

ORACLE®

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

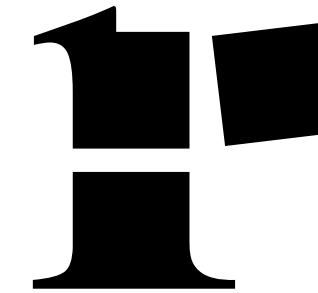
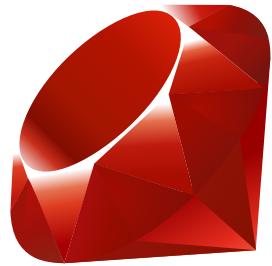
RubyConf 2016

Chris Seaton
Research Manager
Oracle Labs
November 2016

Safe Harbor Statement

The following is intended to provide some insight into a line of research in Oracle Labs. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. Oracle reserves the right to alter its development plans and practices at any time, and the development, release, and timing of any features or functionality described in connection with any Oracle product or service remains at the sole discretion of Oracle. Any views expressed in this presentation are my own and do not necessarily reflect the views of Oracle.

Lots of people want to make Ruby faster

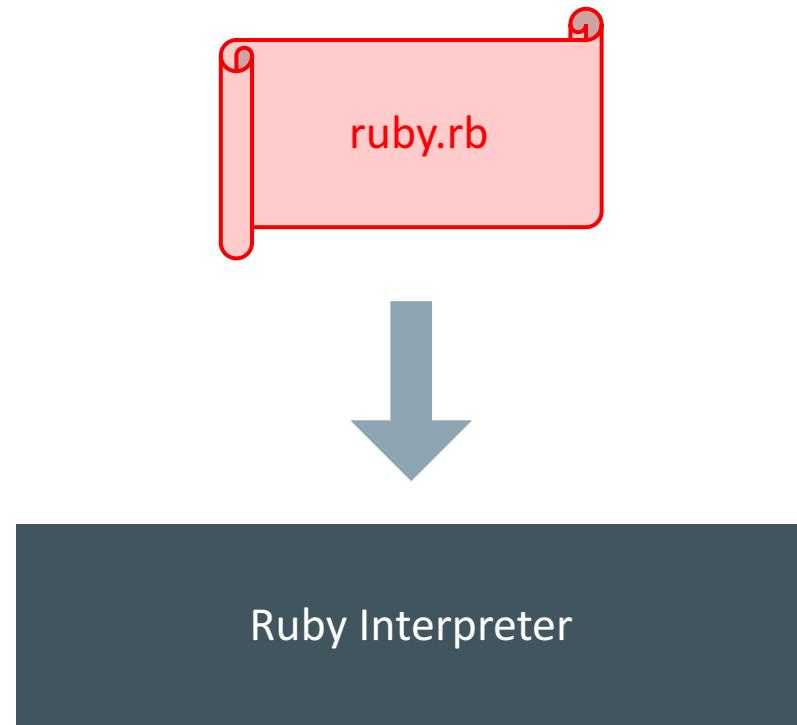


JRuby logo copyright (c) Tony Price 2011, licensed under the terms of the Creative Commons Attribution-NoDerivs 3.0 Unported (CC BY-ND 3.0)
Ruby logo copyright (c) 2006, Yukihiro Matsumoto, licensed under the terms of the Creative Commons Attribution-ShareAlike 2.5 agreement

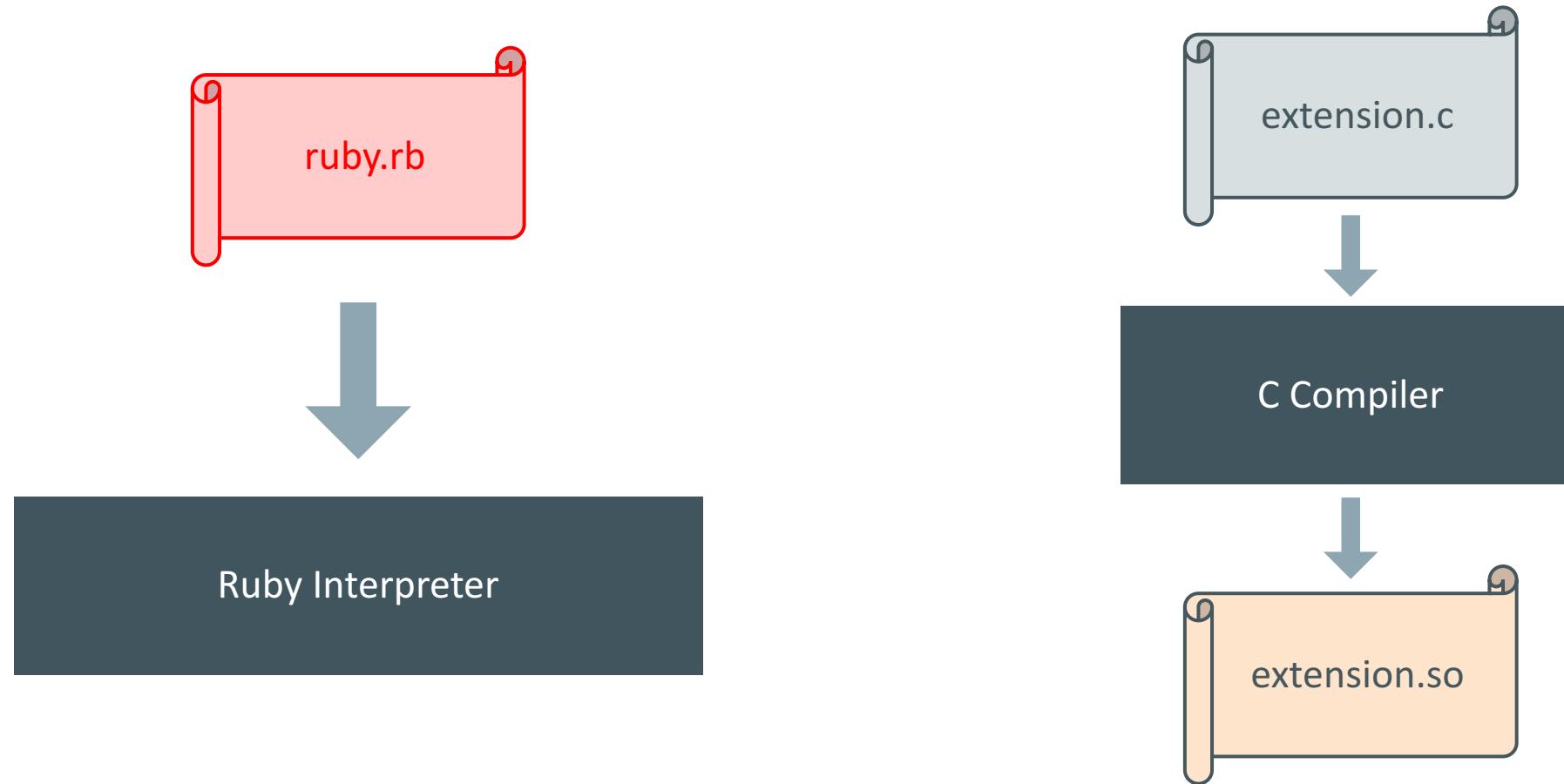
Rubinius logo licensed under the terms of the Creative Commons Attribution-NoDerivs 3.0 Unported
Appfolio logo © AppFolio, Inc. 2016

Maglev logo Copyright © 2008-2010 GemStone Systems
OMR logo copyright Eclipse Foundation

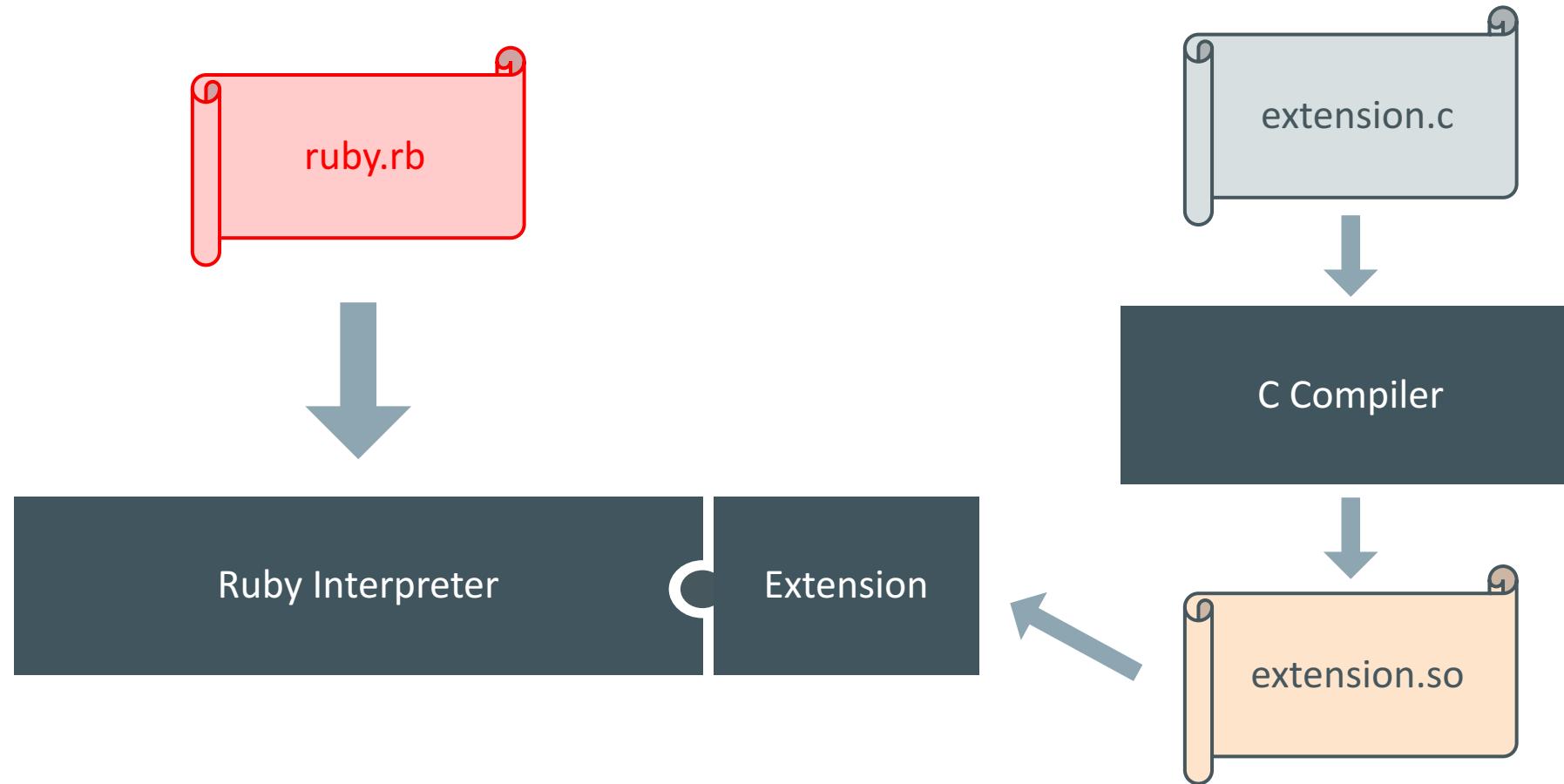
C extensions – the original solution for performance



