(), rb_ary_store() and so on.

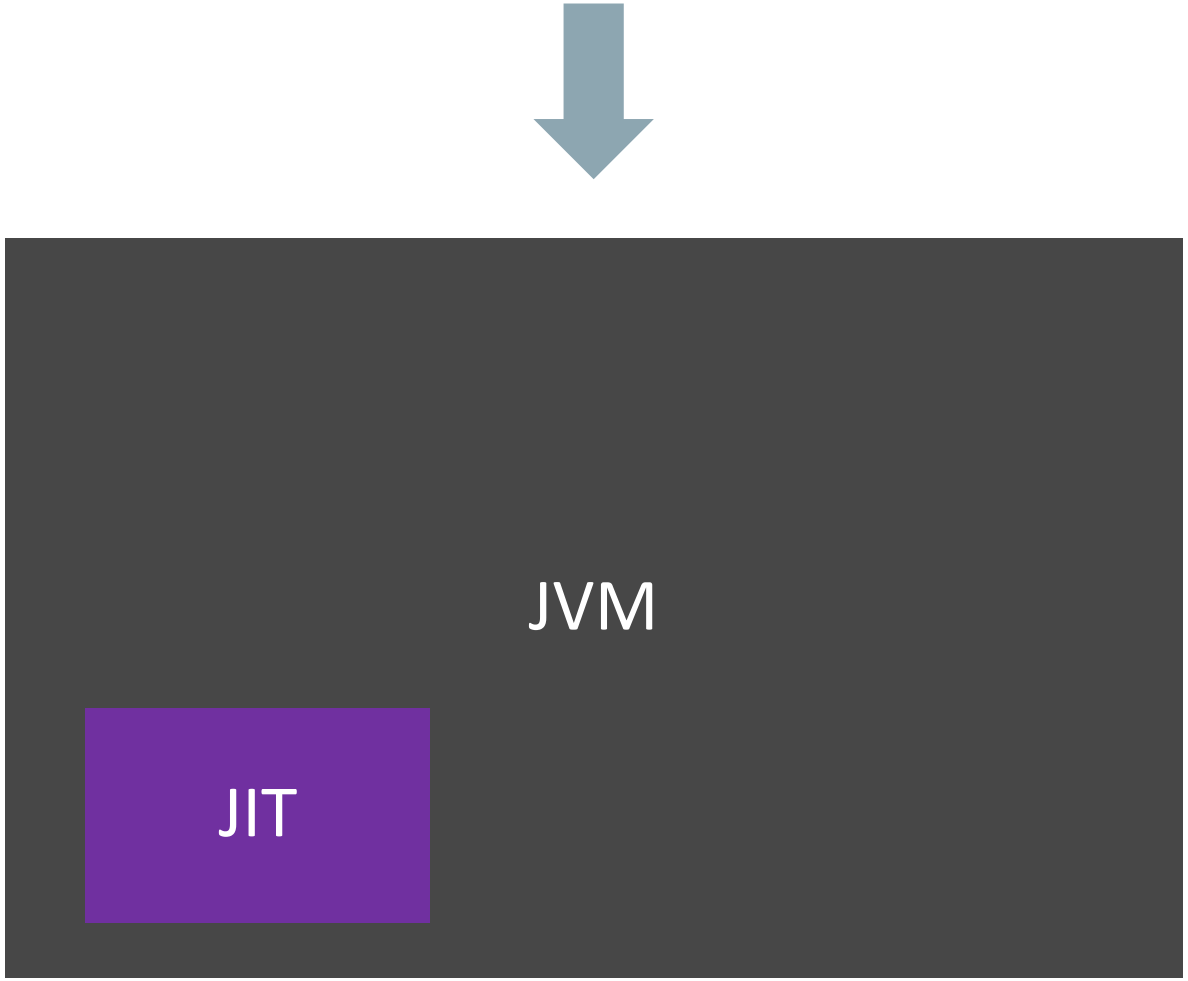
Depression

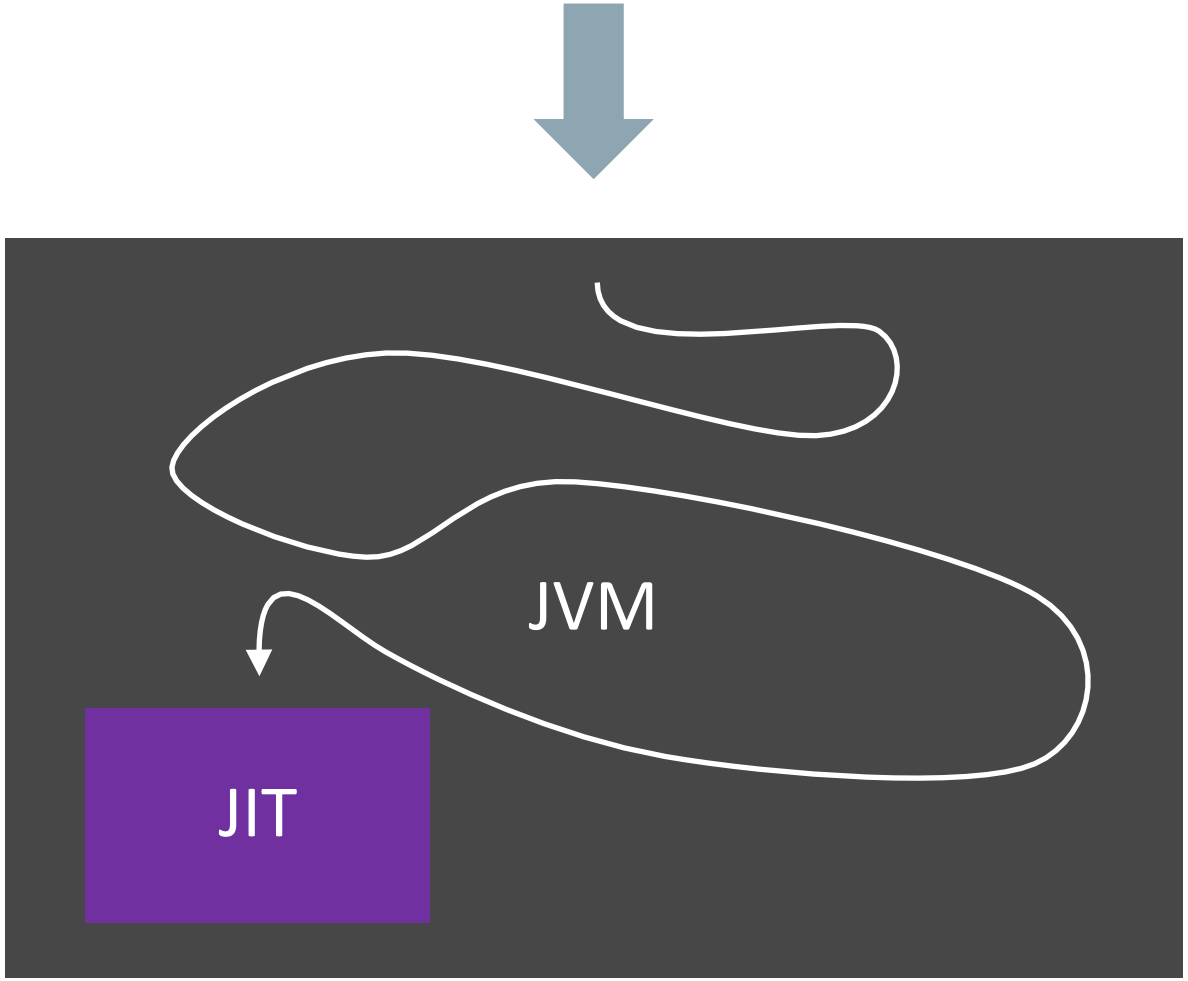
- JRuby unfortunately had to give up on their C extension work
  - They didn't have the resources to maintain it after the original developer moved on
  - Limited compatibility and limited performance
  - In the end, in was removed entirely
  - Maybe it'll return in the future (they could use the same approach as us)

Acceptance

- JRuby encourage Java extensions instead of C extensions
- Try to optimise Ruby while keeping most of the internals the same
  - IBM's OMR adds a new GC and JIT to Ruby while keeping support for C extensions
  - The techniques they can use are therefore limited
  - And so performance increases expected from OMR are more modest

