Ruby.inspect

Koichi Sasada

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Summary.inspect

- Introduction of new Ruby
  - Stable 2.1
  - Next version of 2.2
- How to inspect your application behavior
  - With tools & services
  - Make a tools by inspection primitives
  - Inspection from outside

“Today’s Message”.inspect

Become
a Low-level
engineer
(somtimes)

Ko1.inspect
#=> <Ko1: @name="Koichi Sasada">

- Koichi Sasada a.k.a. ko1
- From Japan
- 笹田 (family name) 耕一 (given name) in Kanji character
  - "Ichi" (Kanji character "一") means "1" or first
  - This naming rule represents I'm the first son of my parents
  - Ko"ichi" → ko1

Ko1.inspect
#=> <Ko1: @job="Programmer">

- CRuby/MRI committer
  - Virtual machine (YARV) from Ruby 1.9
  - YARV development since 2004/1/1
  - Recently, improving GC performance
- Matz team at Heroku, Inc.
  - Full-time CRuby developer
  - Working in Japan
- Director of Ruby Association

RubyAssociation.inspect
#=>

Ruby Association

The Ruby Association was founded to further development of the programming language Ruby.

The goals of the Ruby Association are to improve relationship between Ruby-related projects, communities and businesses, and to address issues connected with using Ruby in an enterprise environment.

