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# Designing an Intuitive Language-Agnostic Integration of Foreign Objects in Ruby

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# Who am I?

Benoit Daloze

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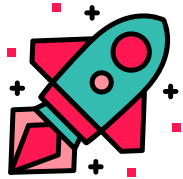
- TruffleRuby lead at Oracle Labs, Zurich
- Worked on TruffleRuby since 2014
- PhD on parallelism in dynamic languages
- Maintainer of ruby/spec
- CRuby (MRI) committer

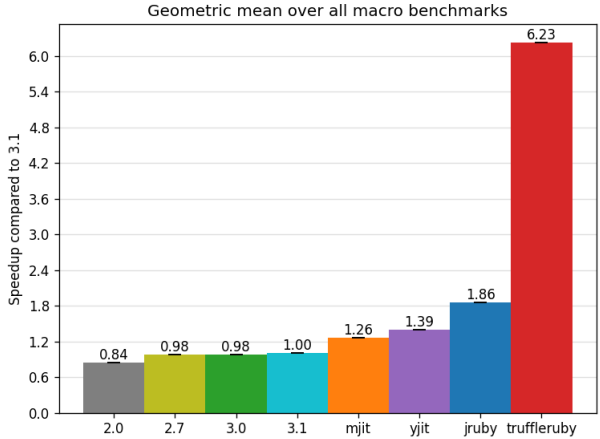
# TruffleRuby



TRUFFLE
RUBY

- A high-performance Ruby implementation
- Uses the GraalVM JIT Compiler
- Targets full compatibility with CRuby 3.0, including C extensions
- GitHub: oracle/truffleruby, Twitter: @TruffleRuby
  Website: `https://graalvm.org/ruby`

# TruffleRuby: Peak performance on yjit-bench (14 benchmarks)




From `https://eregon.me/blog/2022/01/06/benchmarking-cruby-mjit-yjit-jruby-truffleruby.html`

Interoperability with other languages,

and their objects, aka foreign objects




# Once upon a time there was a foreign object

```
# In a Ruby file (.rb)
foreign_object = Polyglot.eval 'js', '({ a: 1, b: 2 })'
```

- What can I do with this object?
- Can I print it?
- Can I access members?
- Can I ask its class? Does it have a Ruby class?
- What methods are available on it?




# GraalVM and Truffle's InteropLibrary (130 methods)

Types:

- Null
- Boolean
- String
- Number
- Date, Time or TimeZone
- Duration
- Exception
- Meta-Object
- Iterator

Traits:

- executable, instantiable
- members
- hash entries
- array elements, buffer elements
- iterable
- pointer
- associated metaobject (getMetaObject)
- declaring meta object
- source location
- identity
- language
- scope




# Which semantics to prefer?

```ruby
# In a Ruby file (.rb)
js_array = Polyglot.eval 'js', '[1, 2, 3]'
js_array.map { |x| x * 2 }
```

- Should that use JS's `Array.prototype.map()` or Ruby's `Array#map` ?
- It should be Ruby's `Array#map`, because this helps more to make existing Ruby code handle foreign objects just fine, just like Ruby objects.
- Still possible to call the foreign object's method explicitly:
  `Interop.invoke_member(js_array, :map, proc { |e, idx| e + idx })`

# To give a Ruby class for foreign objects or not?

Possibilities:

- Do not give a Ruby class. What should `foreign.class` return then?
  How to make code which relies on `object.class` returning a Ruby class work?
- Give the same Ruby class for all foreign objects
- Give a Ruby class based on the traits (and type) of the foreign objects.
  e.g. foreign object with array elements: ObjectTrait + ArrayTrait = ForeignArrayObject.
  Makes it easy to add methods for a trait, and understand what "kind of object" it is.
- Give a unique Ruby class per foreign object
- Give a per-foreign-metaobject Ruby class

# Method lookup for foreign objects

Method lookup for Ruby objects:

- Search method in object.class.ancestors
- Call `method_missing(name, *args)`

Method lookup for foreign objects:

- Search method in object.class.ancestors
- invokeMember(name, *args) if isMemberInvocable(name)
- readMember(name) if isMemberReadable(name) `&&` args.empty? (for `obj.foo`)
- Call `method_missing(name, *args)`

# A foreign object

- Can I print it?

```
p foreign_object
#<Polyglot::ForeignObject[JavaScript] Object:0x1221a708 a=1, b=2>
puts foreign_object
#<Polyglot::ForeignObject[JavaScript] {a: 1, b: 2}>
```

- Can I access members?

```
foreign_object[:a] # => 1
foreign_object.a # => 1
foreign_object.instance_variables # => [:a, :b]
```