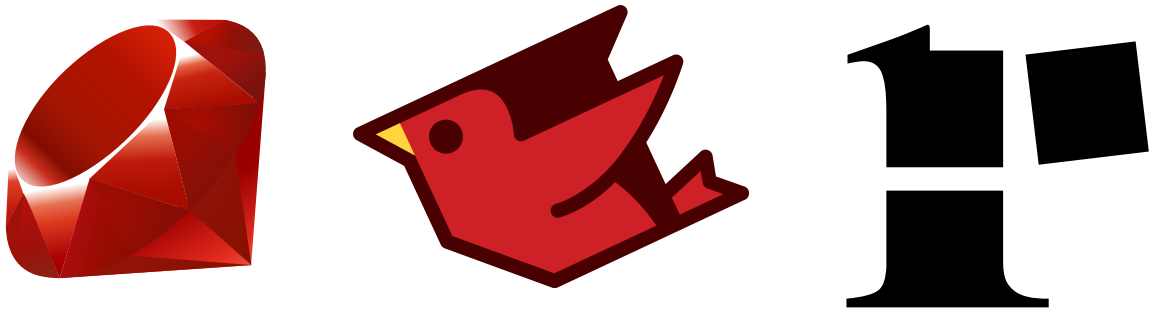
Interlude: JRuby+Truffle





Graal

JVM

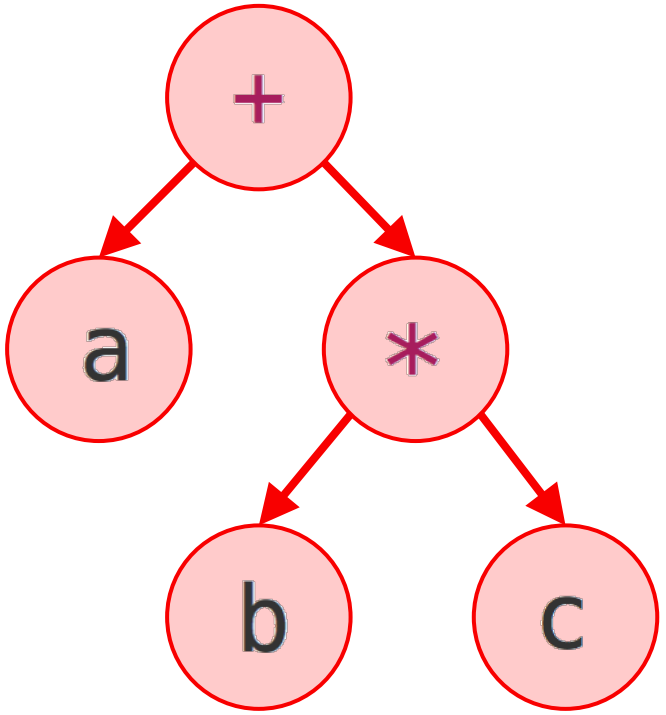


Truffle

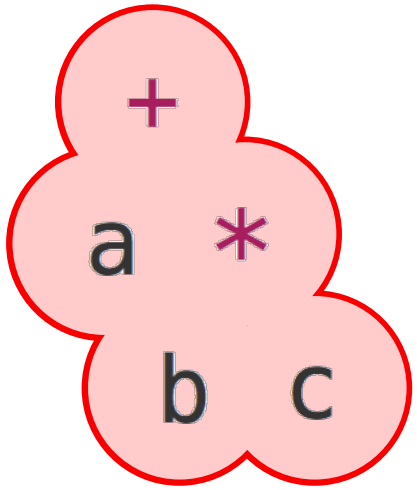
Graal VM

JVM

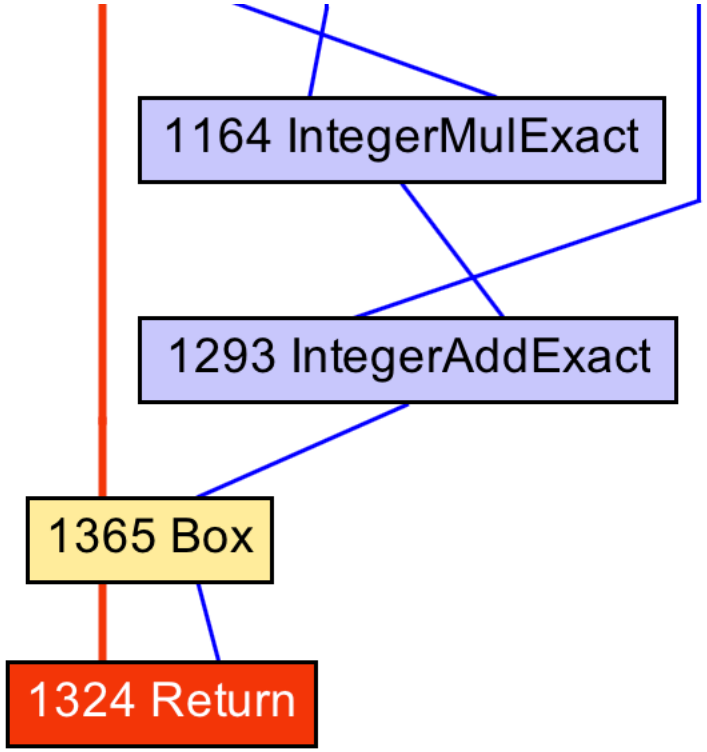
a + b * c



a + b * c



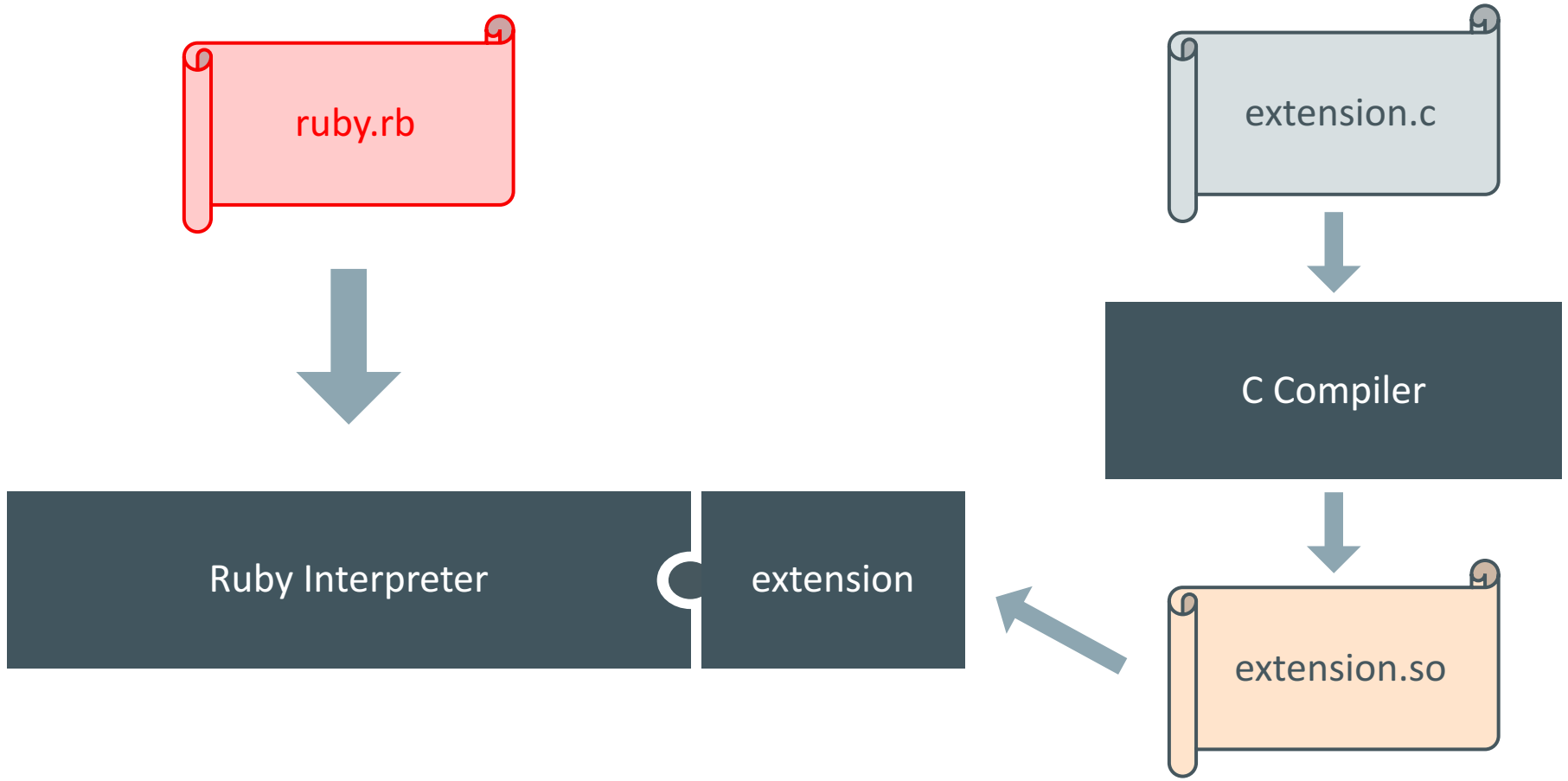
a + b * c

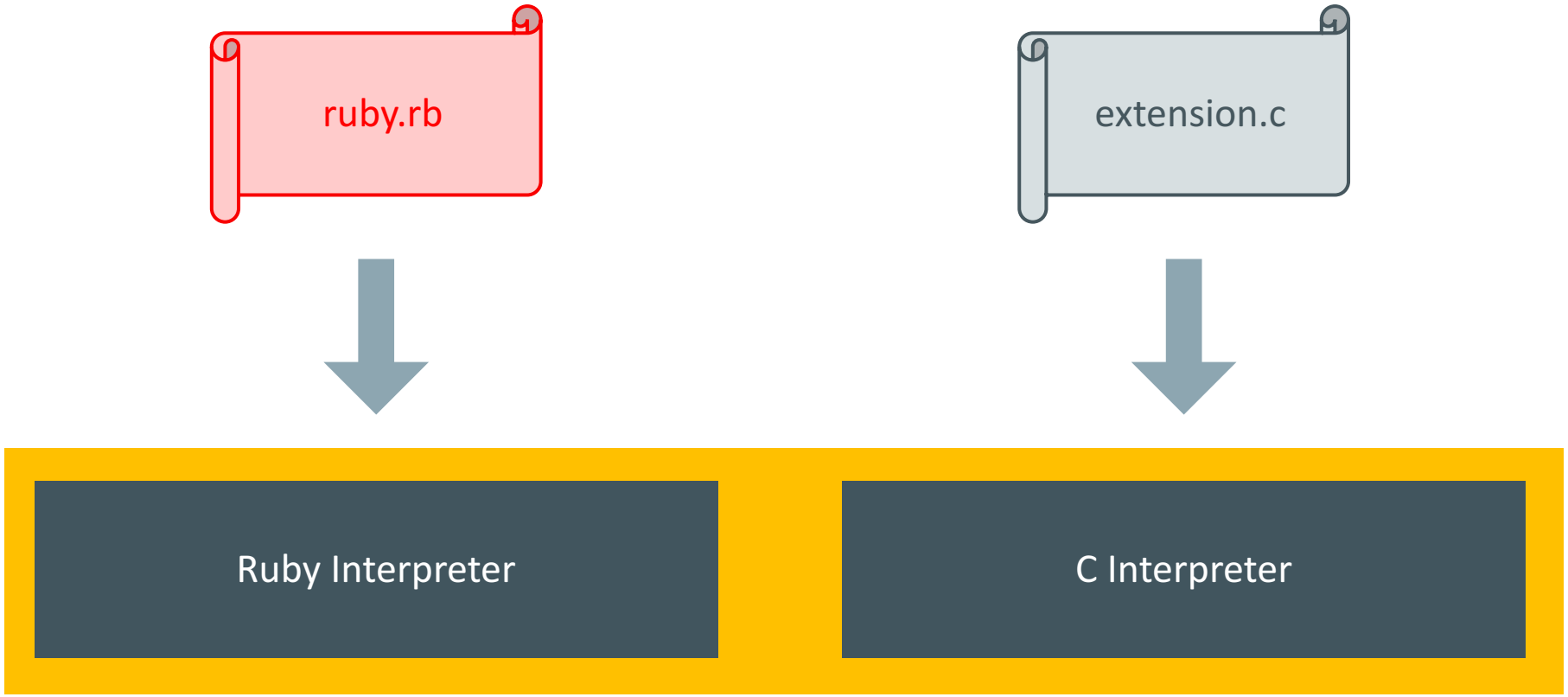


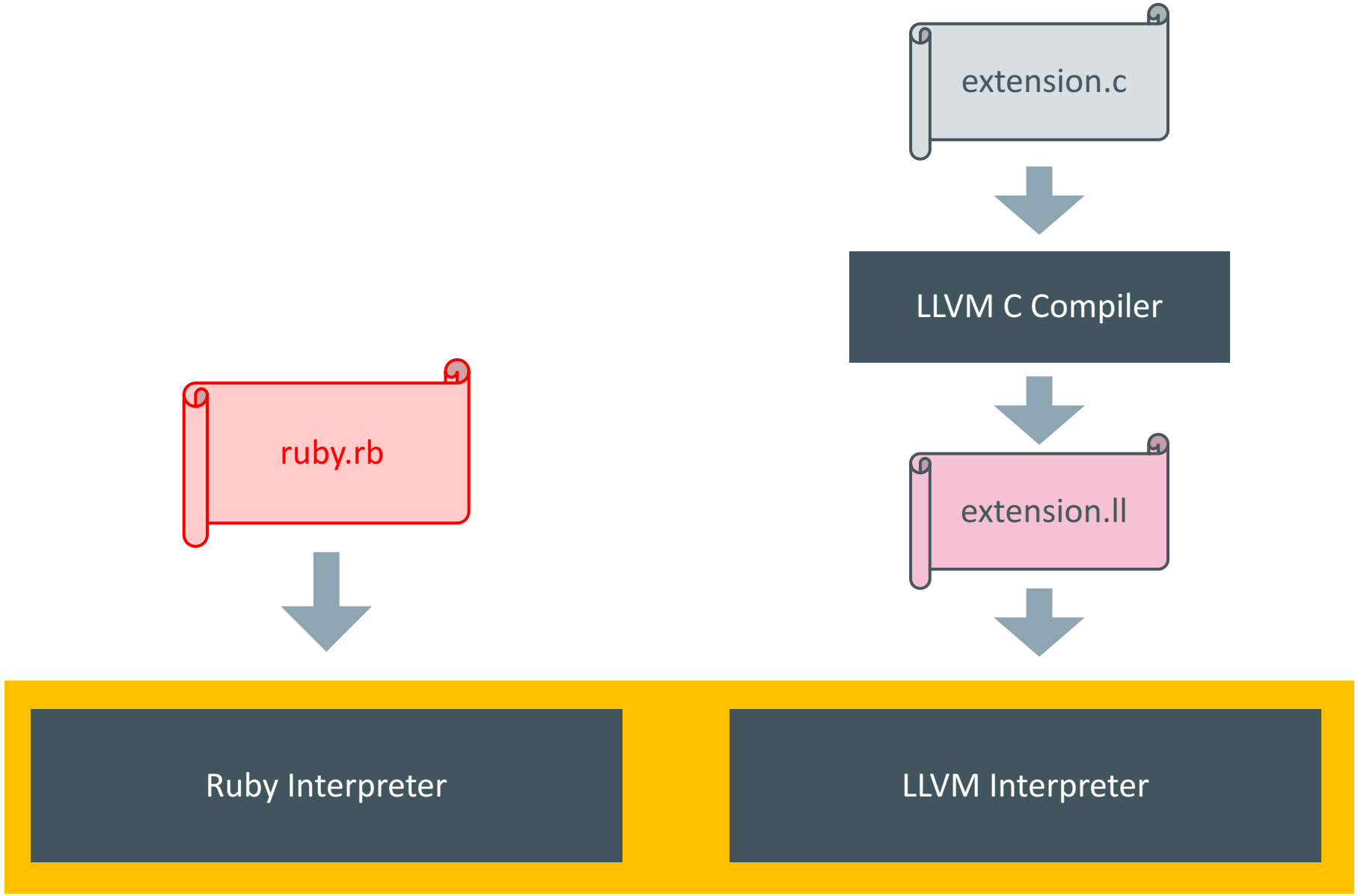
a + b * c

```
imul    %rsi,%rdx
jo      0x00000001171a3fa5
add     %rdi,%rdx
jo      0x00000001171a3fc7
```

Our radical new solution for C extensions…







```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);
}
```

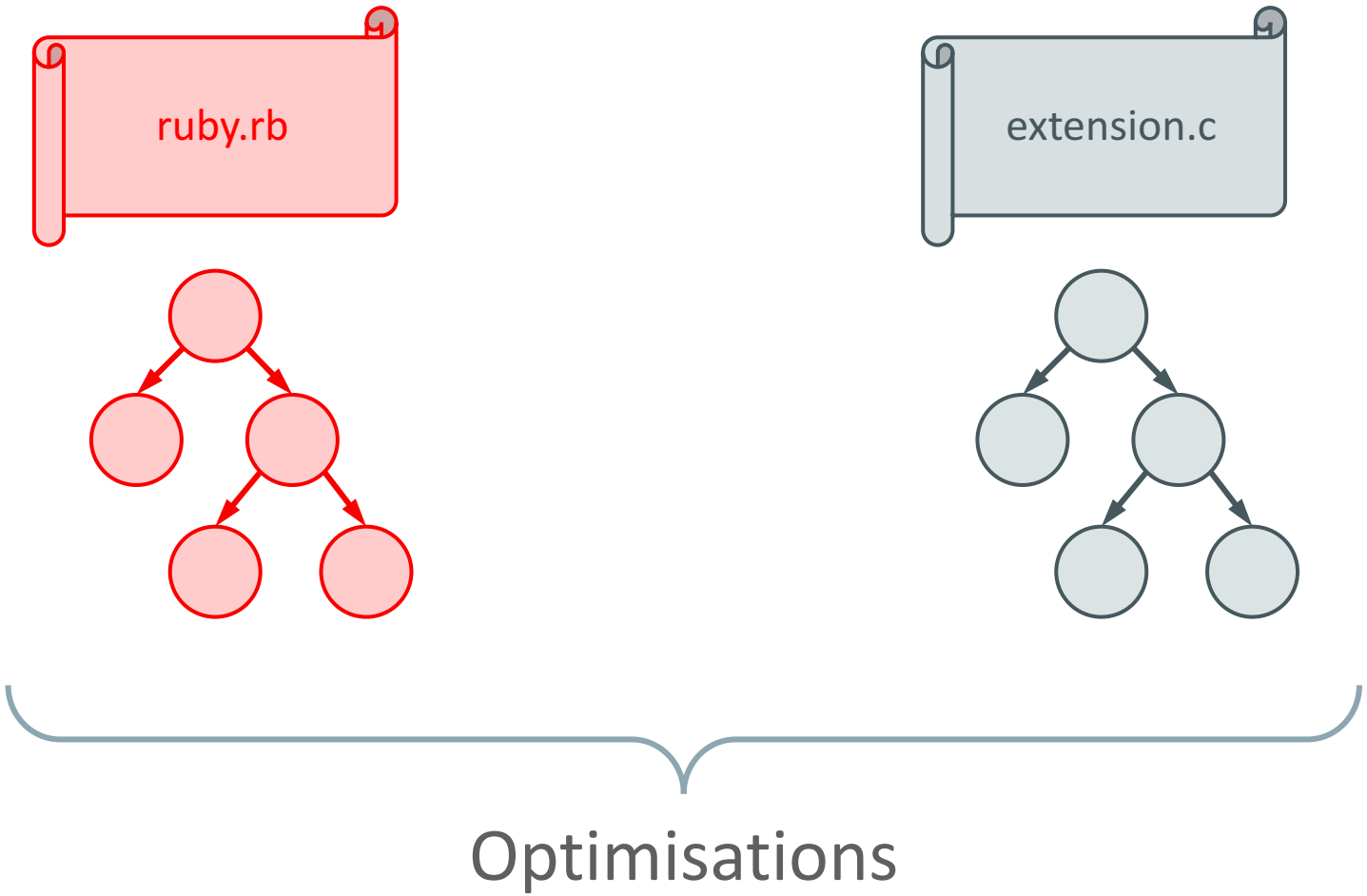
```
define i8* @psd_native_util_clamp(i8* %self,
    i8* %r_num, i8* %r_min, i8* %r_max) nounwind uwtable ssp {
  %1 = call i32 @FIX2INT(i8* %r_num)
  %2 = call i32 @FIX2INT(i8* %r_min)
  %3 = call i32 @FIX2INT(i8* %r_max)
  %4 = icmp sgt i32 %1, %3
  br i1 %4, label %5, label %6
; <label>:5                                       ; 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
}
```

```