Quoted from http://www.ruby.or.jp/en/

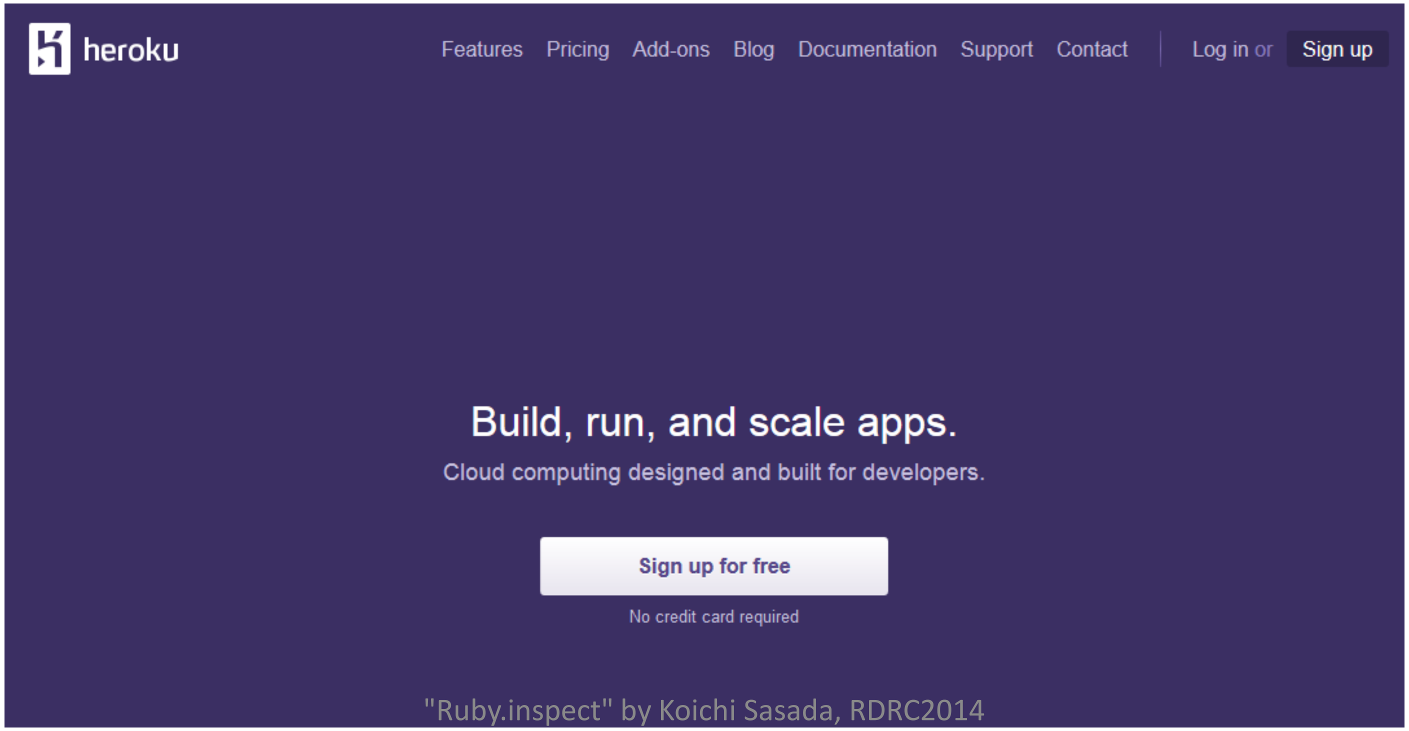
Ruby Association

- Foundation to encourage Ruby dev. and communities
- Activities
  - Ruby programmer certification program
    - http://www.ruby.or.jp/en/certification/examination/ in English
  - Grant project. We have selected **3 proposals** in 2013
  - Ruby Prize
    - To recognize the efforts of “New members” to the Ruby community
    - http://www.ruby.or.jp/en/news/20140627.html
  - Maintenance of Ruby (Cruby) interpreter
    - Now, it is for Ruby 2.0.0
  - Events, especially RubyWorld Conference
    - http://www.rubyworld-conf.org/
  - **Donation** for Ruby developments and communities

heroku

- Heroku, Inc. http://www.heroku.com

You should know about Heroku!!



Build, run, and scale apps.

Cloud computing designed and built for developers.

No credit card required

- Heroku, Inc. http://www.heroku.com
- Heroku supports OSSs / Ruby development
  - Many talents for Ruby, and also other languages
  - Heroku employs 3 **Ruby interpreter core developers**
    - Matz
    - Nobu
    - Ko1 (me)
  - We name our group “Matz team”

“Matz team”.inspect

札幌
青森
秋田
盛岡
日本海
日本
仙台
新潟
福島
富山
長野
金沢
甲府
東京
松江
鳥取
名古屋
大阪
静岡
津
山口
広島
岡山
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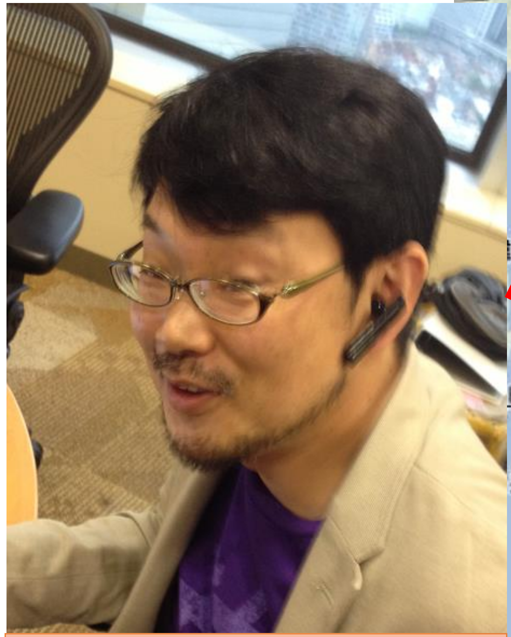
高知
長崎
熊本
宮崎
鹿児島