C extensions – the original solution for performance



C extensions – the original solution for performance

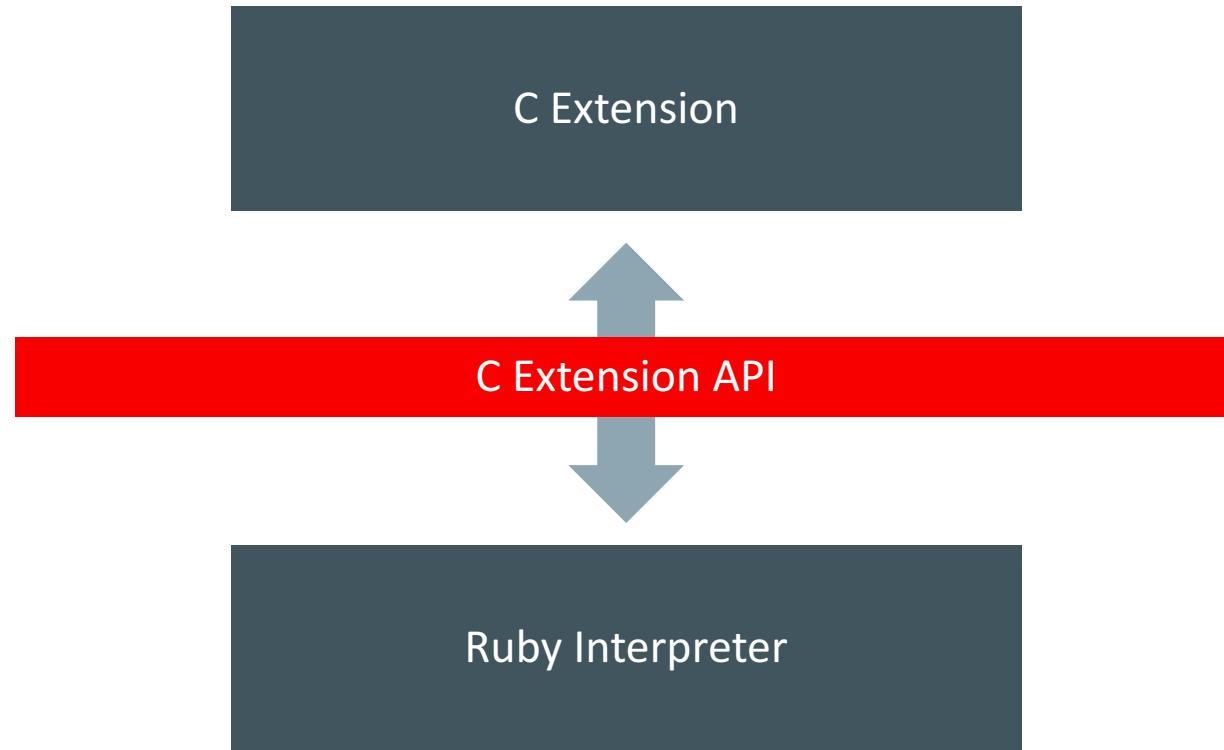


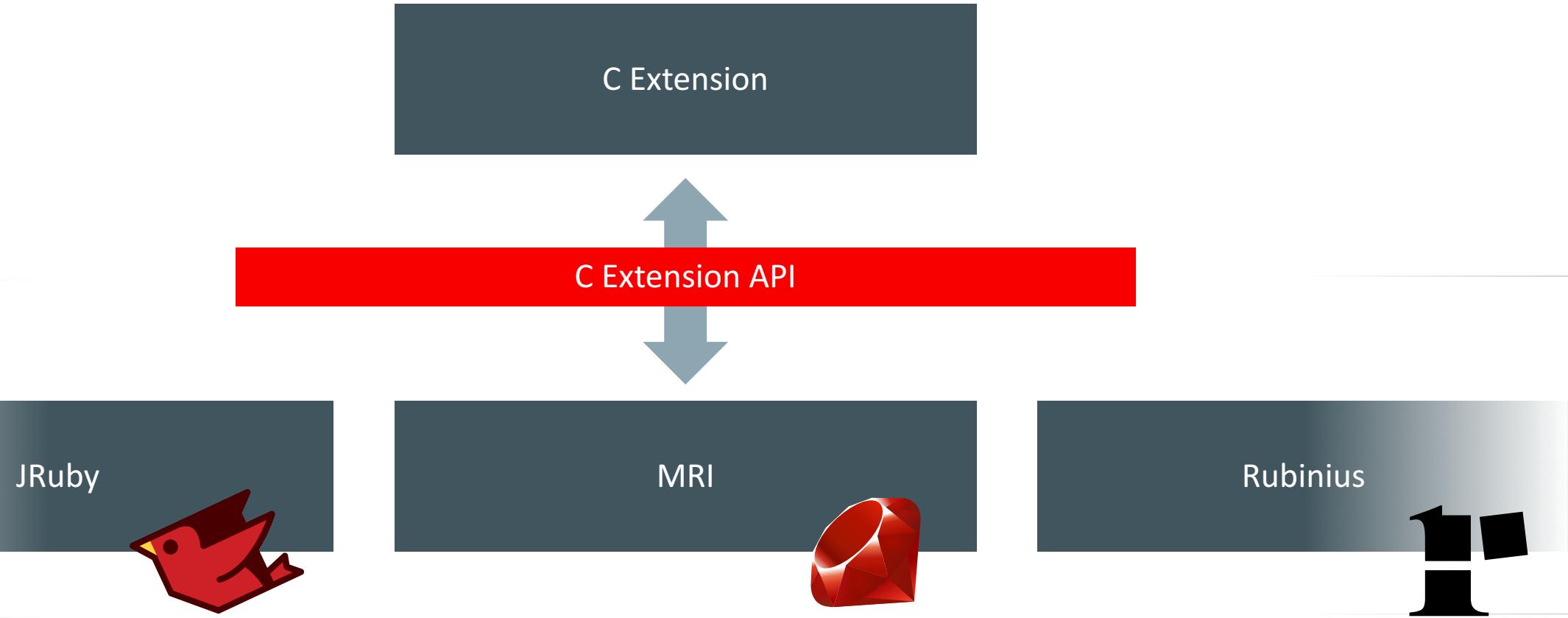
```
def clamp(num, min, max)
    [min, num, max].sort[1]
end
```

```
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);

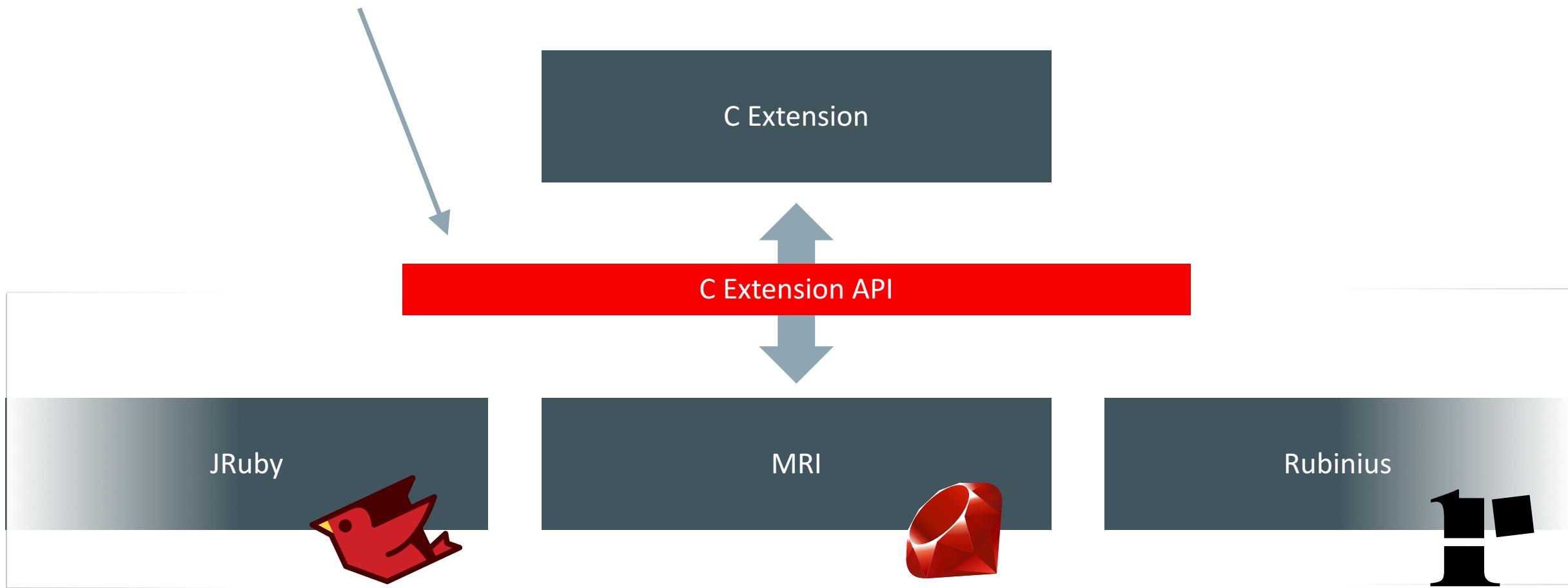
    return num > max ? r_max : (num < min ? r_min : r_num);
}
```