  %4 = icmp sgt i32 %1, %3
  br i1 %4, label %5, label %6
; <label>:5
  br label %12
; <label>:6
  %7 = icmp slt i32 %1, %2
  br i1 %7, label %8, label %9
```

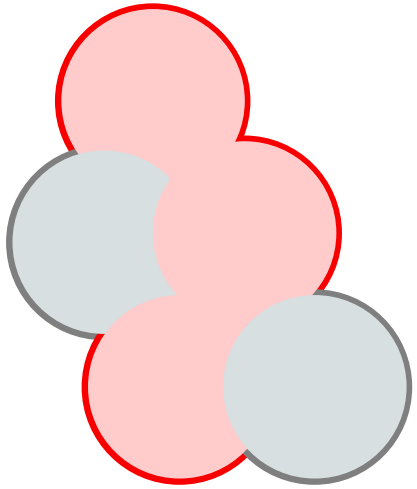
```
  %4 = icmp sgt i32 %1, %3
  br i1 %4, label %5, label %6
; <label>:5
  br label %12
; <label>:6
  %7 = icmp slt i32 %1, %2
  br i1 %7, label %8, label %9
```

```
    t4 = t1 > t3
    if t4
      goto l5
    else
      goto l6
    end
l5: goto l12
l6: t7 = t1 < t2
    if t7
      goto l8
    else
      goto l9
    end
```

Optimise Ruby and C together



Optimise Ruby and C together



Optimisations

Interesting problems and their solutions

Defining the C extension API in Ruby

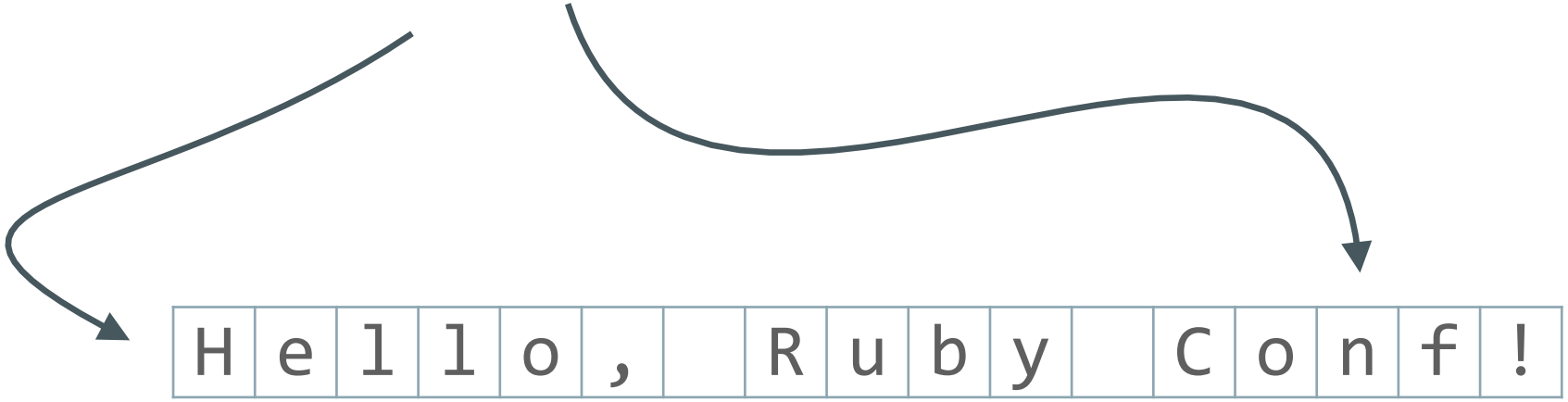
```
int FIX2INT(VALUE value);
```

```
int FIX2INT(VALUE value) {
  return truffle_invoke_i(RUBY_CEXT, "FIX2INT", value);
}
```

```
module Truffle::CExt

  def rb_fix2int(value)
    if value.nil?
      raise TypeError
    else
      int = value.to_int
      raise RangeError if int >= 2**32
      int
    end
  end

end
```