Matz @ Shimane
Title collector

Nobu @ Tochigi
Patch monster

ko1 @ Tokyo
EDD developer

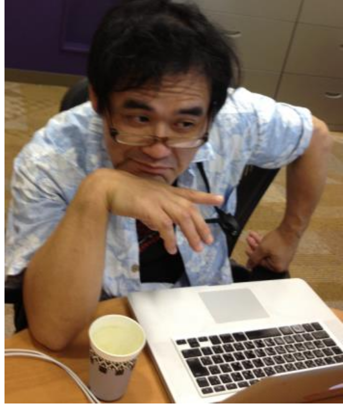
Matz.inspect
#=> Title collector

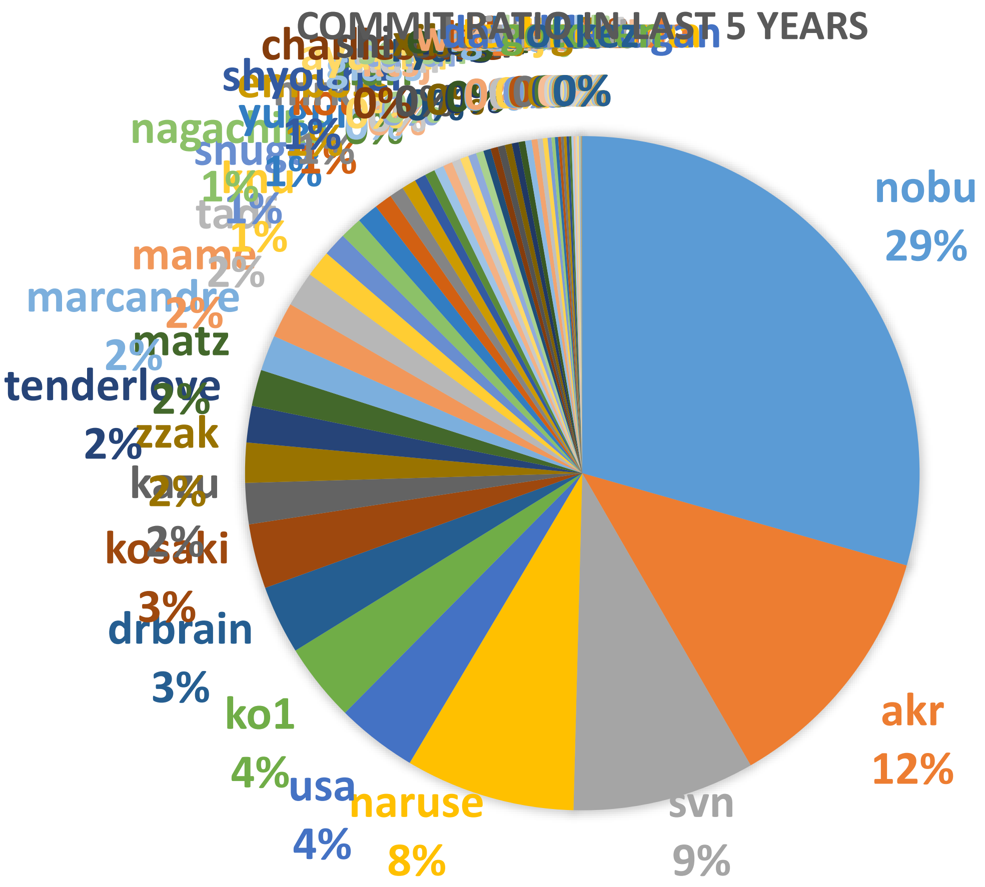
- He has so many (job) title
  - Chairman - Ruby Association
  - Fellow - NaCl
  - Chief architect, Ruby - Heroku
  - Research institute fellow – Rakuten
  - Chairman – NPO mruby Forum
  - Senior researcher – Kadokawa Ascii Research Lab
  - Visiting professor – Shimane University
  - Honorable citizen (living) – Matsue city
  - Honorable member – Nihon Ruby no Kai
  - …
- This margin is too narrow to contain