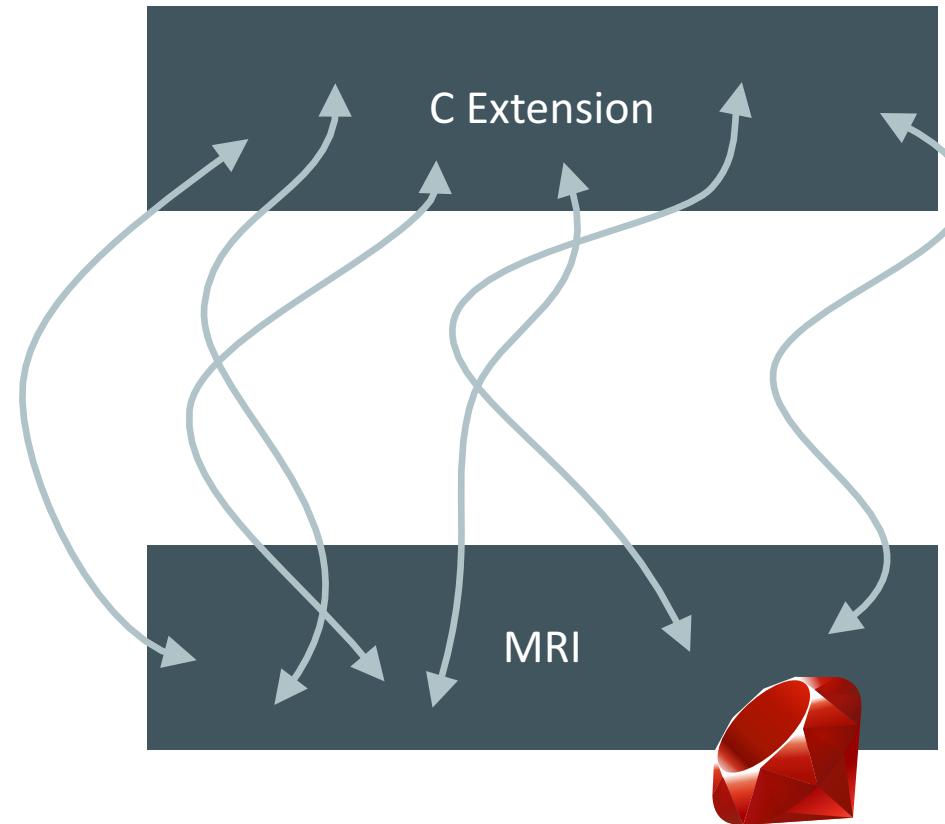
Why C extensions hold us back

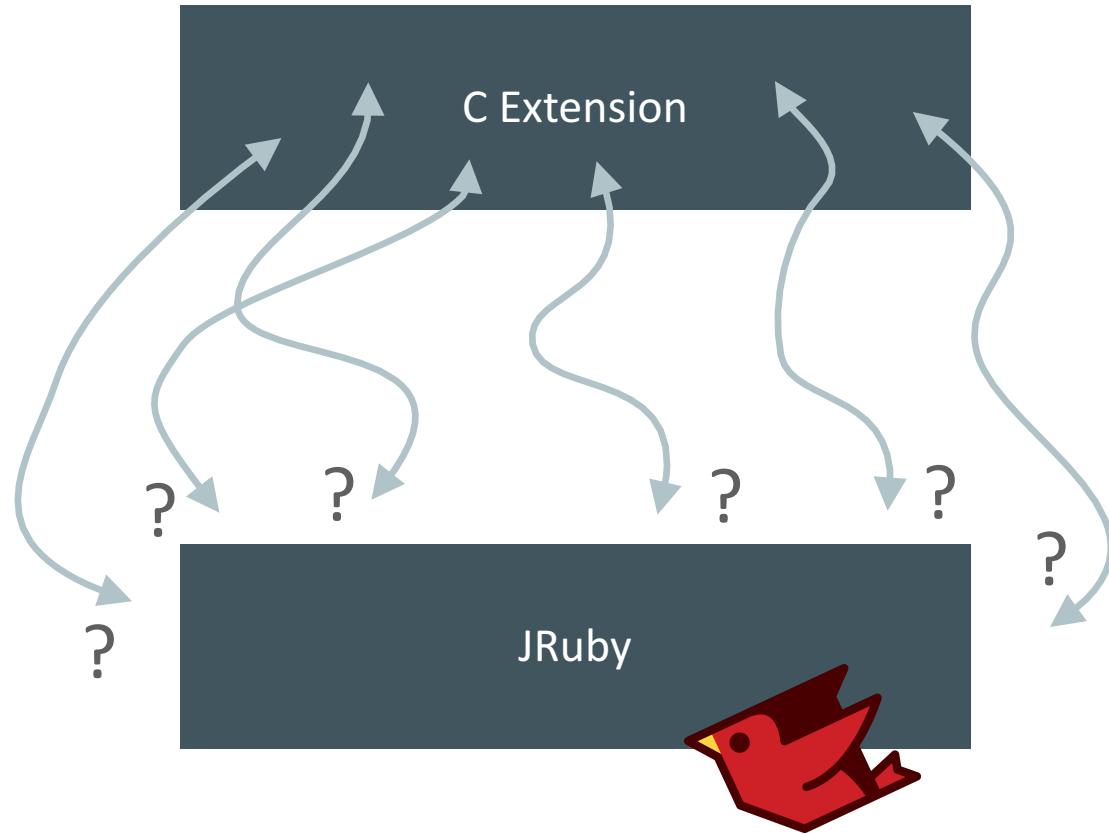


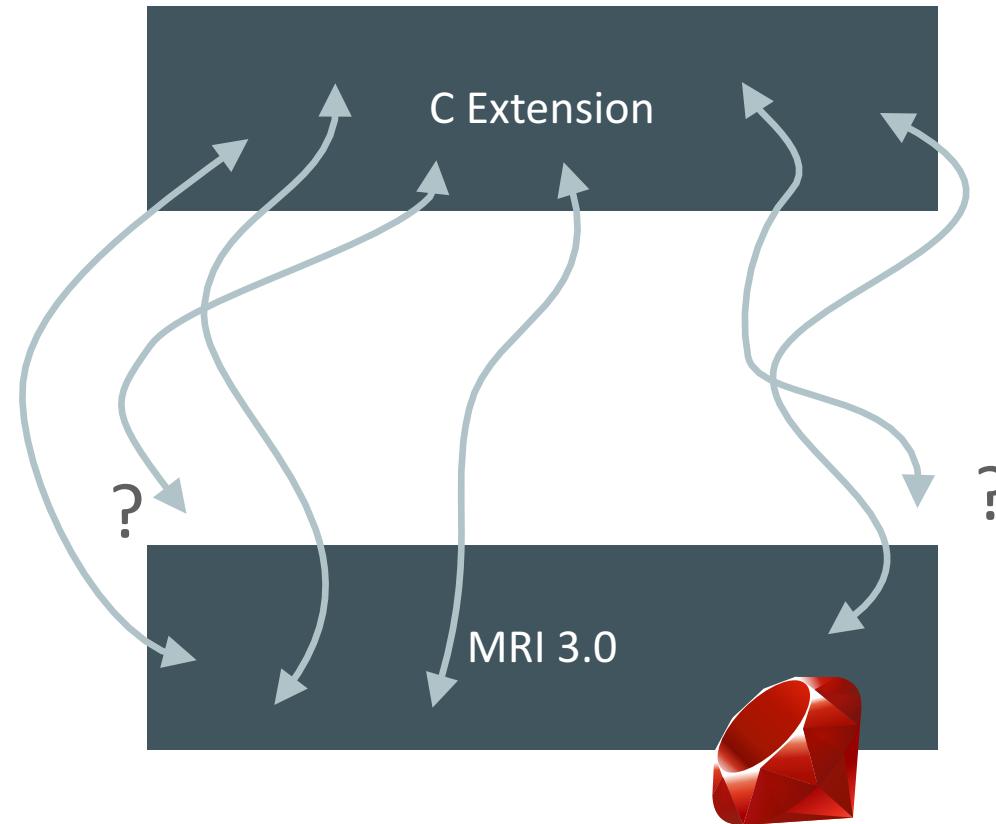


Bad news – this isn't really a thing in practice









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

`foo.to_s`

Last time we called
to_s this is the
method we used

```
method_name = rb_intern("to_s")
rb_funcall(foo, method_name, 0);
```

?

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)
```

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

```
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, it 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

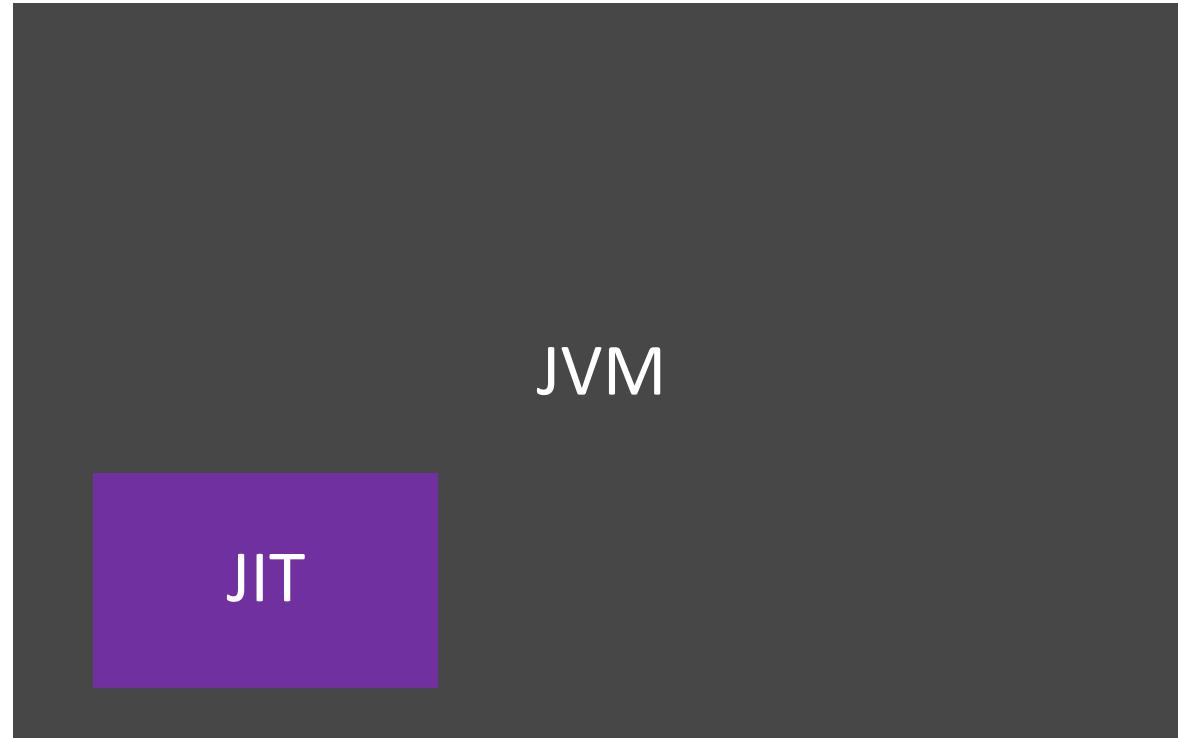
Interlude: JRuby+Truffle

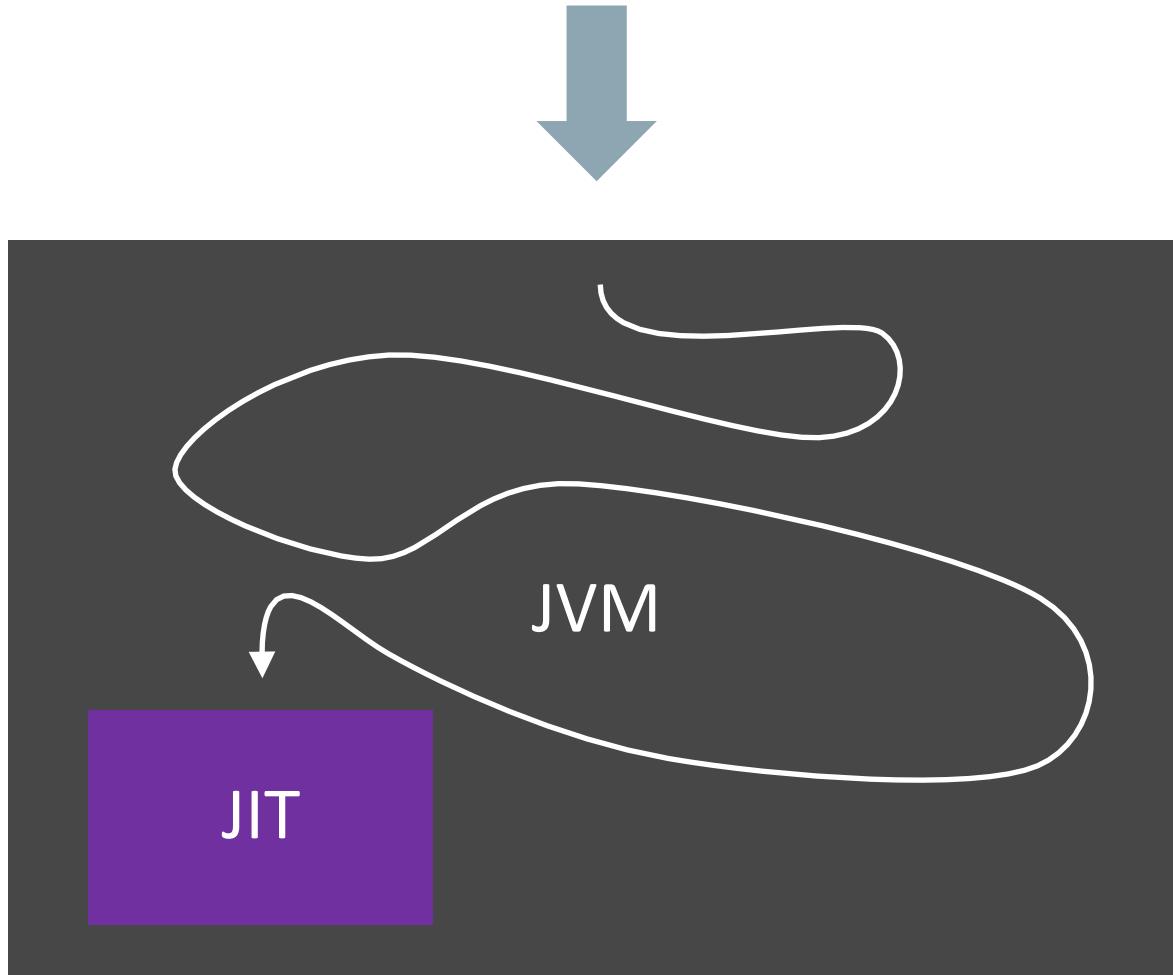


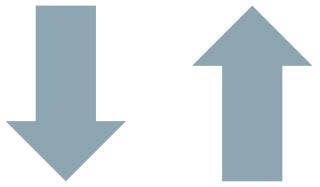
JVM



JVM





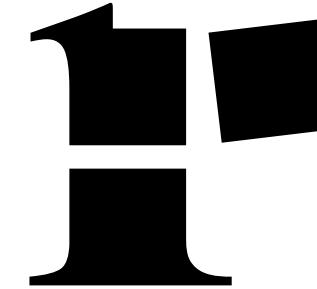
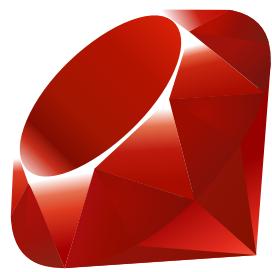