Imaginary strings

```
char *chars = RSTRING_PTR(my_string);
chars[14]
```



Imaginary strings

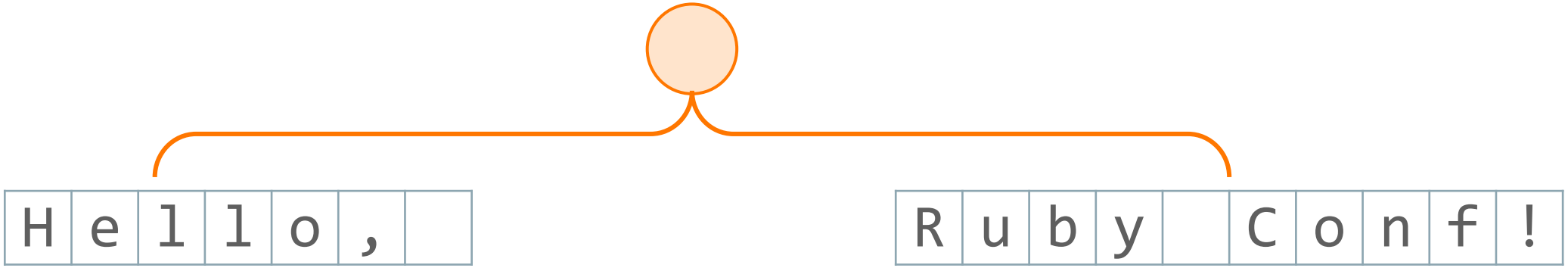
A Tale of Two String Representations

Kevin Menard - RubyKaigi 2016

Imaginary strings

```
%1 = call @RSTRING_PTR(%my_string)
%2 = getelementptr %14, 14
```

```
char *chars = RSTRING_PTR(my_string);
chars[14]
```

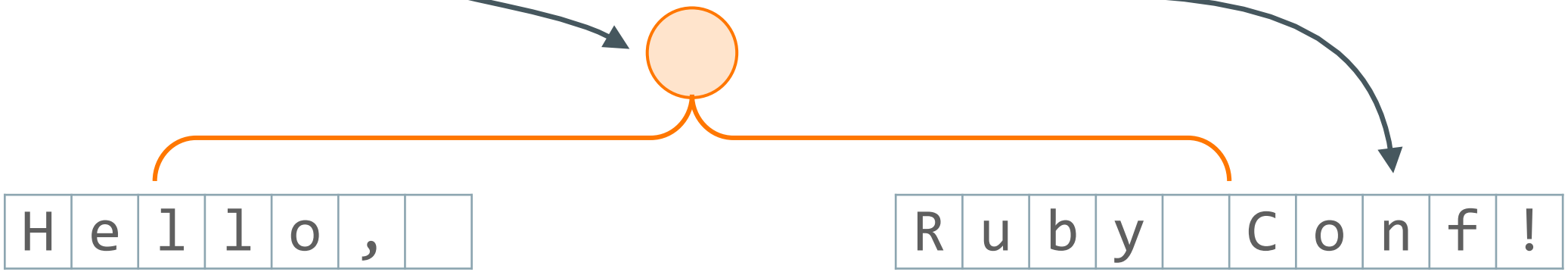


Imaginary strings

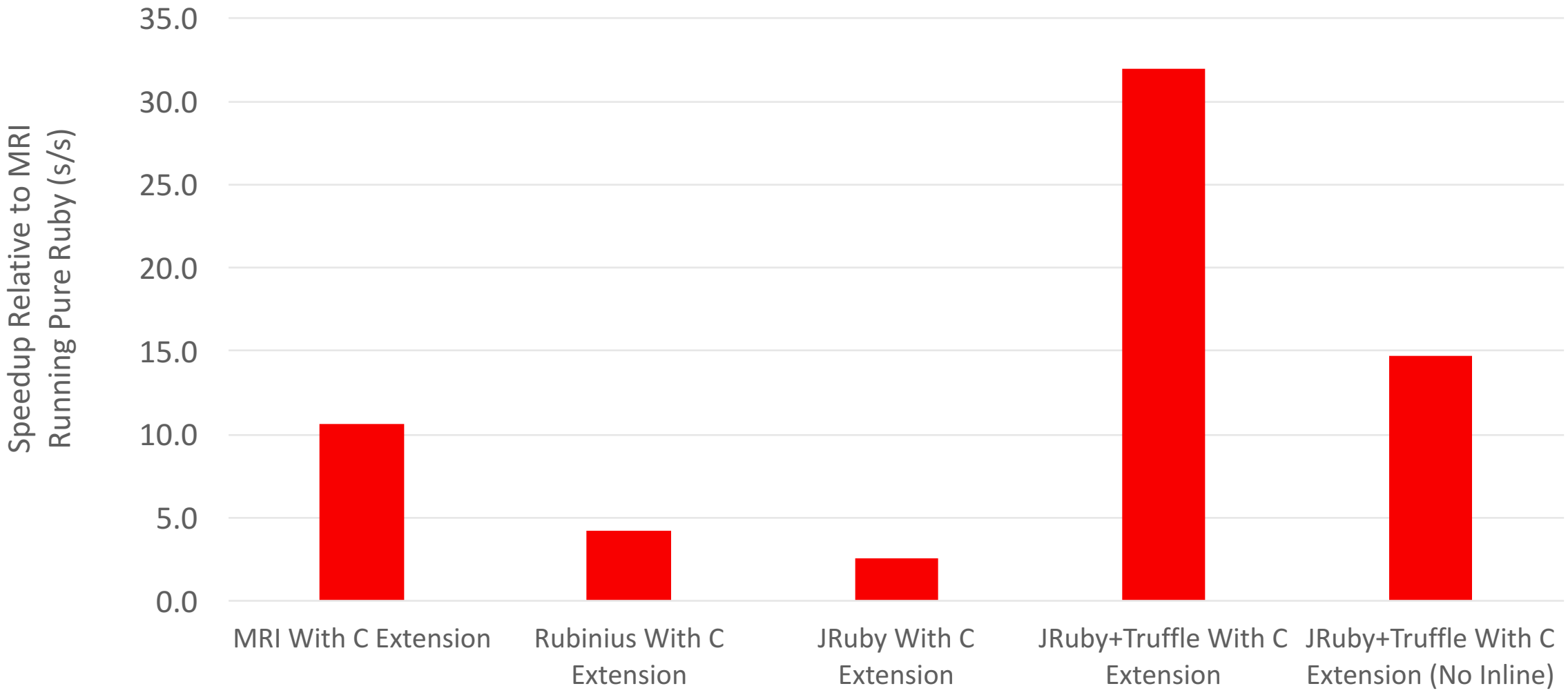
```
%1 = call @RSTRING_PTR(%my_string)
%2 = getelementptr %14, 14
```

String#[]

```
char *chars = RSTRING_PTR(my_string);
chars[14]
```



Results

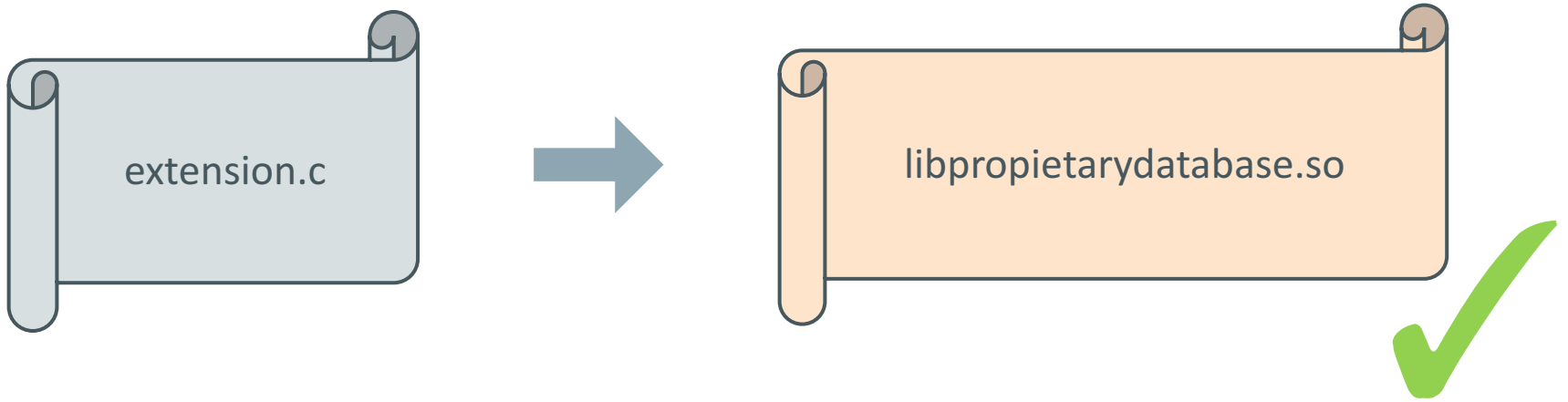


Matthias Grimmer, Chris Seaton, Thomas Wuerthinger, Hanspeter Moessenboeck:
Dynamically Composing Languages in a Modular Way: Supporting C Extensions for Dynamic Languages
Modularity '14 Proceedings of the 14th International Conference on Modularity

Some limitations

You do need the source code of the C extension

- Means no closed source C extensions
  - Is this a problem in reality for anyone?
  - I'm not aware of any closed source C extensions
  - C extensions in turn using closed source libraries like database drivers is fine