Nobu.inspect
#=> Patch monster

- Great patch creator

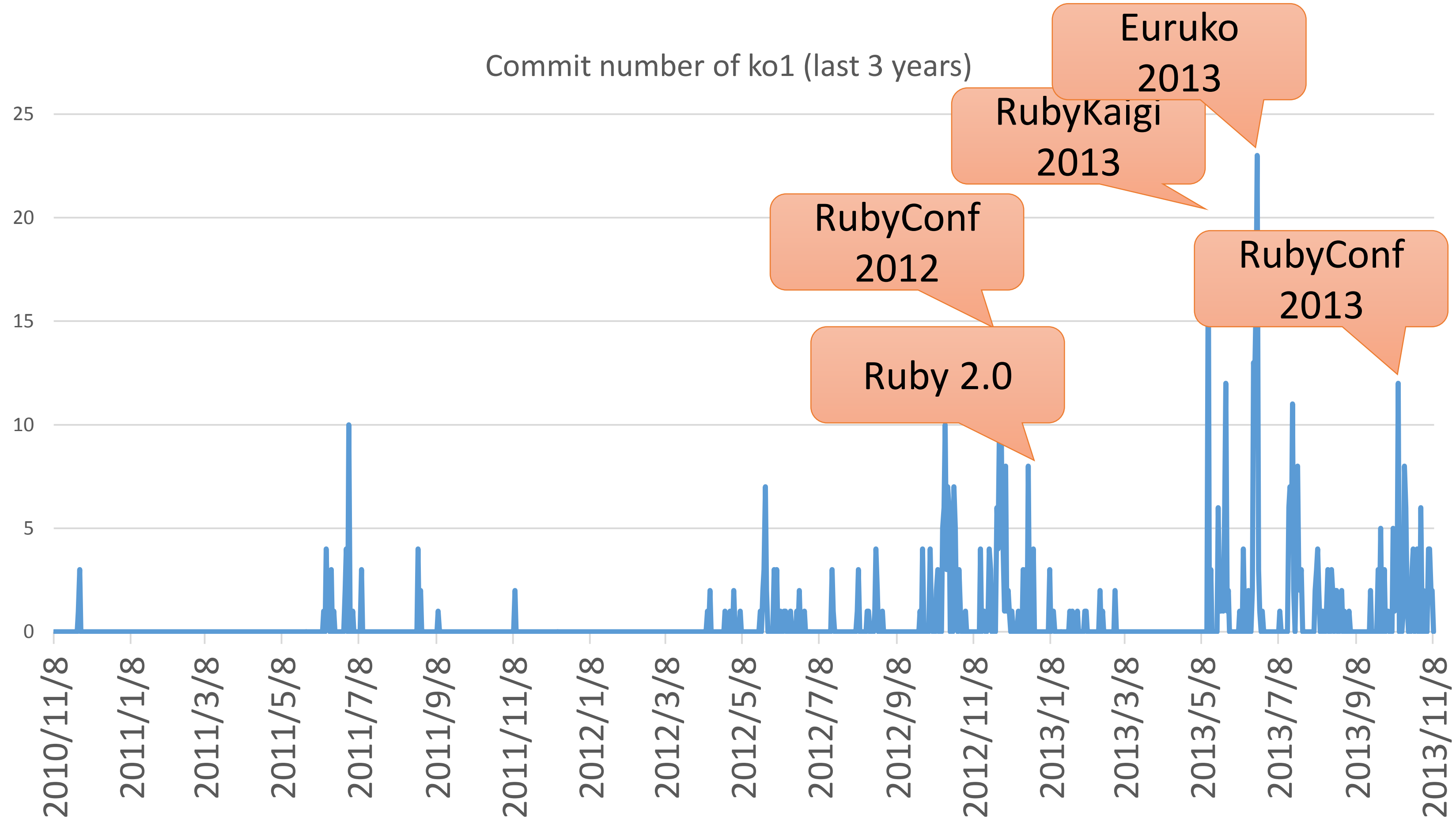
Nobu is Great Patch Monster





"Ruby.inspect" by Koichi Sasada, RDRC2014

Ko1.inspect
#=> EDD developer



EDD: Event Driven Development

“Mission of Matz team”.inspect

- **Improve quality of next version of CRuby**
  - Matz decides a spec finally
  - Nobu fixed huge number of bugs
  - Ko1 improves the performance