Truffle



Graal

JVM

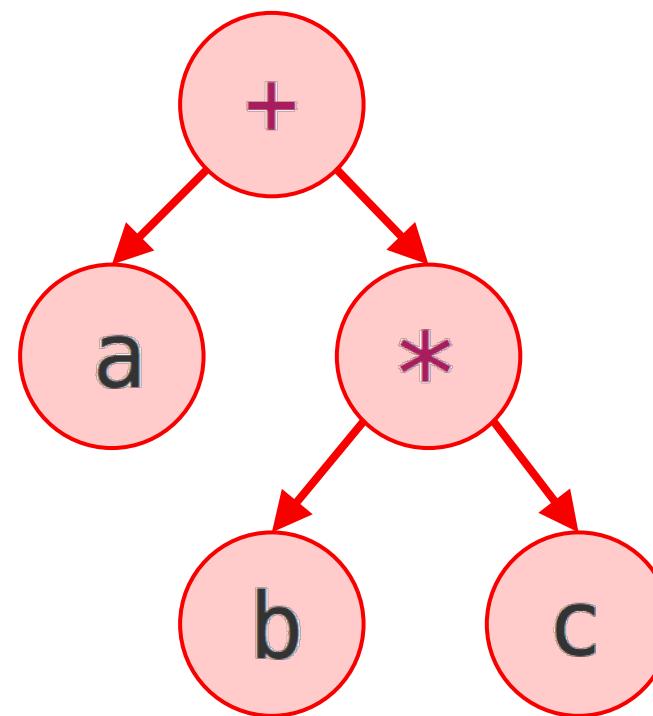


Truffle

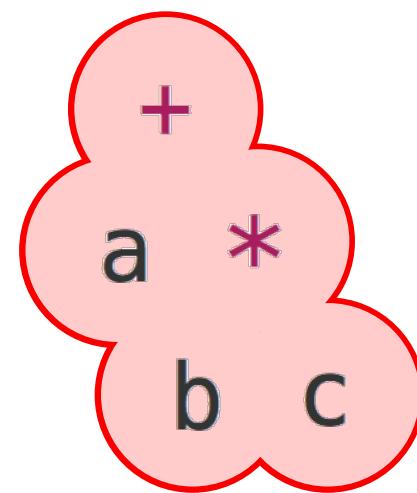
Graal VM

JVM

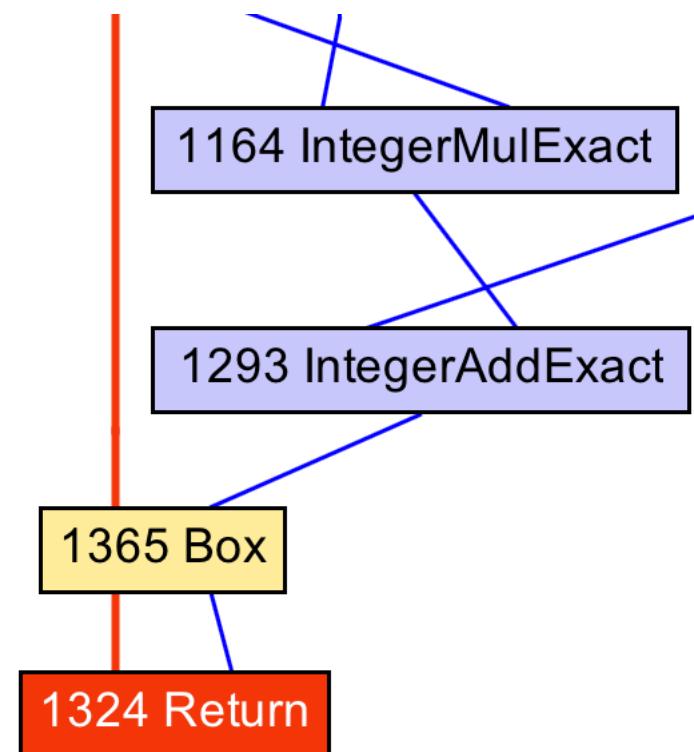
a + b * c



a + b * c



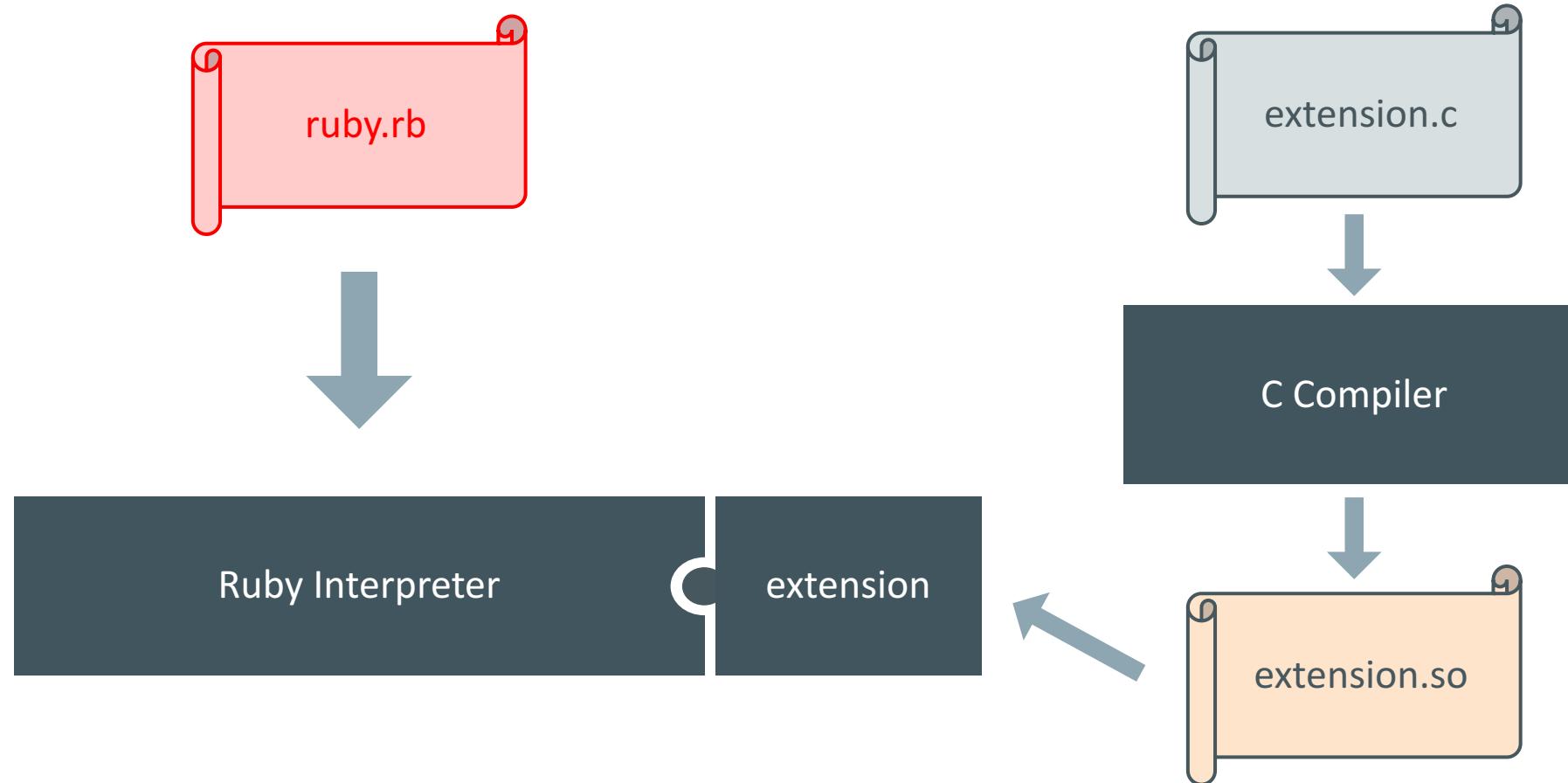
a + b * c



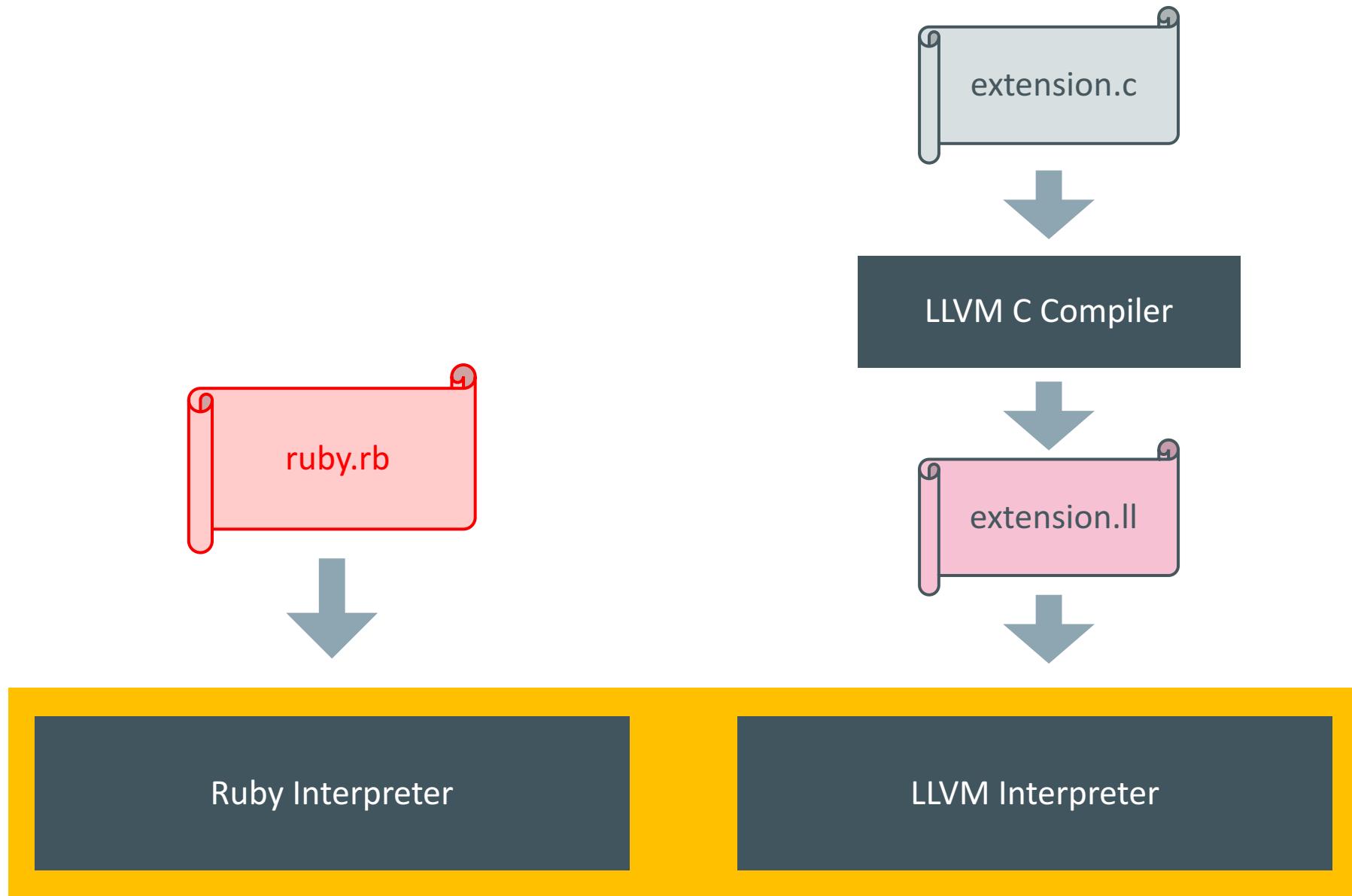
$$a + b * c$$

```
imul    %rsi,%rdx
jo      0x0000001171a3fa5
add    %rdi,%rdx
jo      0x0000001171a3fc7
```

Our radical new solution for C extensions...







```

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);
}