You can’t store pointers to Ruby objects in native code

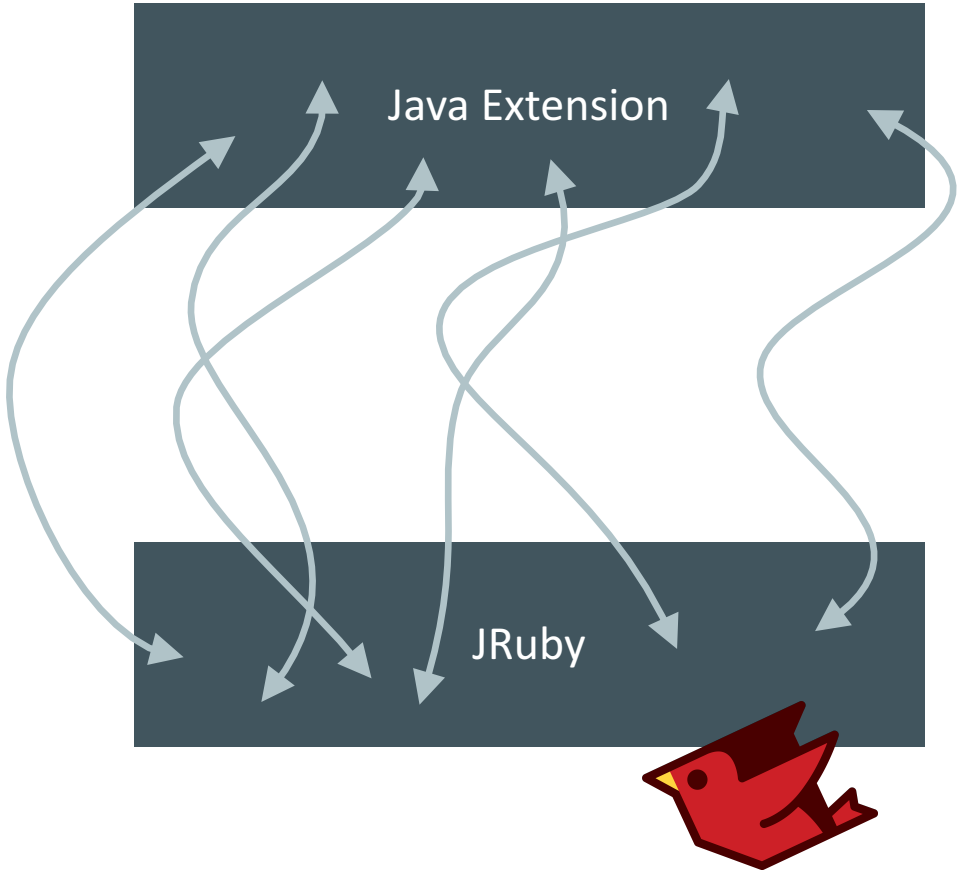
- If your C extension uses a compiled library, such as libssl.so
  - You can’t give that compiled library a reference to a Ruby object
  - The Ruby object may not really exist
  - The GC may want to move the object

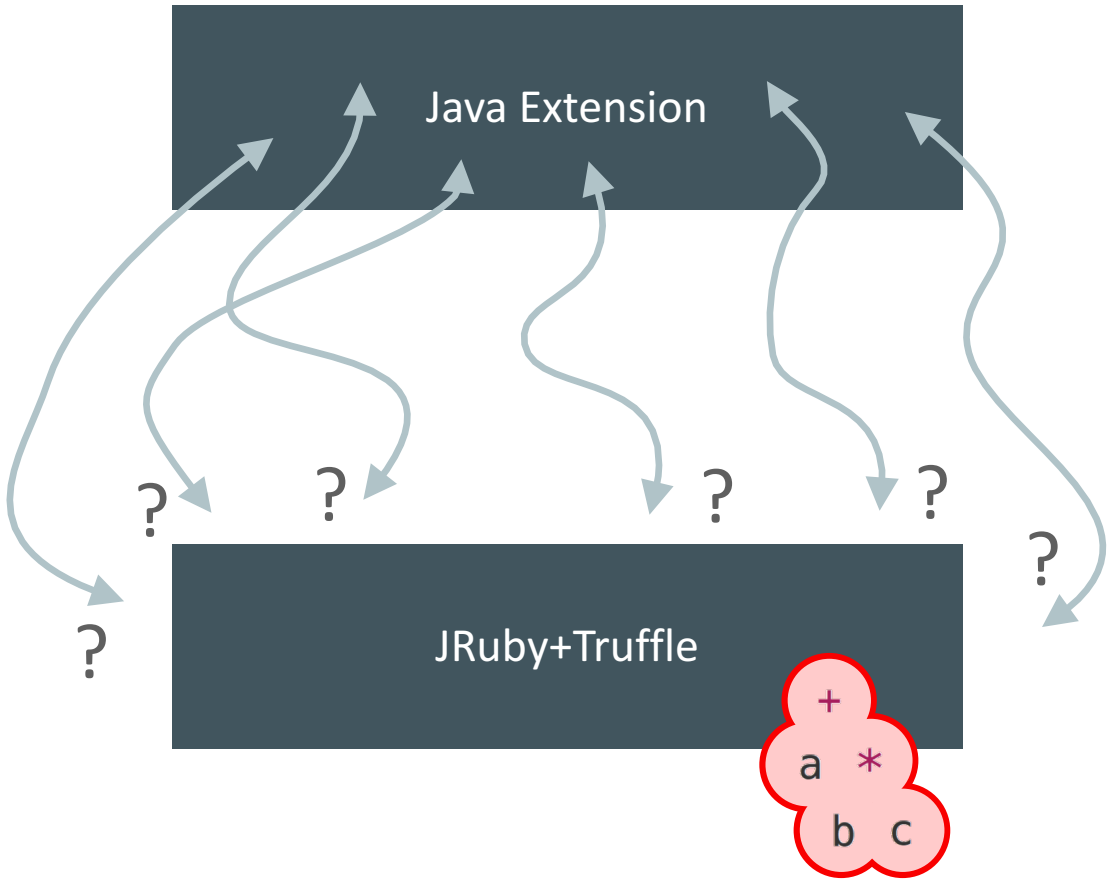
```
void *rb_jt_to_native_handle(VALUE managed);
VALUE rb_jt_from_native_handle(void *native);

SSL_CTX_set_ex_data(ctx, ossl_ssl_ex_ptr_idx, obj);

SSL_CTX_set_ex_data(ctx, ossl_ssl_ex_ptr_idx, rb_jt_to_native_handle(obj));
```

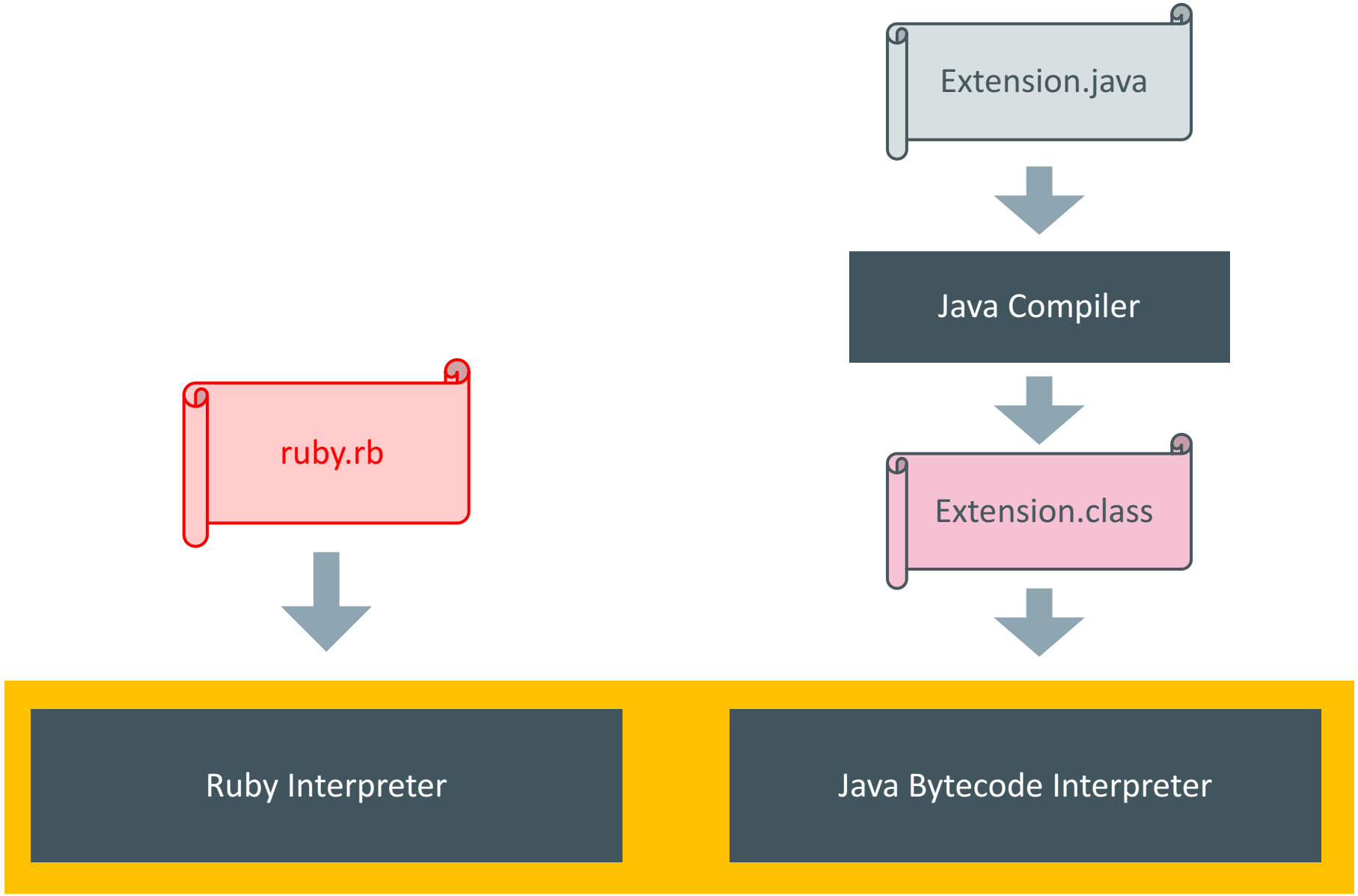
By the way…

- It is probably still best to use the FFI if you are writing new extensions
  - Wide support across Ruby implementations
  - Although we don't actually implement the FFI in JRuby+Truffle yet
  - Implementing the FFI in JRuby+Truffle would be a great internship project!
- If you do write a C extension for performance
  - Write a pure Ruby baseline version as well
- Or if you just needed better performance:
  - Write pure Ruby code
  - Run with JRuby+Truffle