# A foreign object

- Can I ask its class? Does it have a Ruby class?

```
foreign_object.class
# => Polyglot::ForeignObject
foreign_object.class.ancestors
# => [Polyglot::ForeignObject, Polyglot::ObjectTrait,
#     Object, Kernel, BasicObject]
```

- What methods are available on it?

```
foreign_object.methods
# => [:[], :[]=, :==, :nil?, :instance_variables, :hash, :send, ...
```




# A foreign array

```
foreign_array = Polyglot.eval 'js', '[1, 2, 3]'
```

- Can I read and write elements?

```
foreign_array[0] = foreign_array[1] + 2
```

- Can I iterate it? Can I use any method from `Enumerable`?

```
foreign_array.map { |e| e * 3 }.select { |e| e.even? }
```

- Does it have a Ruby class? What is the hierarchy?

```
foreign_array.class
# => Polyglot::ForeignArray
foreign_array.class.ancestors
# => [Polyglot::ForeignArray, Polyglot::ArrayTrait,
#     Polyglot::IterableTrait, Enumerable,
#     Polyglot::ForeignObject, Polyglot::ObjectTrait,
#     Object, Kernel, BasicObject]
```

# Going further

```
42 + foreign_number

foreign_string.capitalize

foreign_array.each_slice { |a, b| ... }

foreign_map.each_pair { |key, value| ... }

begin
  foreign_object.foo()
rescue Exception => foreign_exception
  puts foreign_exception.message, foreign_exception.backtrace
end
```

# A look at the implementation

```
module Polyglot
  module HashTrait
  module ArrayTrait
  module ExceptionTrait
  module ExecutableTrait
  module InstantiableTrait
  module IterableTrait
  module IteratorTrait
  module MetaObjectTrait
  module NullTrait
  module NumberTrait
  module PointerTrait
  module StringTrait
  module ObjectTrait
end
```

# A look at the implementation

```
module Polyglot
  class ForeignObject < Object
    include ObjectTrait
  end

  class ForeignException < Exception
    include ObjectTrait
    include ExceptionTrait
  end
end
```




# A look at the implementation

```ruby
module HashTrait
  def [](key)
    Truffle::Interop.read_hash_value_or_default(self, key, nil)
  end
end

module ArrayTrait
  def [](index)
    size = Truffle::Interop.array_size(self)
    index += size if index < 0
    return nil if index < 0 || index >= size
    Truffle::Interop.read_array_element(self, index)
  end
end
```

# Inner contexts

- JavaScript is single-threaded, i.e., can only be executed on one thread at a time
- Ruby is multi-threaded, many Ruby programs and the standard library use multiple threads
- In practice, this means Truffle errors when Ruby tries to create additional threads when JavaScript is used in the same Context
- Truffle inner contexts to the rescue! Ruby can have multiple threads in the root context, and JavaScript is on its own in an inner context.
- What about passing objects between these contexts? All is transparently proxied via InteropLibrary with `TruffleContext#eval(String language, Source source)`!

# Polyglot::InnerContext

```ruby
Polyglot::InnerContext.new do |ctx|
  js_object = ctx.eval('js', '({ a: 1 })')
  # => #<Polyglot::ForeignObject[JavaScript] Object:0x46c805be a=1>

  js_function = ctx.eval('js', '(function(arg) { console.log(arg) })')
  ruby_object = [1, 2, 3]
  js_function.call(ruby_object)
  # => 1,2,3
end
```

- `js_object` is a wrapper object implementing InteropLibrary and forwarding all messages to the real JavaScript object. It looks exactly like a foreign object to Ruby and there is no difference
- `ruby_object` is wrapped similarly, but for the other direction

# Gems using this deep integration

- `rails/execjs`: Executing JavaScript from Ruby. Each `ExecJS::Context` has its own isolated state.

- `rubyjs/mini_racer`: Embedded JavaScript engine in Ruby. Supports attaching Ruby lambdas and calling them from JavaScript and many more features.

For both:

- Their GraalVM backend is written entirely in Ruby using ways from this talk.

- They use Truffle inner contexts for isolation (and to let the Ruby context use multiple threads).

# Try it yourself

- Get GraalVM, either a release or from `https://github.com/graalvm/graalvm-ce-dev-builds`
- `export PATH=graalvm/bin:$PATH`
- Install Ruby: `gu install ruby`
- 
```
ruby --polyglot --jvm -e 'Polyglot::InnerContext.new { |ctx|
  p ctx.eval "js", "({ a: 1 })" }'
```
- Start a shell: `ruby --polyglot --jvm`

# Conclusion

For best integrations of foreign objects:

- They should be given a class/meta object of the language representing their interop traits
- They should have the same methods as corresponding objects of the language
- Using inner context avoids the issue of multithreading incompatible with single-threaded languages
- When the integration is deep enough, a lot of existing code just works on foreign objects