```

```

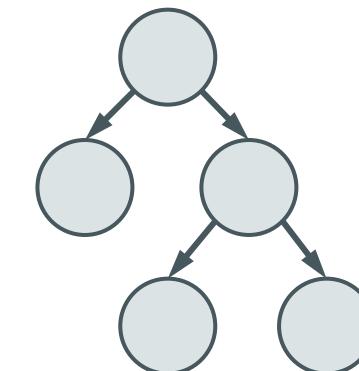
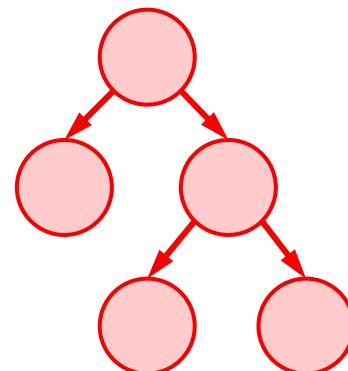
define i8* @psd_native_util_clamp(i8* %self,
    i8* %r_num, i8* %r_min, i8* %r_max) nounwind uwtable ssp {
    %1 = call i32 @FIX2INT(i8* %r_num)
    %2 = call i32 @FIX2INT(i8* %r_min)
    %3 = call i32 @FIX2INT(i8* %r_max)
    %4 = icmp sgt i32 %1, %3
    br i1 %4, label %5, label %6
    ; <label>:5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

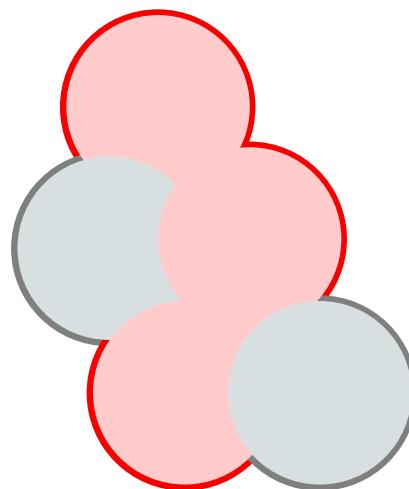
```
%4 = icmp sgt i32 %1, %3
br i1 %4, label %5, label %6
; <label>:5
br label %12
; <label>:6
%7 = icmp slt i32 %1, %2
br i1 %7, label %8, label %9
t4 = t1 > t3
if t4
    goto l5
else
    goto l6
end
l5: goto l12
l6: t7 = t1 < t2
if t7
    goto l8
else
    goto l9
end
```

Optimise Ruby and C together



Optimisations

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);
}

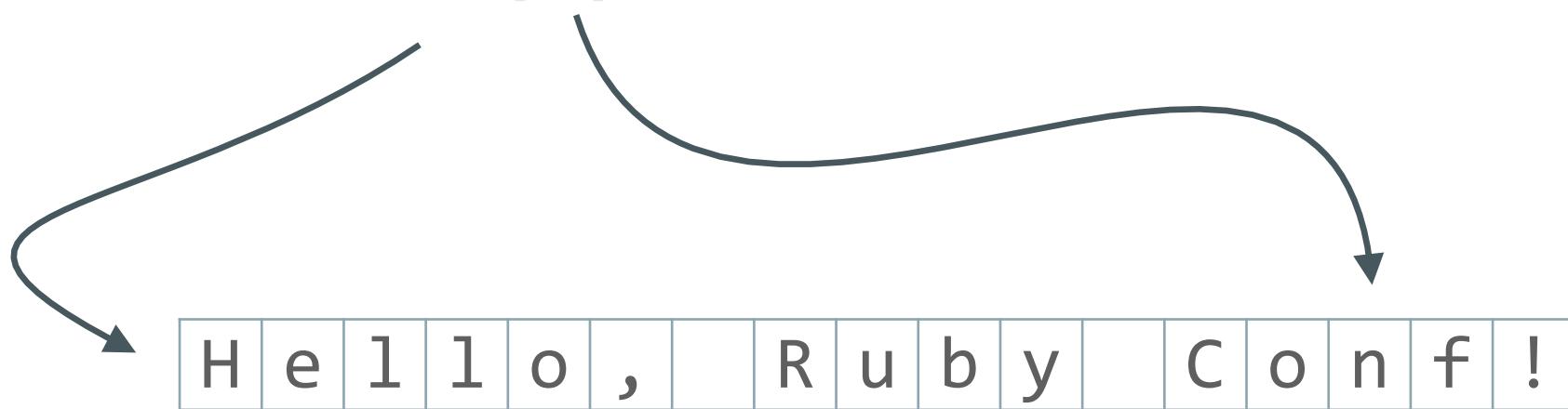
module Truffle::CExt

    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



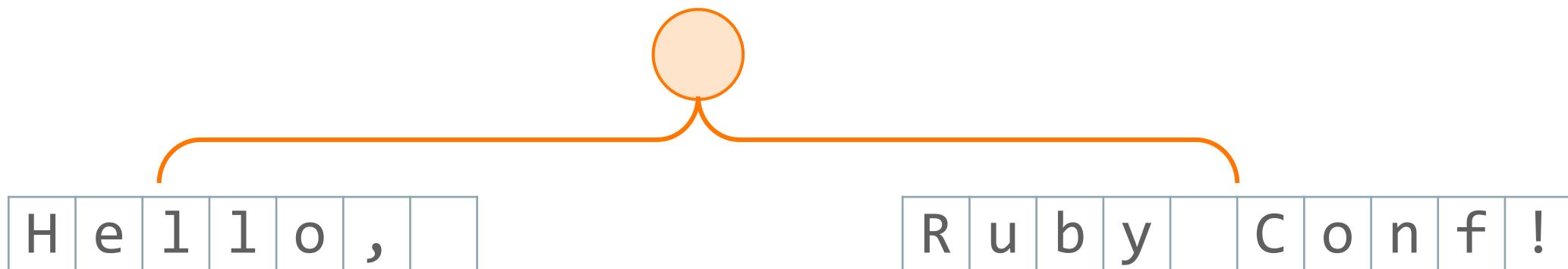
A Tale of Two String Representations

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

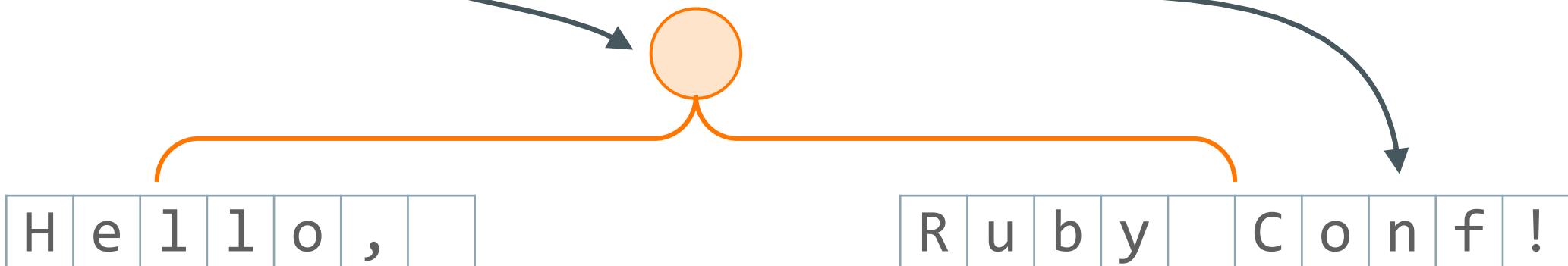
%1 = call @RSTRING_PTR(%my_string)

%2 = getelementptr %14, 14

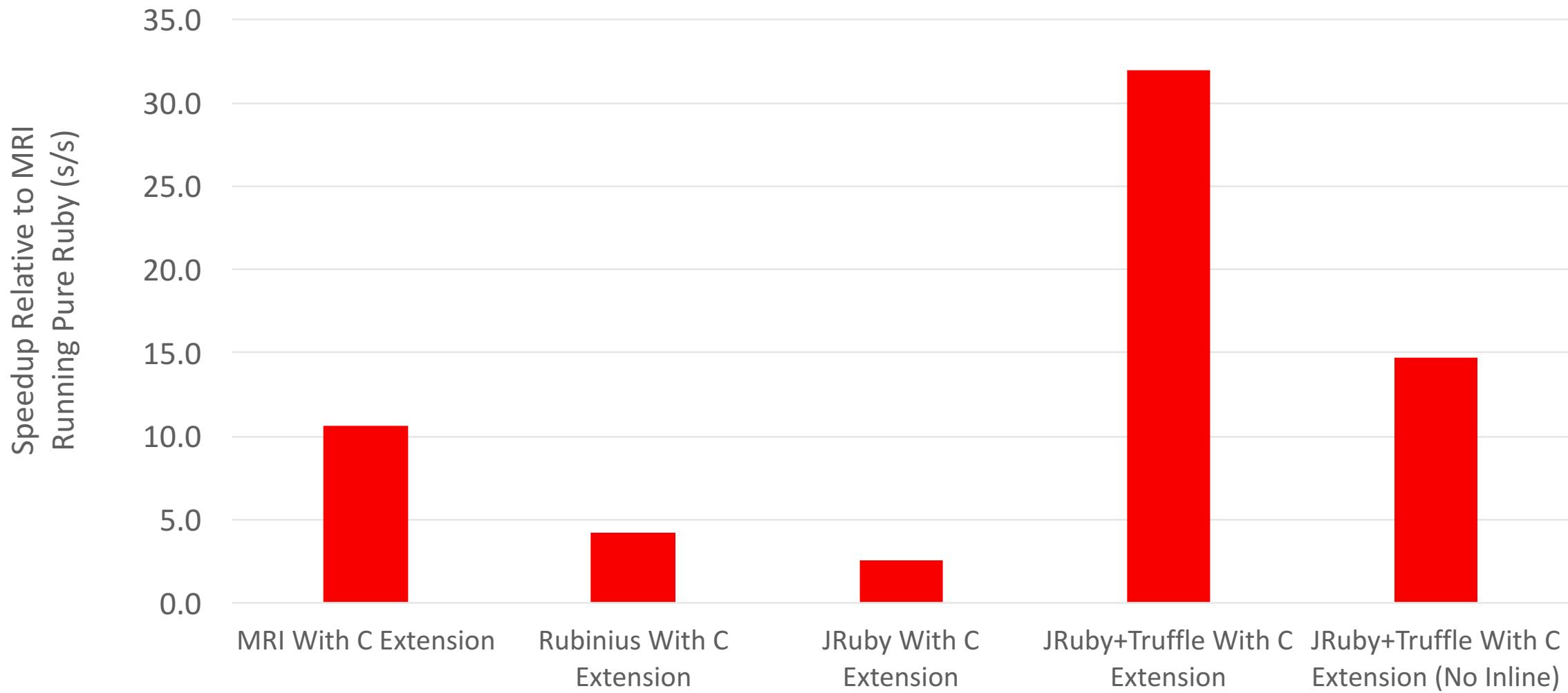
String#[]

char *chars = RSTRING_PTR(my_string);

chars[14]



Results

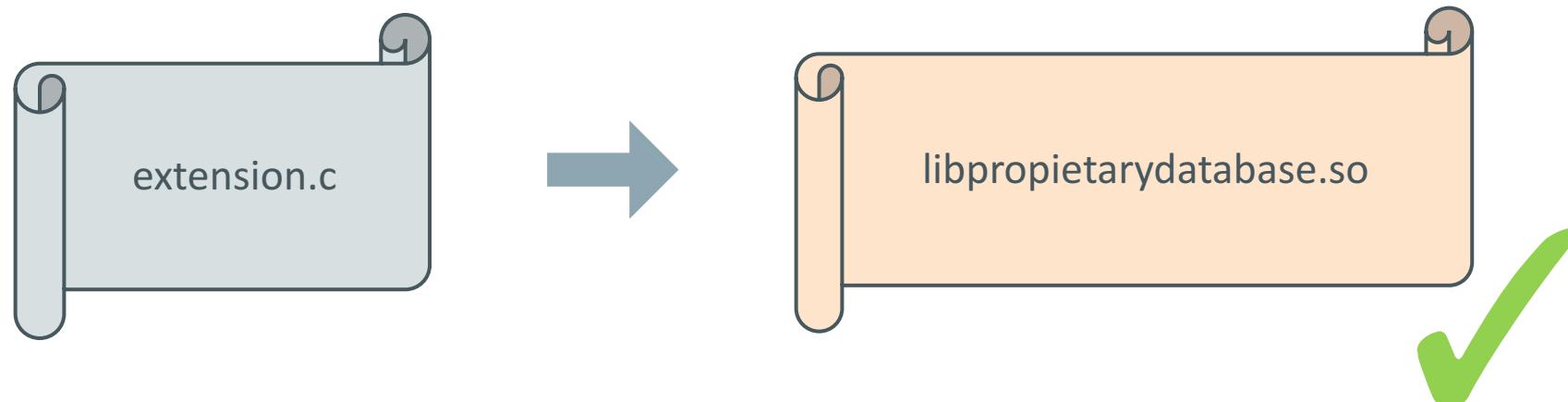


Matthias Grimmer, Chris Seaton, Thomas Wuerthinger, Hanspeter Moessenboeck:
Dynamically Composing Languages in a Modular Way: Supporting C Extensions for Dynamic Languages
Modularity '14 Proceedings of the 14th International Conference on Modularity

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);

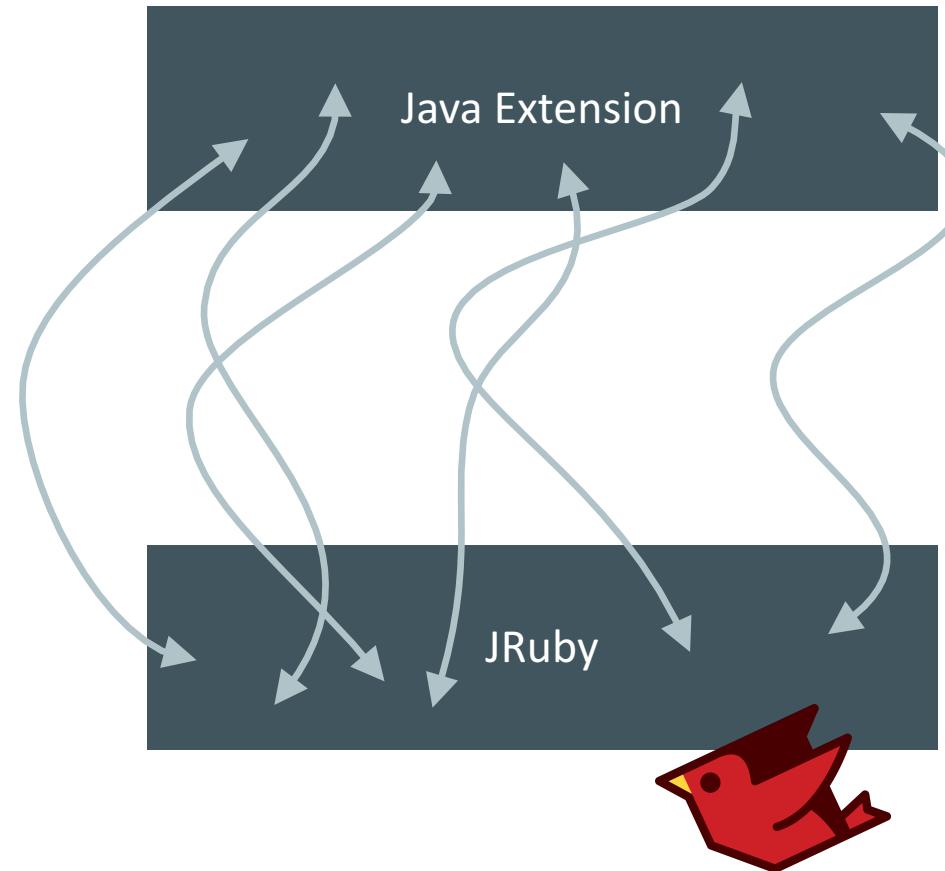
SSL_CTX_set_ex_data(ctx, ossl_ssl_ex_ptr_idx, obj);

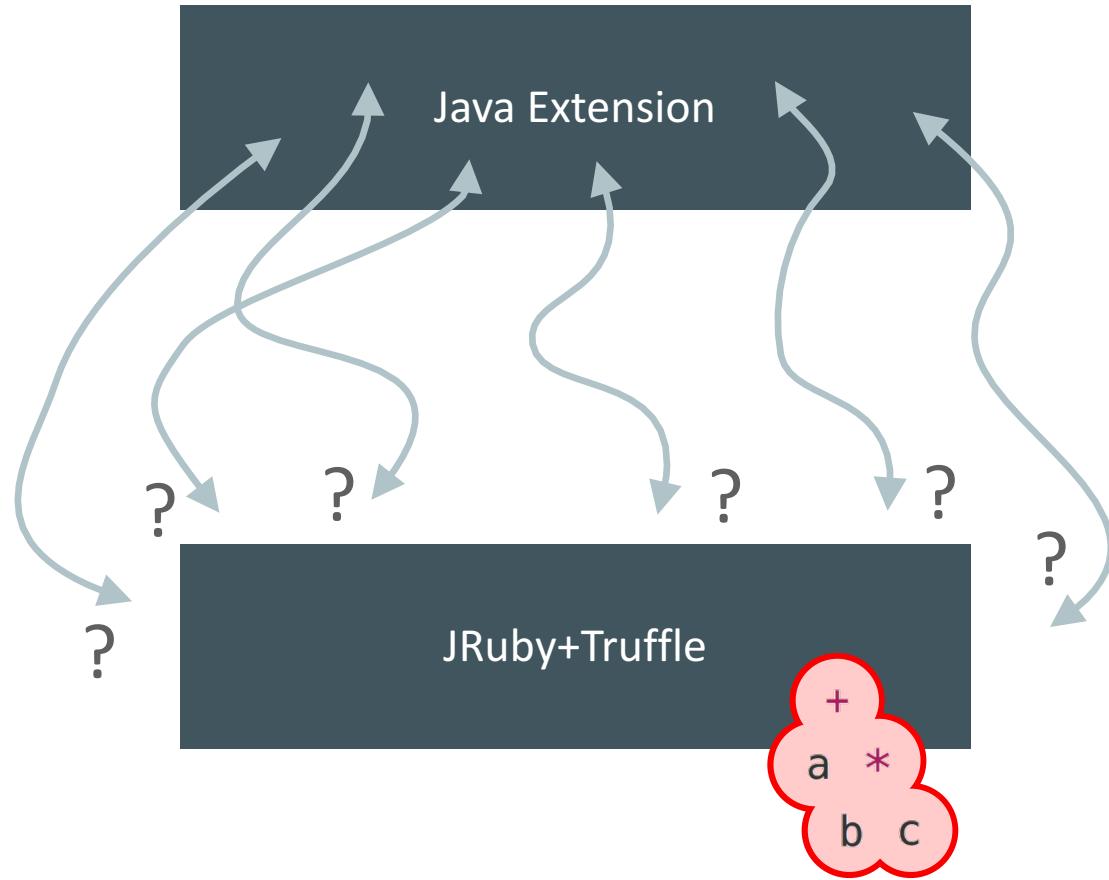
SSL_CTX_set_ex_data(ctx, ossl_ssl_ex_ptr_idx, rb_jt_to_native_handle(obj));
```