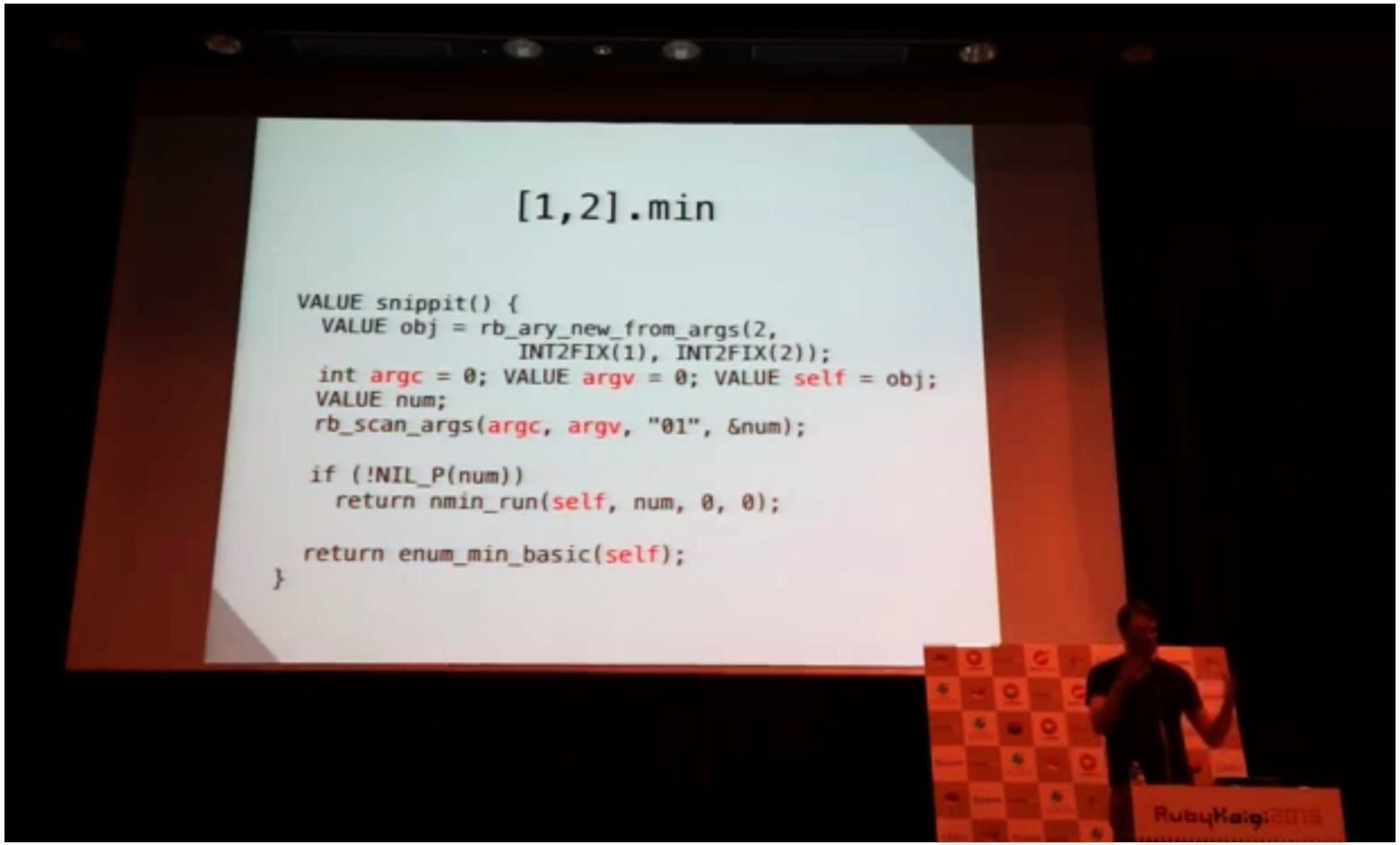
Java extensions







This could be a direction for MRI as well

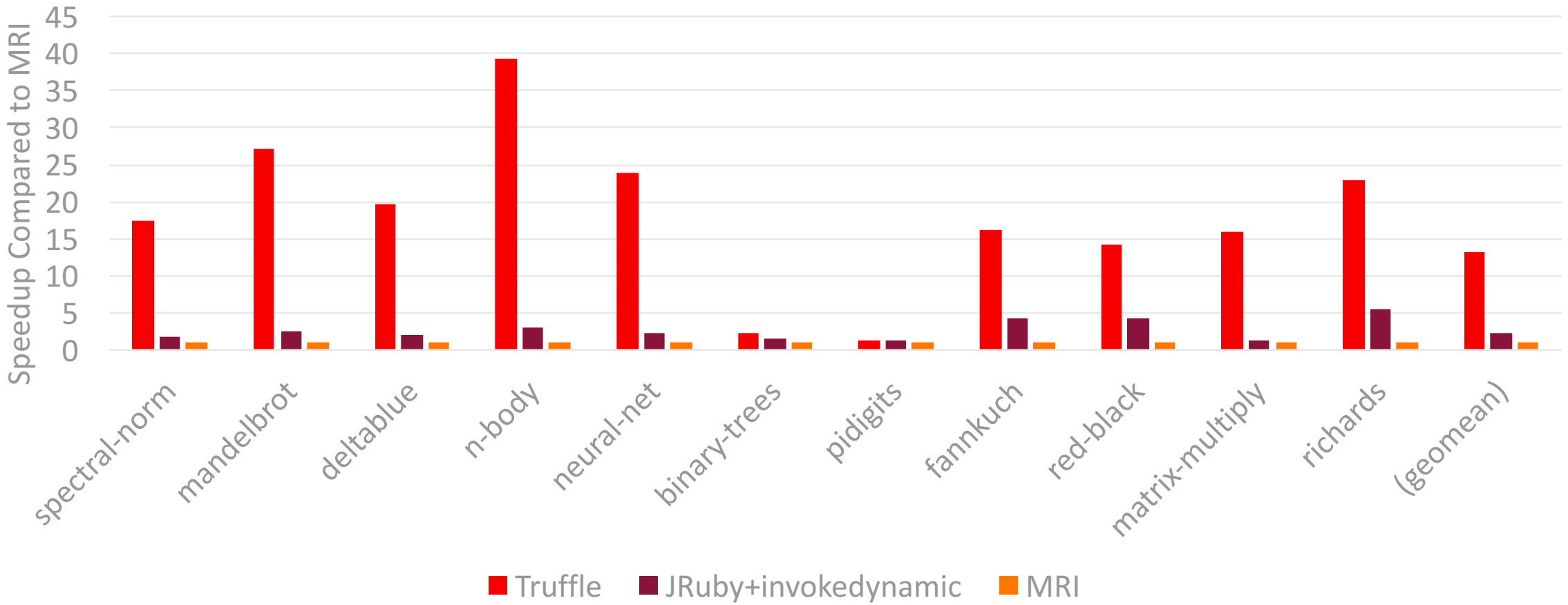


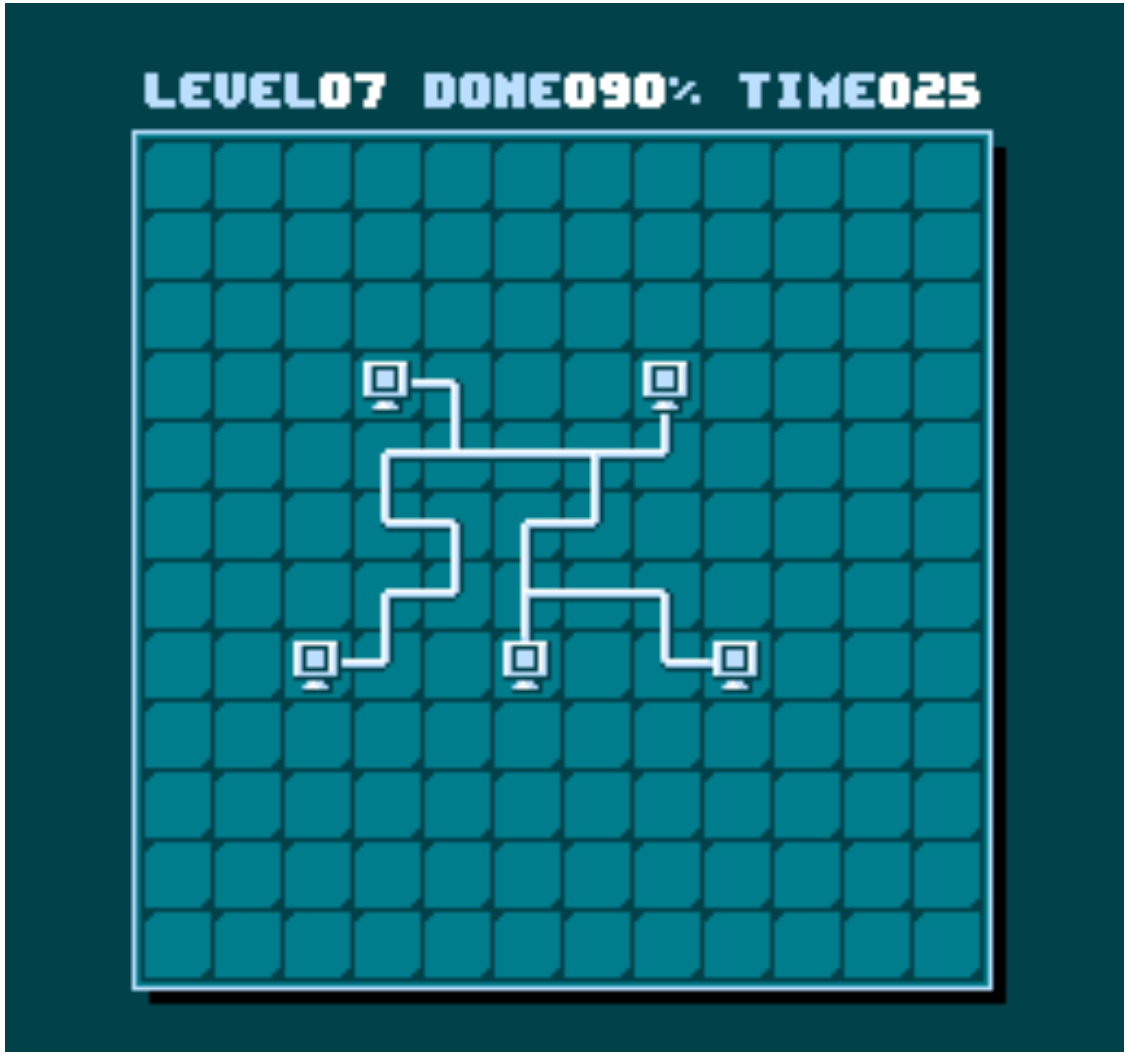
Evan Phoenix: store the LLVM IR of the MRI implementation code and JIT it