http://www.flickr.com/photos/loginesta/5266114104

“Ruby 2.1”.inspect
#=> Current stable

“Ruby 2.1”.inspect
#=> a bit old Ruby

- **Ruby 2.1.0** was released at **2013/12/25**
  - New features
  - Performance improvements
- **Ruby 2.1.1** was released at 2014/02/24
  - Includes many bug fixes found after 2.1.0 release
  - Introduce a new GC tuning parameter to change generational GC behavior (introduce it later)
- **Ruby 2.1.2** was released at **2014/05/09**
  - Solves critical bugs (OpenSSL and so on)

Ruby 2.1 the biggest change Version policy

- Change the versioning policy
  - Drop “patch level” in the version
  - Teeny represents patch level
    - Release new teeny versions about every 3 month
    - Teeny upgrades keep compatibility
  - Minor upgrades can break backward compatibility
    - We make an effort to keep compatibility

      (recently. Remember Ruby 1.9 ☺)

Ruby 2.1 New syntax

- New syntaxes
  - Required keyword parameter
  - Rational number literal
  - Complex number literal
  - \`def’ returns symbol of method name

```
    **** COMMODORE 64 BASIC V2 ****
 64K RAM SYSTEM  38911 BASIC BYTES FREE
READY.
SHIFTRUNSTOP.CO.UK

?SYNTAX  ERROR
READY.
```

http://www.flickr.com/photos/rooreynolds/4133549889

Ruby 2.1 Syntax
Required keyword parameter

- Keyword argument (from Ruby 2.0.0)
  - def foo(a: 1, b: 2); end
  - `a’ and `b’ are optional parameters
  - OK: foo(); foo(a: 1); foo(a: 1, b: 2); foo(b: 2)
- Required keyword argument from 2.1
  - def foo(a: 1, b:)
  - `a’ is optional, but `b’ is required parameter
  - OK: foo(a: 1, b: 2); foo(b: 2)
  - NG: foo(); foo(a: 1)

Ruby 2.1 Syntax Rational number literals

- To represent ½, in Ruby “Rational(1, 2)”

  → Too long!!
- Introduce “r” suffix

  ½ → 1/2r
- “[digits]r” represents “Rational([digits], 1)”
- ½ → 1/2r
  - 1/2r #=> 1/Rational(2, 1)
  - 1/Rational(2, 1) #=> Rational(1/2)

Ruby 2.1 Syntax
Complex number literals

- We already have “Integer#i” method to make imaginary number like “1+2.i”
- We already introduced “r” suffix for Rational

  → No reason to prohibit “i” suffix!!
- [digits]i represents “Complex(0, [digits])”
- 1+2i #=> 1+Complex(0, 2)
- 1+Complex(0, 2) #=> Complex(1, 2)

- You can mix “r” and “i” suffix

Ruby 2.1 Syntax
Return value of `def’ syntax

- Return value of method definition
  - Method definition syntax returns symbol of defined method name
  - `def foo; …; end’ #=> :foo
- Method modifier methods
  - Example:
    - private def foo; …; end
    - public static void def main(args); …; end

Ruby 2.1 Runtime new features

- String#scrub
- Process.clock_gettime
- Binding#local_variable_get/set
- Bignum now uses GMP (if available)
- Extending ObjectSpace