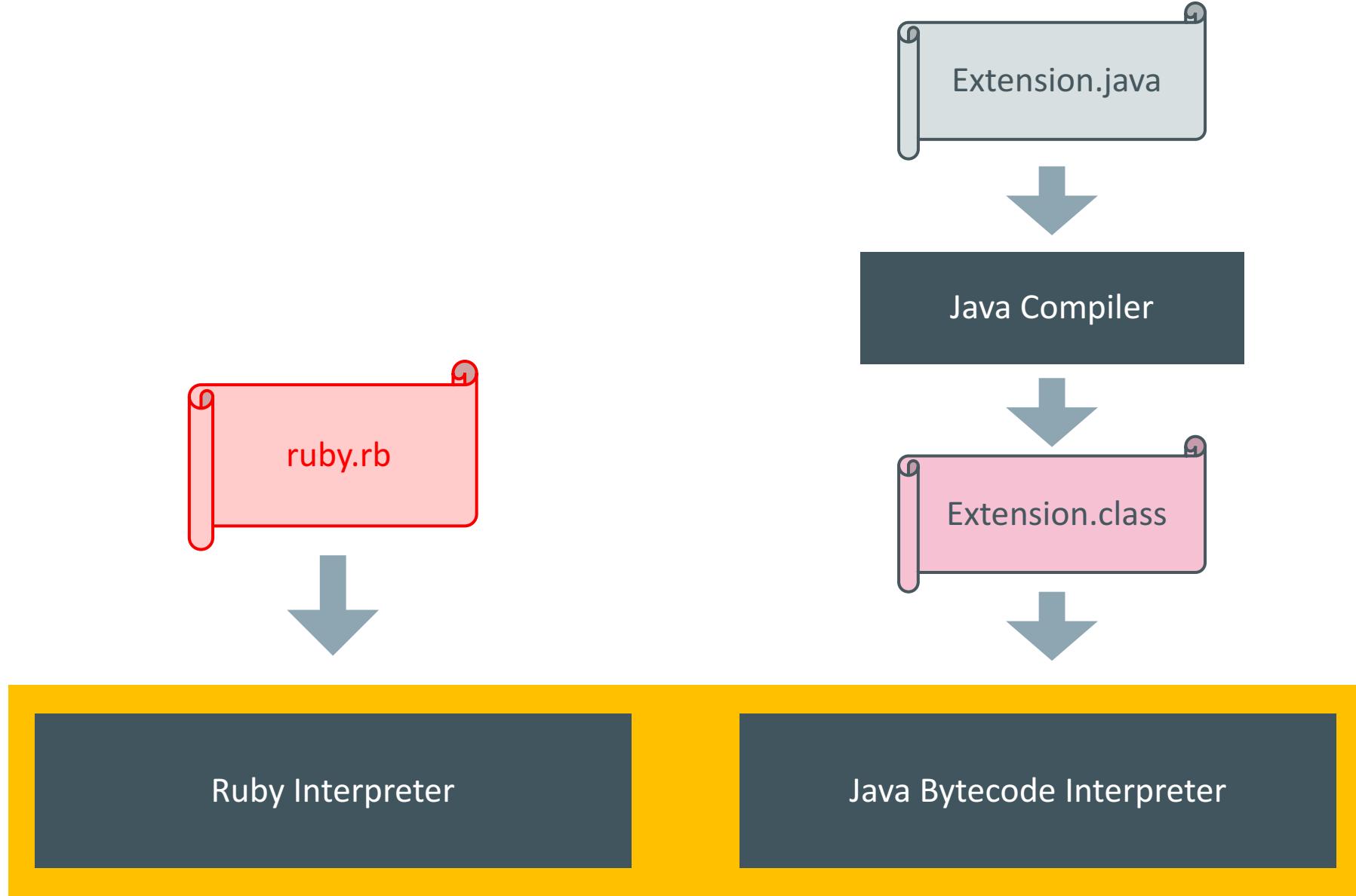
By the way...

- 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

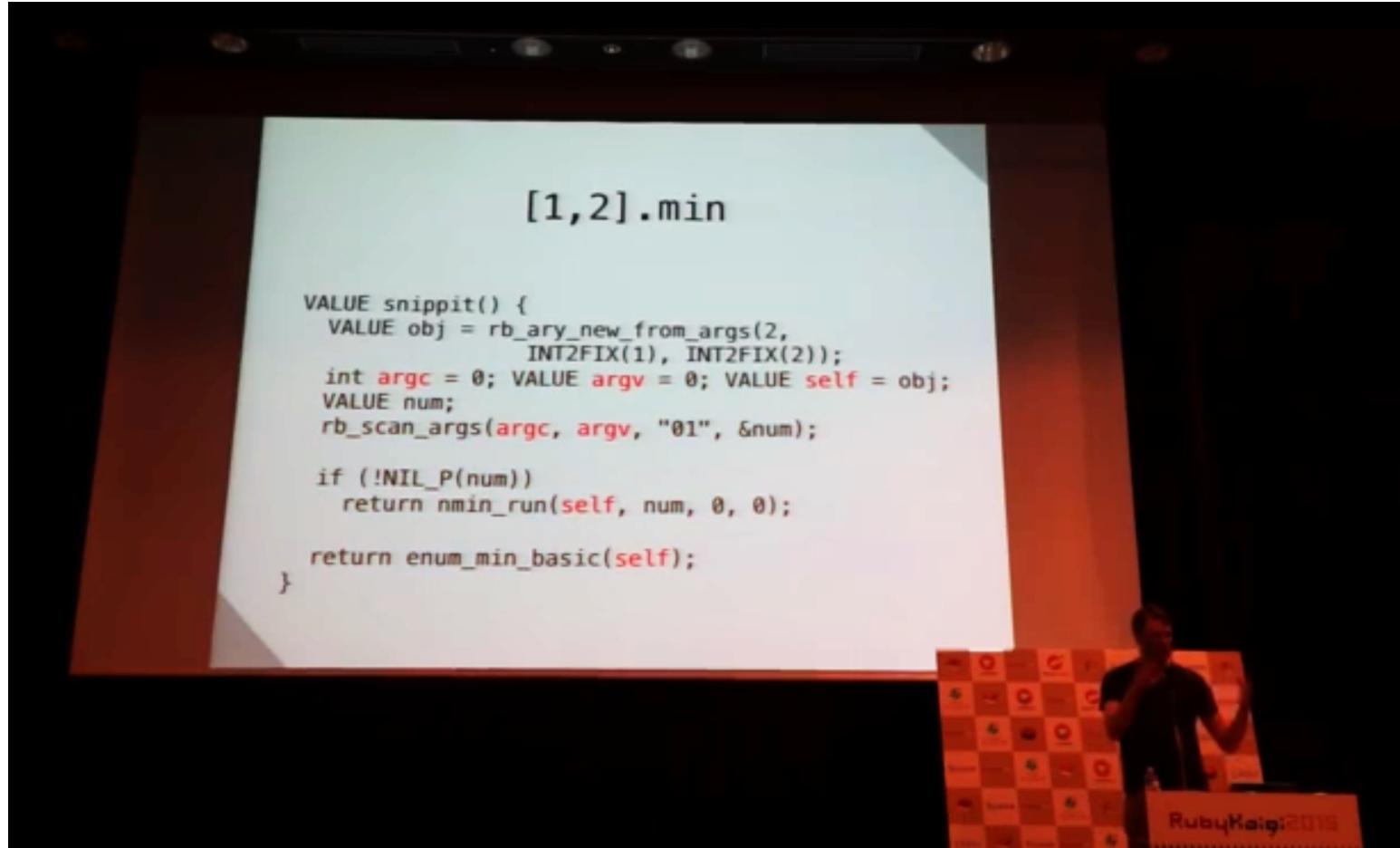
Java extensions







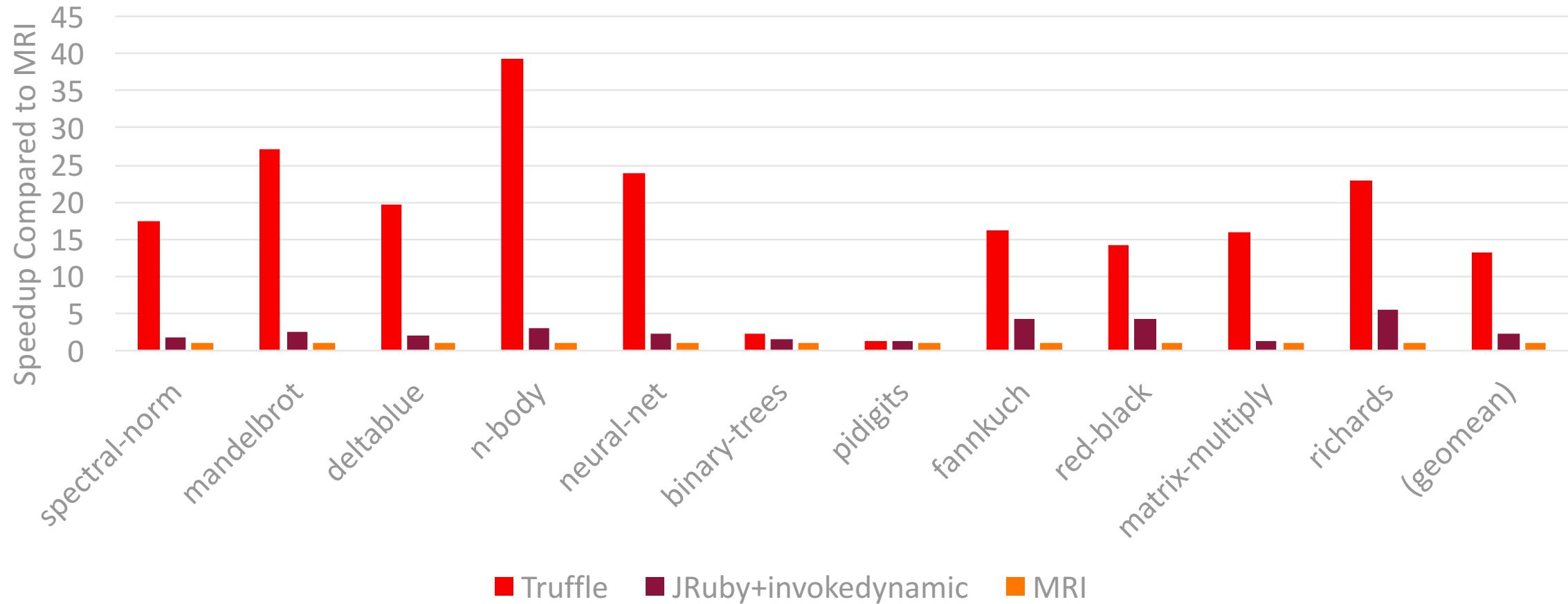
This could be a direction for MRI as well