Ruby: 2020 - RubyKaigi 2015 Keynote

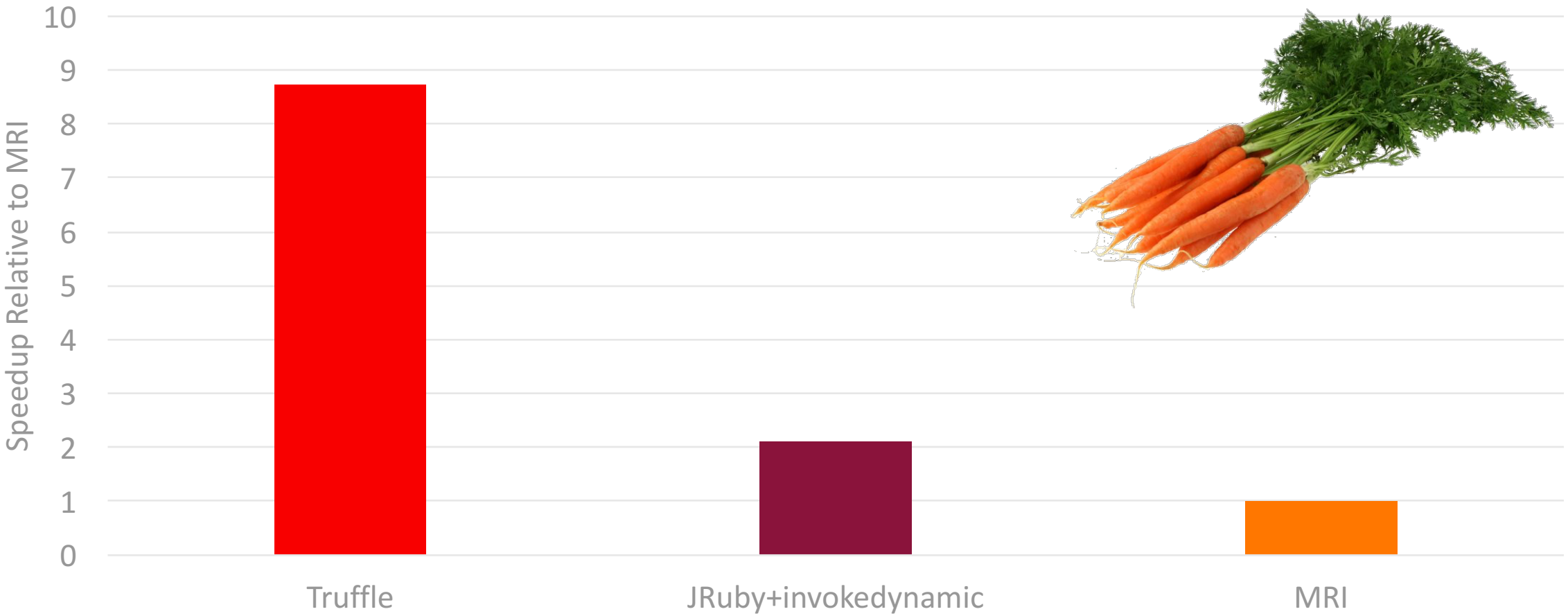
A quick status update on JRuby+Truffle

Classic research benchmarks – 10-20x faster than MRI





‘optcarrot’ NES emulator benchmark – 9x faster than MRI



Ruby specs

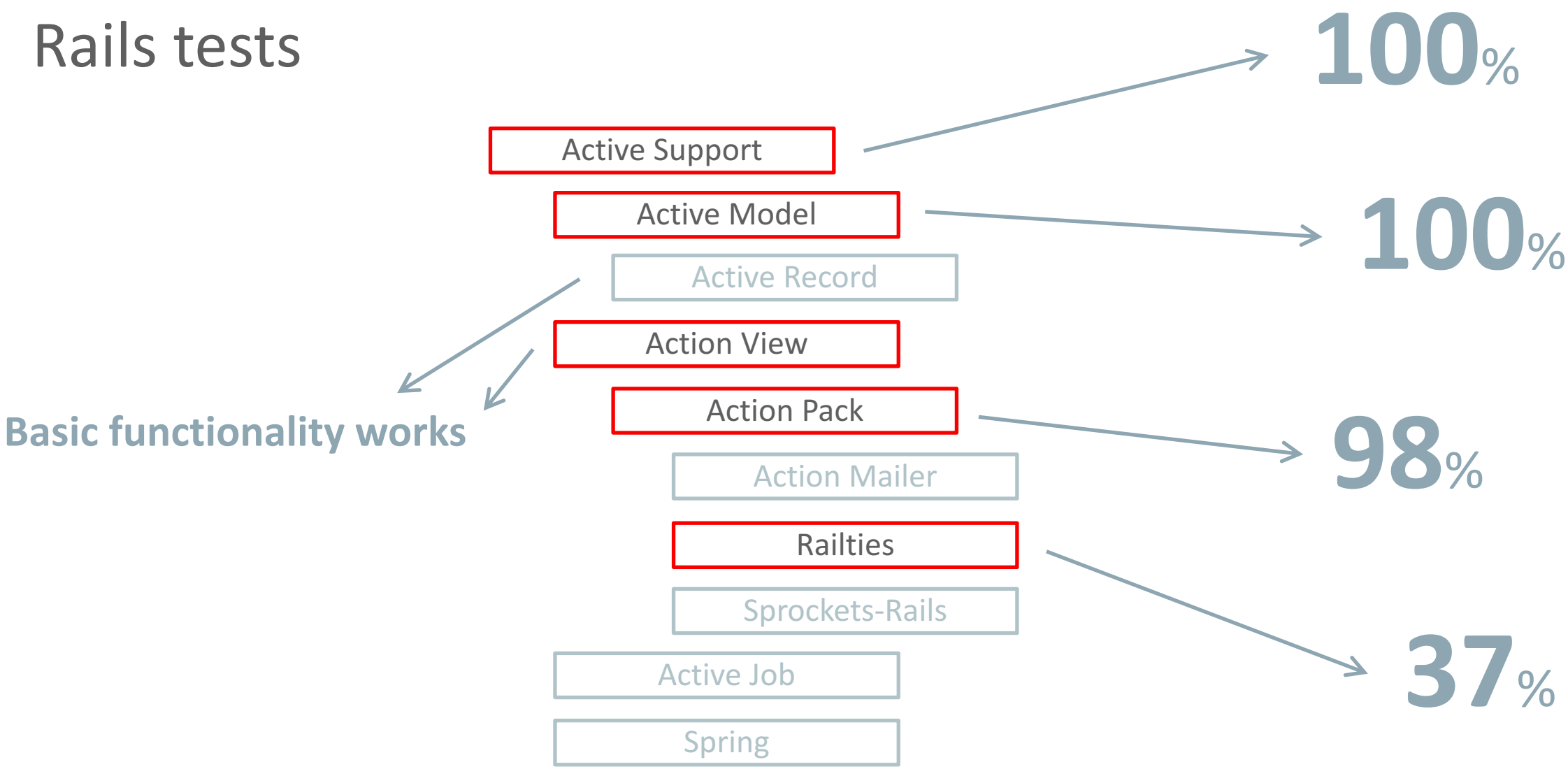
99% Language specs

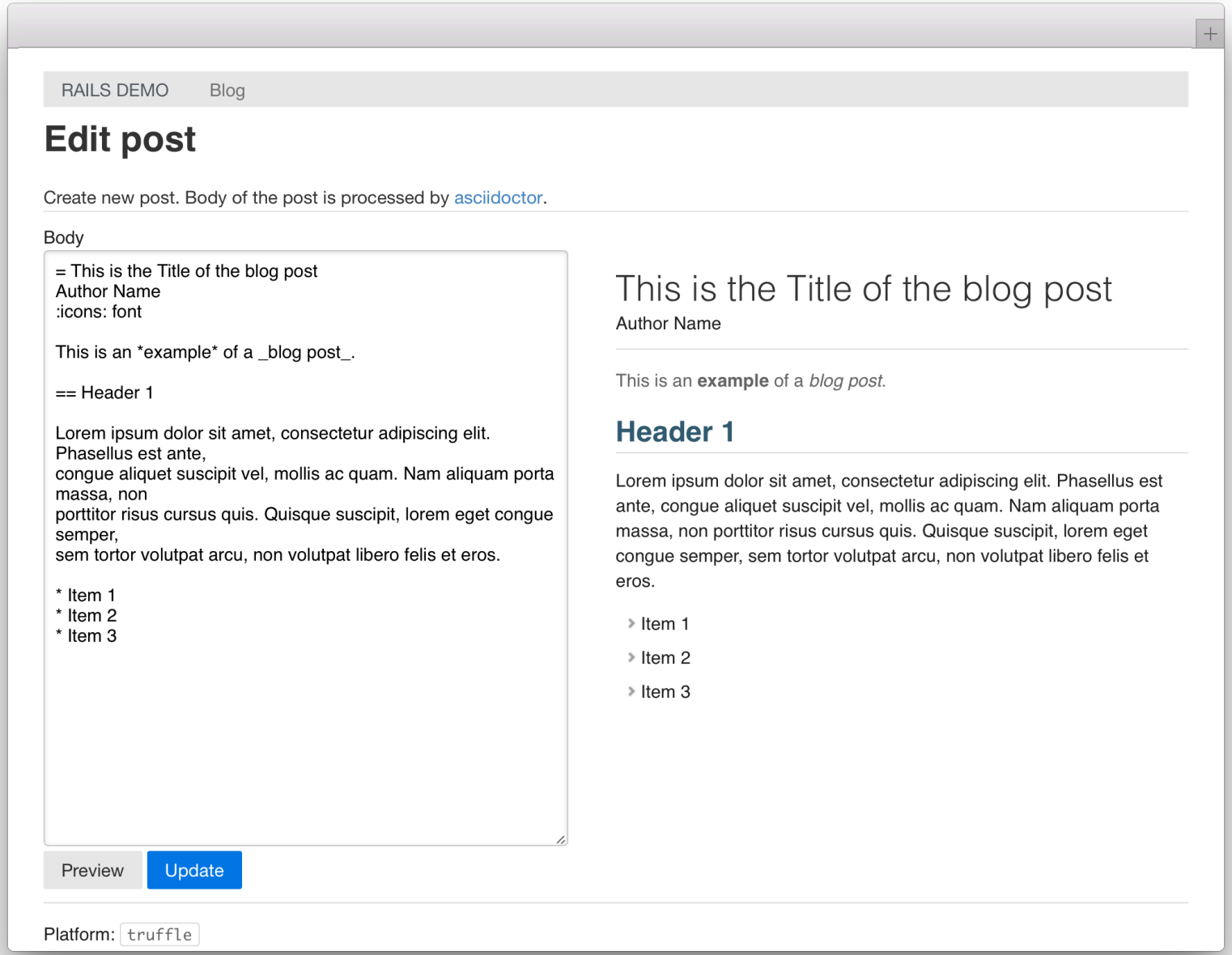
96% Core library specs

78% Standard library specs*

coverage is very limited here; probably a bit misleading

Rails tests

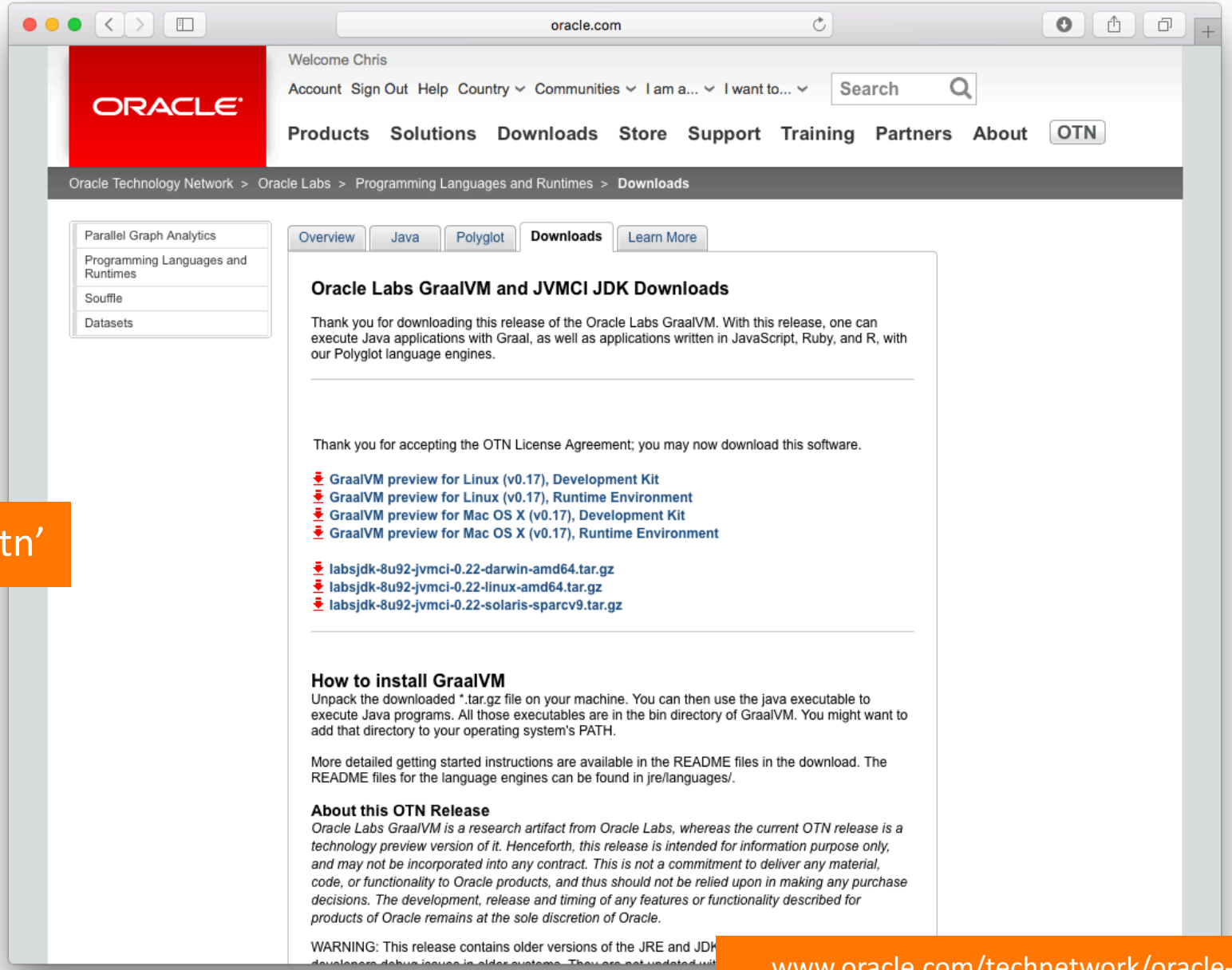




So then why can’t we run real applications yet?

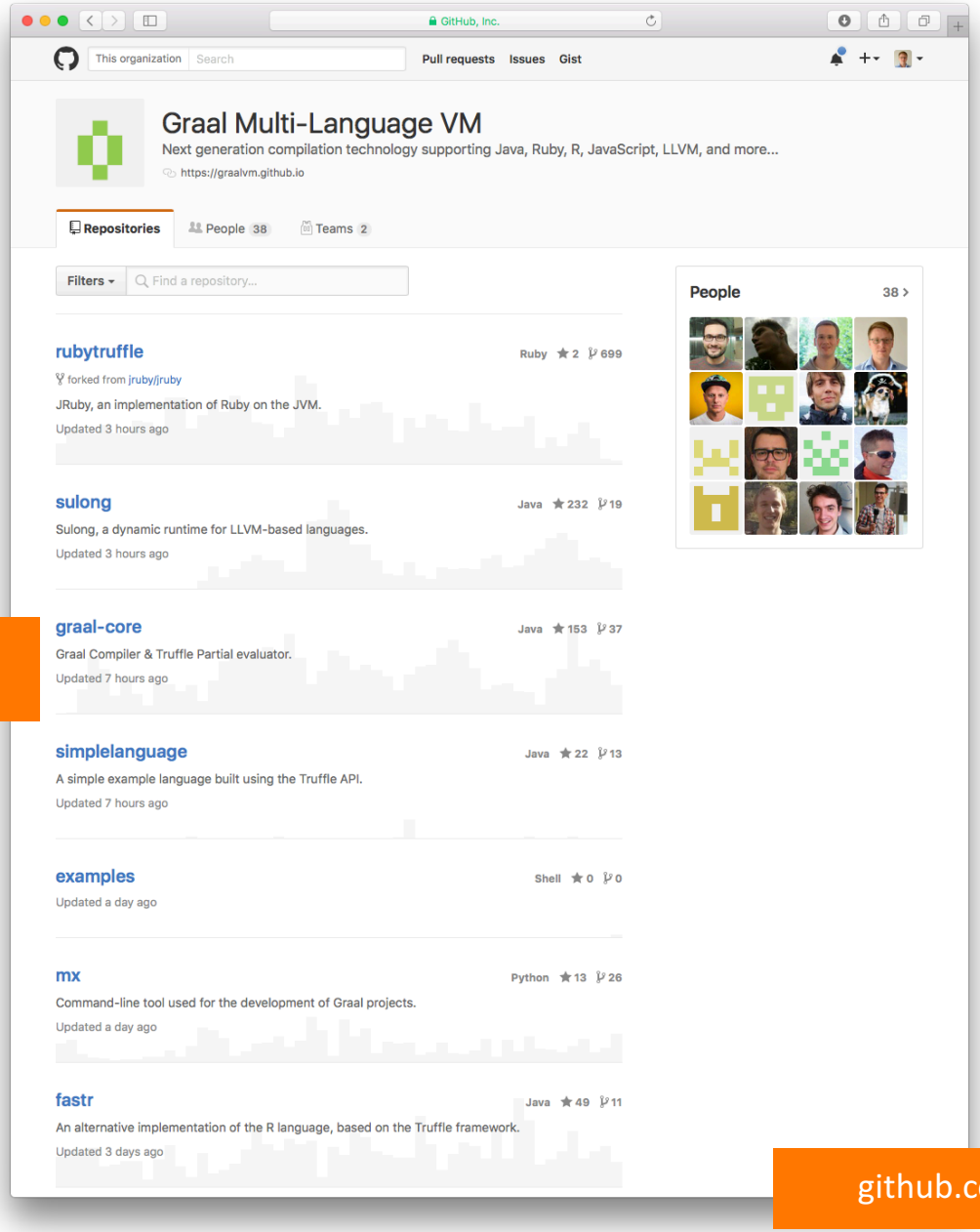
- C extensions are still a work in progress