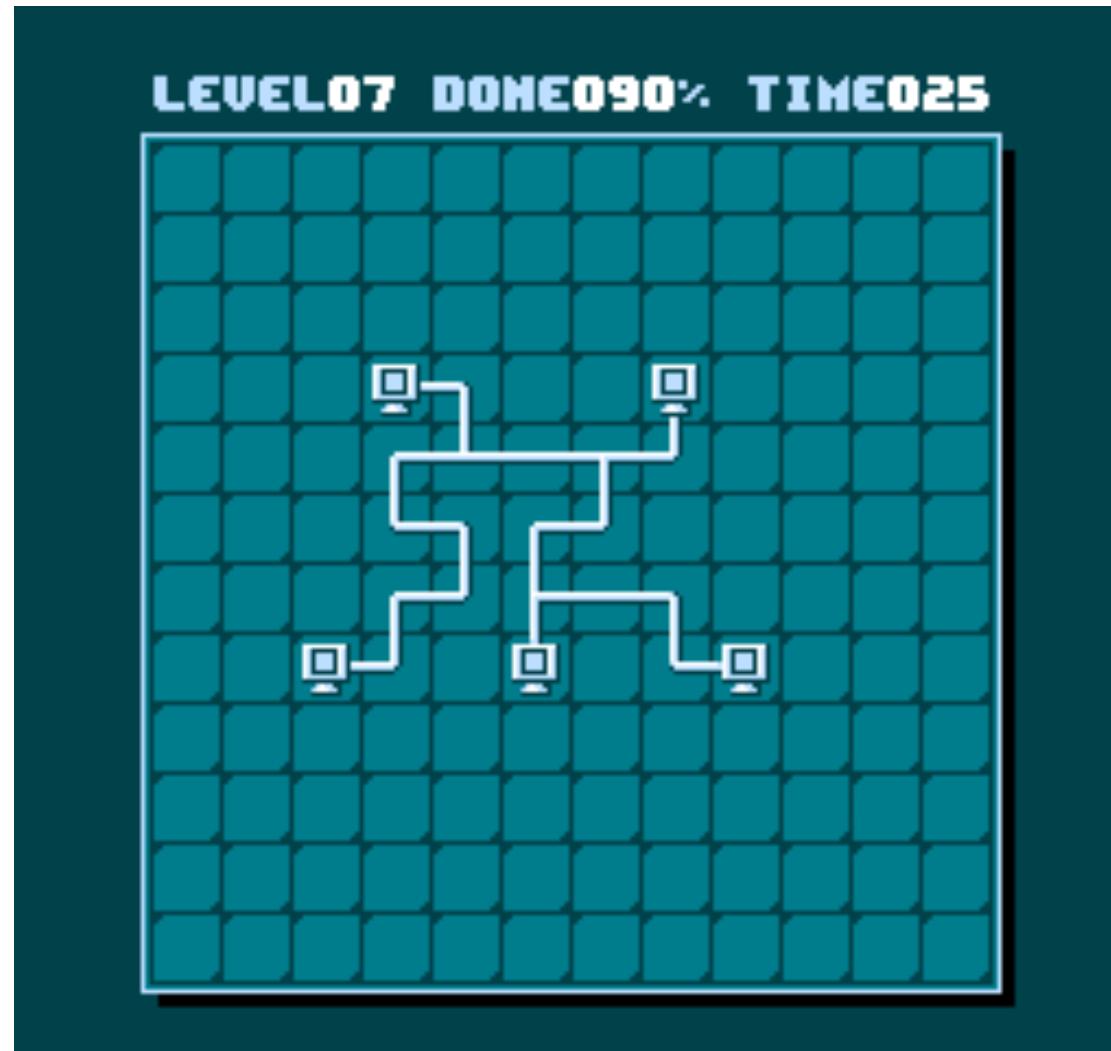


Evan Phoenix: store the LLVM IR of the MRI implementation code and JIT it
Ruby: 2020 - RubyKaigi 2015 Keynote

A quick status update on JRuby+Truffle

Classic research benchmarks – 10-20x faster than MRI





'optcarrot' NES emulator benchmark – 9x faster than MRI

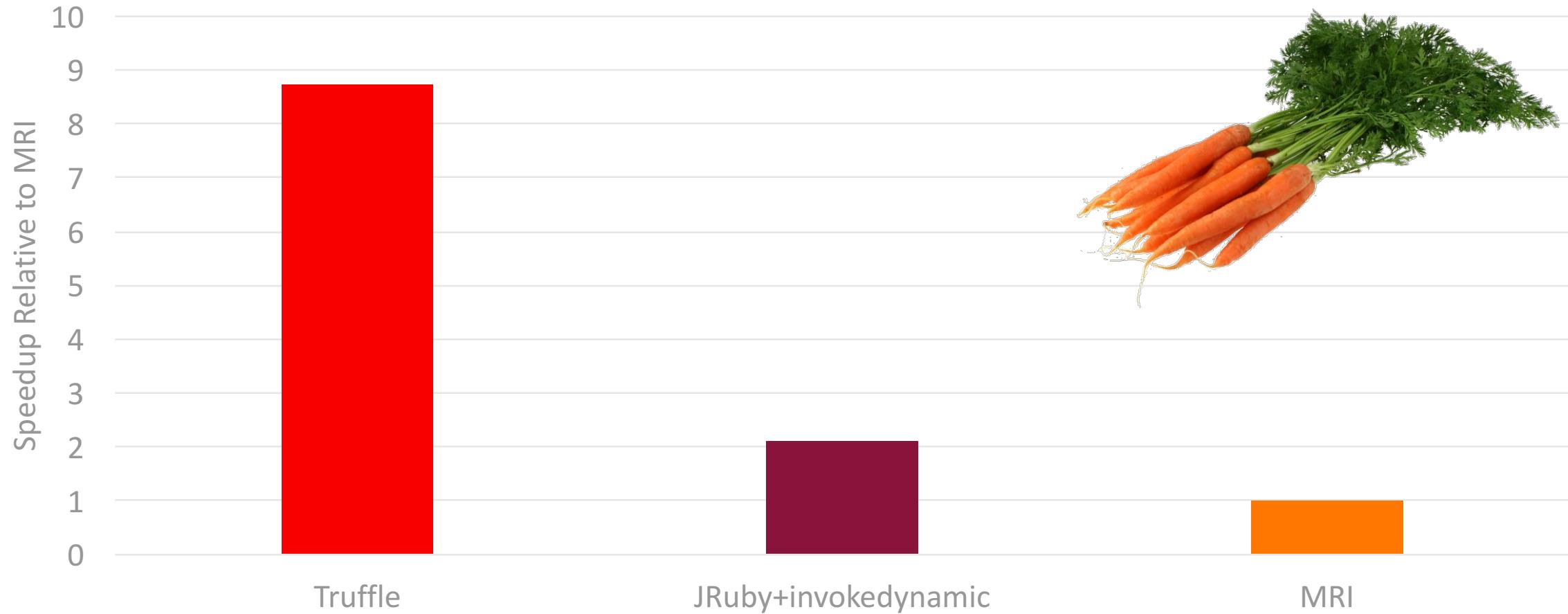


Image copyright NY - <http://nyphotographic.com/> - Creative Commons 3 - CC BY-SA 3.0

Ruby specs

99%

Language specs

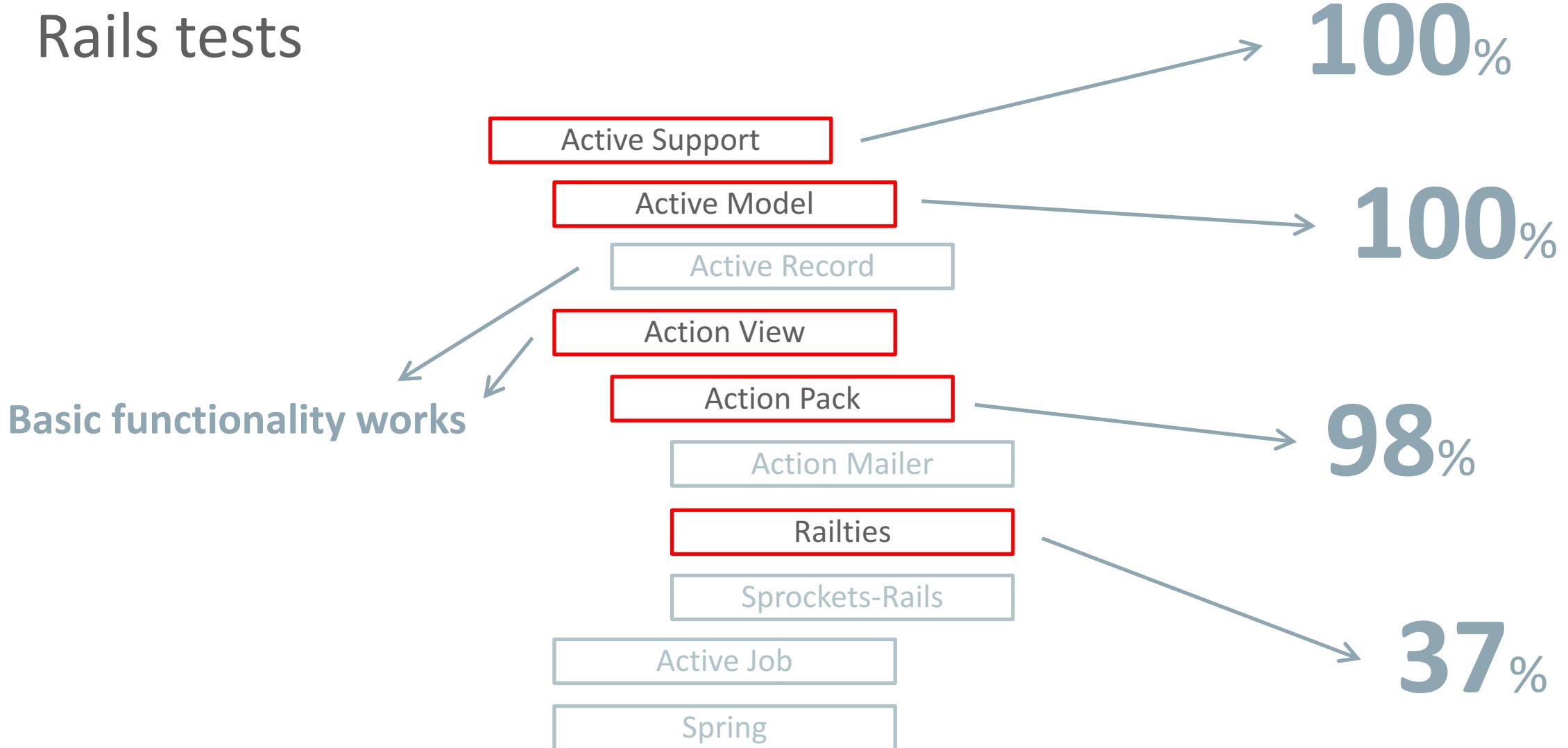
96%

Core library specs

78%

Standard library specs*
coverage is very limited here; probably a bit misleading

Rails tests



The screenshot shows a web-based application for editing blog posts. At the top, there's a header bar with 'RAILS DEMO' and 'Blog' buttons. A '+' icon is in the top right corner of the main content area. The main title is 'Edit post'. Below it, a sub-instruction says 'Create new post. Body of the post is processed by asciidoctor.' The body of the post contains the following content:

```
= This is the Title of the blog post  
Author Name  
:icons: font  
  
This is an *example* of a _blog post_.  
  
== Header 1  
  
Lorem ipsum dolor sit amet, consectetur adipiscing elit.  
Phasellus est ante,  
congue aliquet suscipit vel, mollis ac quam. Nam aliquam porta  
massa, non  
porttitor risus cursus quis. Quisque suscipit, lorem eget congue  
semper,  
sem tortor volutpat arcu, non volutpat libero felis et eros.  
  
* Item 1  
* Item 2  
* Item 3
```

At the bottom of the editor, there are 'Preview' and 'Update' buttons. Below the editor, it says 'Platform: truffle'.

The preview on the right side shows the processed content:

This is the Title of the blog post
Author Name

This is an **example** of a *blog post*.

Header 1

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Phasellus est ante, congue aliquet suscipit vel, mollis ac quam. Nam aliquam porta massa, non porttitor risus cursus quis. Quisque suscipit, lorem eget congue semper, sem tortor volutpat arcu, non volutpat libero felis et eros.

- » Item 1
- » Item 2
- » Item 3

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

The screenshot shows a web browser window with the Oracle website (oracle.com) open. The user is logged in as 'Chris'. The navigation bar includes links for Account, Sign Out, Help, Country, Communities, I am a..., I want to..., Search, Products, Solutions, Downloads, Store, Support, Training, Partners, About, and OTN. The page title is 'Oracle Technology Network > Oracle Labs > Programming Languages and Runtimes > Downloads'. On the left, there's a sidebar with links for Parallel Graph Analytics, Programming Languages and Runtimes (selected), Souffle, and Datasets. The main content area is titled 'Oracle Labs GraalVM and JVMCI JDK Downloads'. It thanks the user for downloading the release and states that one can execute Java applications with Graal, as well as applications written in JavaScript, Ruby, and R, with our Polyglot language engines. It also notes that the user has accepted the OTN License Agreement. Below this, there are download links for GraalVM preview versions (Linux v0.17, Mac OS X v0.17) and their corresponding runtime environments, as well as specific tar.gz files for different platforms (labsjdk-8u92-jvmci-0.22-darwin-amd64.tar.gz, labsjdk-8u92-jvmci-0.22-linux-amd64.tar.gz, labsdk-8u92-jvmci-0.22-solaris-sparcv9.tar.gz). A section titled 'How to install GraalVM' provides instructions on unpacking the downloaded file and adding it to the system's PATH. Another section, 'About this OTN Release', contains a detailed disclaimer about the research nature of the software. A warning at the bottom notes that older versions of the JRE and JDK are included for compatibility with developers debugging issues in older systems. The URL www.oracle.com/technetwork/oracle-labs/program-languages is highlighted in an orange box.

Search for 'graal otn'

Welcome Chris

Account Sign Out Help Country Communities I am a... I want to... Search

Products Solutions Downloads Store Support Training Partners About OTN

Oracle Technology Network > Oracle Labs > Programming Languages and Runtimes > Downloads

Parallel Graph Analytics

Programming Languages and Runtimes

Souffle

Datasets

Overview Java Polyglot Downloads Learn More

Oracle Labs GraalVM and JVMCI JDK Downloads

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.

Thank you for accepting the OTN License Agreement; you may now download this software.

- [GraalVM preview for Linux \(v0.17\), Development Kit](#)
- [GraalVM preview for Linux \(v0.17\), Runtime Environment](#)
- [GraalVM preview for Mac OS X \(v0.17\), Development Kit](#)
- [GraalVM preview for Mac OS X \(v0.17\), Runtime Environment](#)

- [labsjdk-8u92-jvmci-0.22-darwin-amd64.tar.gz](#)
- [labsdk-8u92-jvmci-0.22-linux-amd64.tar.gz](#)
- [labsdk-8u92-jvmci-0.22-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 execute Java programs. All those executables are in the bin directory of GraalVM. You might want to add that directory to your operating system's PATH.

More detailed getting started instructions are available in the README files in the download. The README files for the language engines can be found in jre/languages/.

About this OTN Release

Oracle Labs GraalVM is a research artifact from Oracle Labs, whereas the current OTN release is a technology preview version of it. Henceforth, this release is intended for information purpose only, and may not be incorporated into any contract. This is not a commitment to deliver any material, code, or functionality to Oracle products, and thus should not be relied upon in making any purchase decisions. The development, release and timing of any features or functionality described for products of Oracle remains at the sole discretion of Oracle.

WARNING: This release contains older versions of the JRE and JDK developer debug issues in older systems. They are not updated with

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

The screenshot shows the GitHub organization page for 'Graal Multi-Language VM'. The page features a header with the organization's logo, name, and a brief description: 'Next generation compilation technology supporting Java, Ruby, R, JavaScript, LLVM, and more...'. Below the header, there are tabs for 'Repositories', 'People' (38), and 'Teams' (2). A search bar allows users to 'Find a repository...'. The main content area displays several repositories: 'rubytruffle' (Ruby, 2 stars, 699 forks), 'sulong' (Java, 232 stars, 19 forks), 'graal-core' (Java, 153 stars, 37 forks), 'simplelanguage' (Java, 22 stars, 13 forks), 'examples' (Shell, 0 stars, 0 forks), 'mx' (Python, 13 stars, 26 forks), and 'fastr' (Java, 49 stars, 11 forks). To the right of the repositories is a 'People' section showing a grid of 38 user profiles. At the bottom right of the page is a call-to-action button with the text 'github.com/graalvm'.

Graal Multi-Language VM

Next generation compilation technology supporting Java, Ruby, R, JavaScript, LLVM, and more...

<https://graalvm.github.io>

Repositories People 38 Teams 2

Filters Find a repository...

rubytruffle Ruby ★ 2 ⚡ 699
forked from jruby/jruby
JRuby, an implementation of Ruby on the JVM.
Updated 3 hours ago

sulong Java ★ 232 ⚡ 19
Sulong, a dynamic runtime for LLVM-based languages.
Updated 3 hours ago

graal-core Java ★ 153 ⚡ 37
Graal Compiler & Truffle Partial evaluator.
Updated 7 hours ago

simplelanguage Java ★ 22 ⚡ 13
A simple example language built using the Truffle API.
Updated 7 hours ago

examples Shell ★ 0 ⚡ 0
Updated a day ago

mx Python ★ 13 ⚡ 26
Command-line tool used for the development of Graal projects.
Updated a day ago

fastr Java ★ 49 ⚡ 11
An alternative implementation of the R language, based on the Truffle framework.
Updated 3 days ago

People 38 >

github.com/graalvm

Search for 'github graalvm'

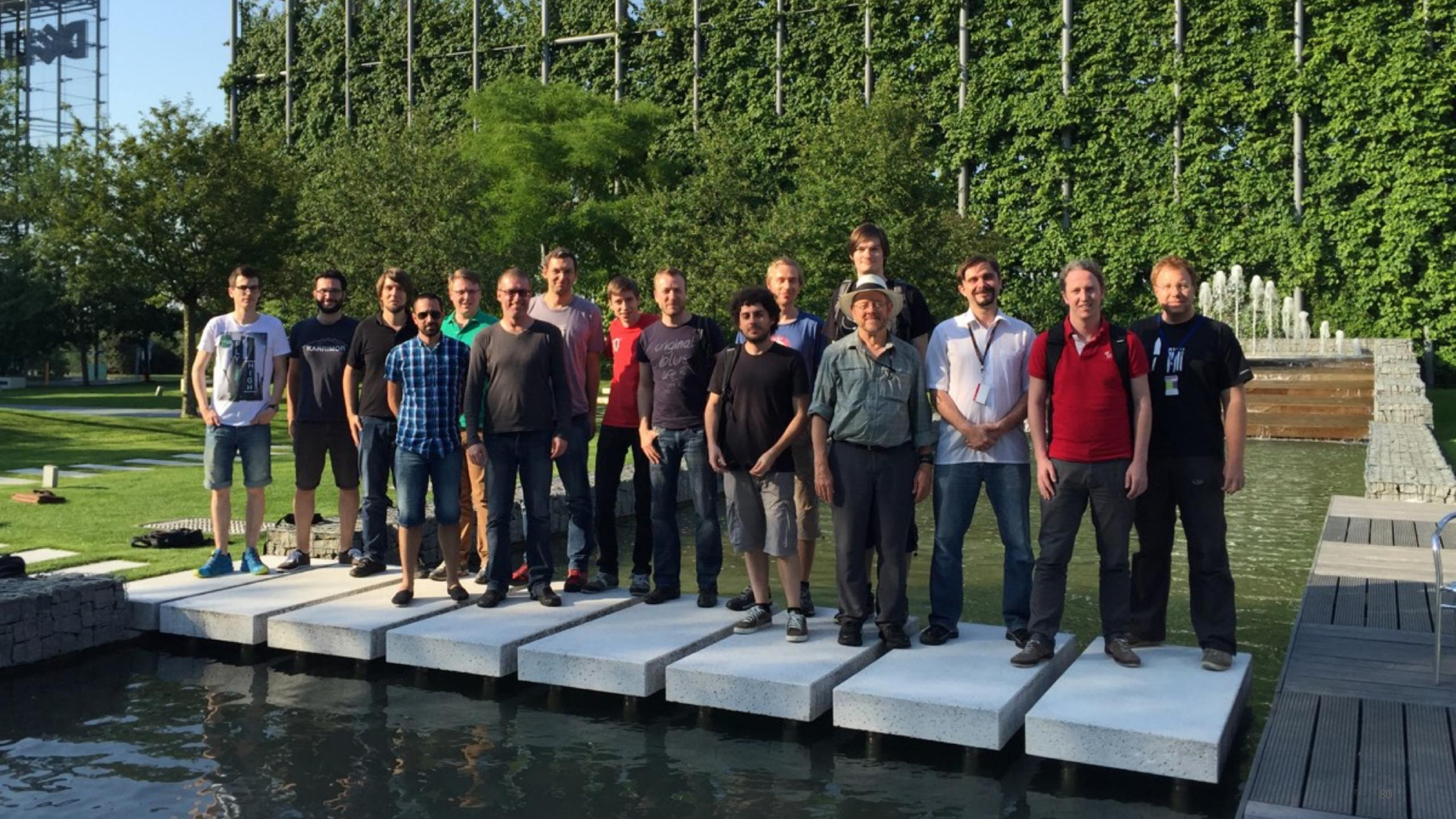
chrisseaton.com/rubytruffle

Freenode #jruby

gitter.im/jruby/jruby

@ChrisGSeaton

‘jruby truffle’



Acknowledgements

Oracle

Danilo Ansaloni
Stefan Anzinger
Cosmin Basca
Daniele Bonetta
Matthias Brantner
Petr Chalupa
Jürgen Christ
Laurent Daynès
Gilles Duboscq
Martin Entlicher
Brandon Fish
Bastian Hossbach
Christian Hummer
Mick Jordan
Vojin Jovanovic
Peter Kessler
David Leopoldseder
Kevin Menard
Jakub Podlešák
Aleksandar Prokopec
Tom Rodriguez

Oracle (continued)

Roland Schatz
Chris Seaton
Doug Simon
Štěpán Šindelář
Zbyněk Šlajchrt
Lukas Stadler
Codrut Stancu
Jan Štola
Jaroslav Tulach
Michael Van De Vanter
Adam Welc
Christian Wimmer
Christian Wirth
Paul Wögerer
Mario Wolczko
Andreas Wöß
Thomas Würthinger

Oracle Interns

Brian Belleville
Miguel Garcia
Shams Imam
Alexey Karyakin
Stephen Kell
Andreas Kunft
Volker Lanting
Gero Leinemann
Julian Lettner
Joe Nash
David Piorkowski
Gregor Richards
Robert Seilbeck
Rifat Shariyar

Alumni

Erik Eckstein
Michael Haupt
Christos Kotselidis
Hyunjin Lee
David Leibs
Chris Thalinger
Till Westmann

JKU Linz

Prof. Hanspeter Mössenböck
Benoit Daloze
Josef Eisl
Thomas Feichtinger
Matthias Grimmer
Christian Häubl
Josef Haider
Christian Huber
Stefan Marr
Manuel Rigger
Stefan Rumzucker
Bernhard Urban

University of Edinburgh

Christophe Dubach
Juan José Fumero Alfonso
Ranjeet Singh
Toomas Remmelg

LaBRI

Floréal Morandat

University of California, Irvine

Prof. Michael Franz
Gulfem Savrun Yeniceri
Wei Zhang

Purdue University

Prof. Jan Vitek
Tomas Kalibera
Petr Maj
Lei Zhao

T. U. Dortmund

Prof. Peter Marwedel
Helena Kotthaus
Ingo Korb

University of California, Davis

Prof. Duncan Temple Lang
Nicholas Ulle

University of Lugano, Switzerland

Prof. Walter Binder
Sun Haiyang
Yudi Zheng

Safe Harbor Statement

The preceding is intended to provide some insight into a line of research in Oracle Labs. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. Oracle reserves the right to alter its development plans and practices at any time, and the development, release, and timing of any features or functionality described in connection with any Oracle product or service remains at the sole discretion of Oracle. Any views expressed in this presentation are my own and do not necessarily reflect the views of Oracle.

Integrated Cloud Applications & Platform Services

ORACLE®