  - Almost no database drivers
  - No openssl
  - No nokogiri
  - Prevents us running almost everything unfortunately
- The specs don’t have perfect coverage
- Our sophisticated optimisations mean the program state space is huge
  - Lots more to test
  - Lots more to tune for performance

Search for ’graal otn’



www.oracle.com/technetwork/oracle-labs/program-languages

Search for ‘github graalvm’



github.com/graalvm

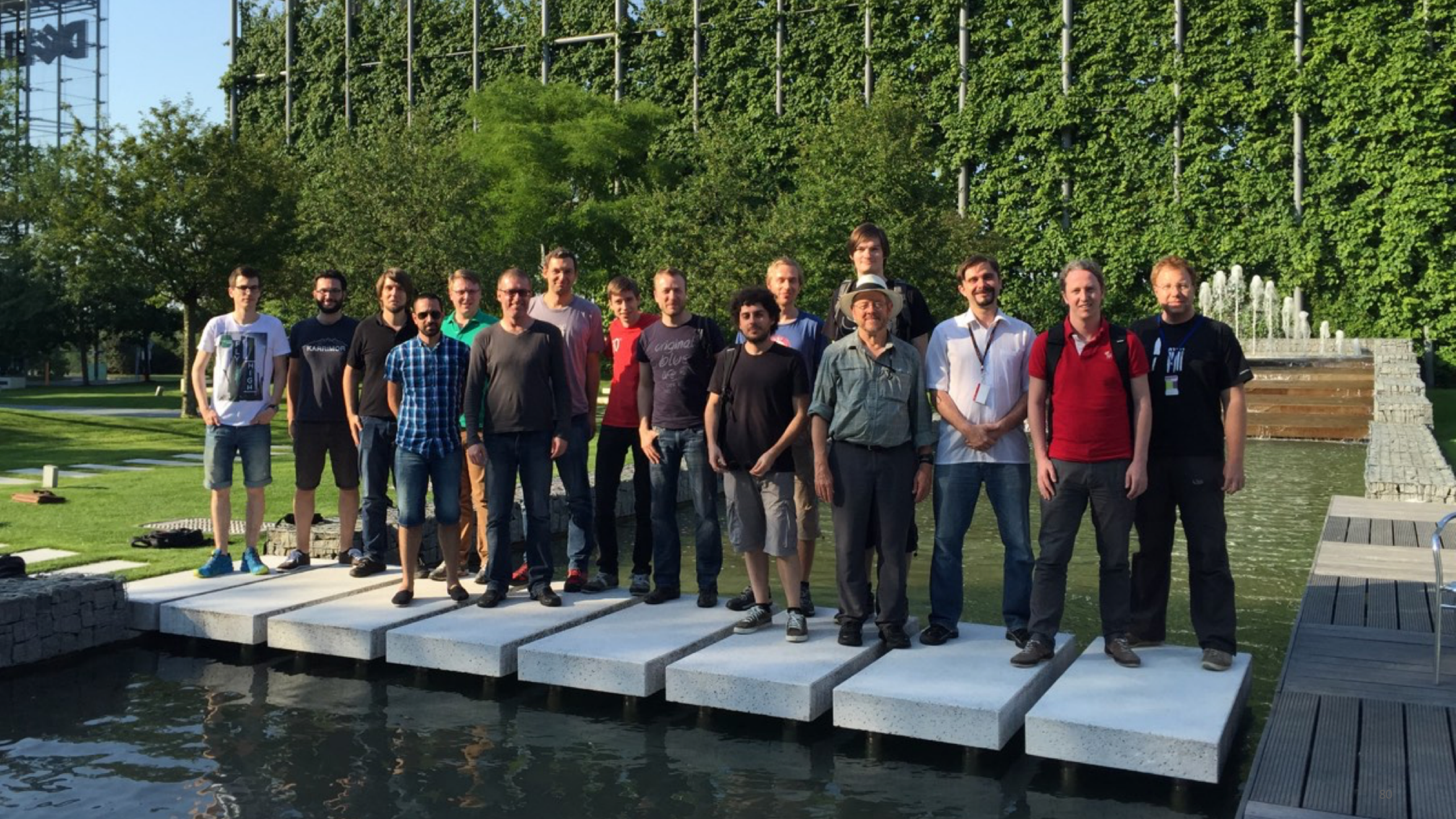
chrisseaton.com/rubytruffle

Freenode #jruby

gitter.im/jruby/jruby

@ChrisGSeaton

‘jruby truffle’



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