Performance improvements

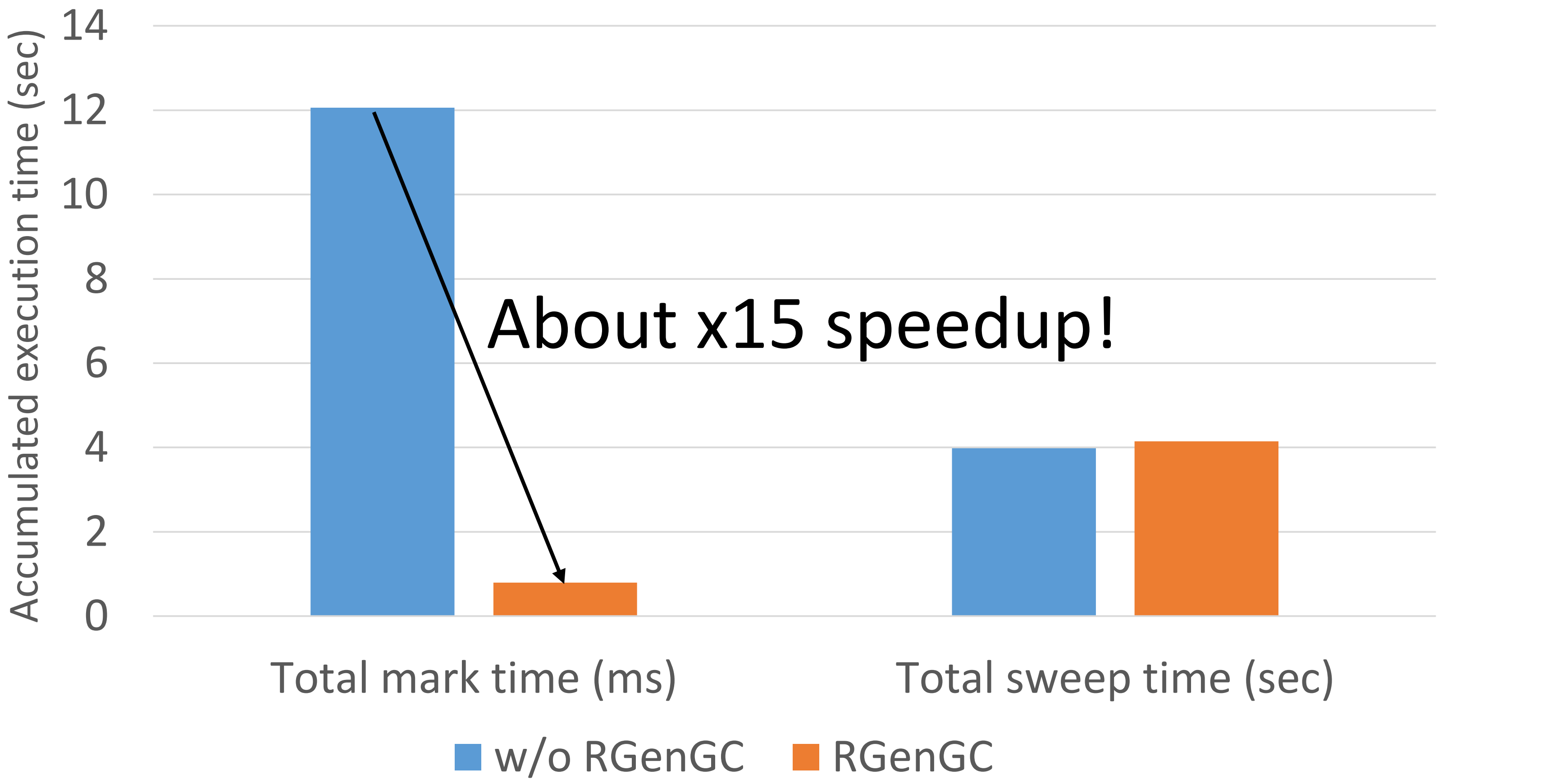
- Optimize “string literal”.freeze
- Sophisticated inline method cache
- Introducing Generational GC: RGenGC

RGenGC: Generational GC for Ruby

- RGenGC: Restricted Generational GC
  - Generational GC (minor/major GC uses M&S)
  - **Dramatically speedup for GC-bottleneck applications**
  - New generational GC algorithm allows mixing “Write-barrier protected objects” and “WB unprotected objects”

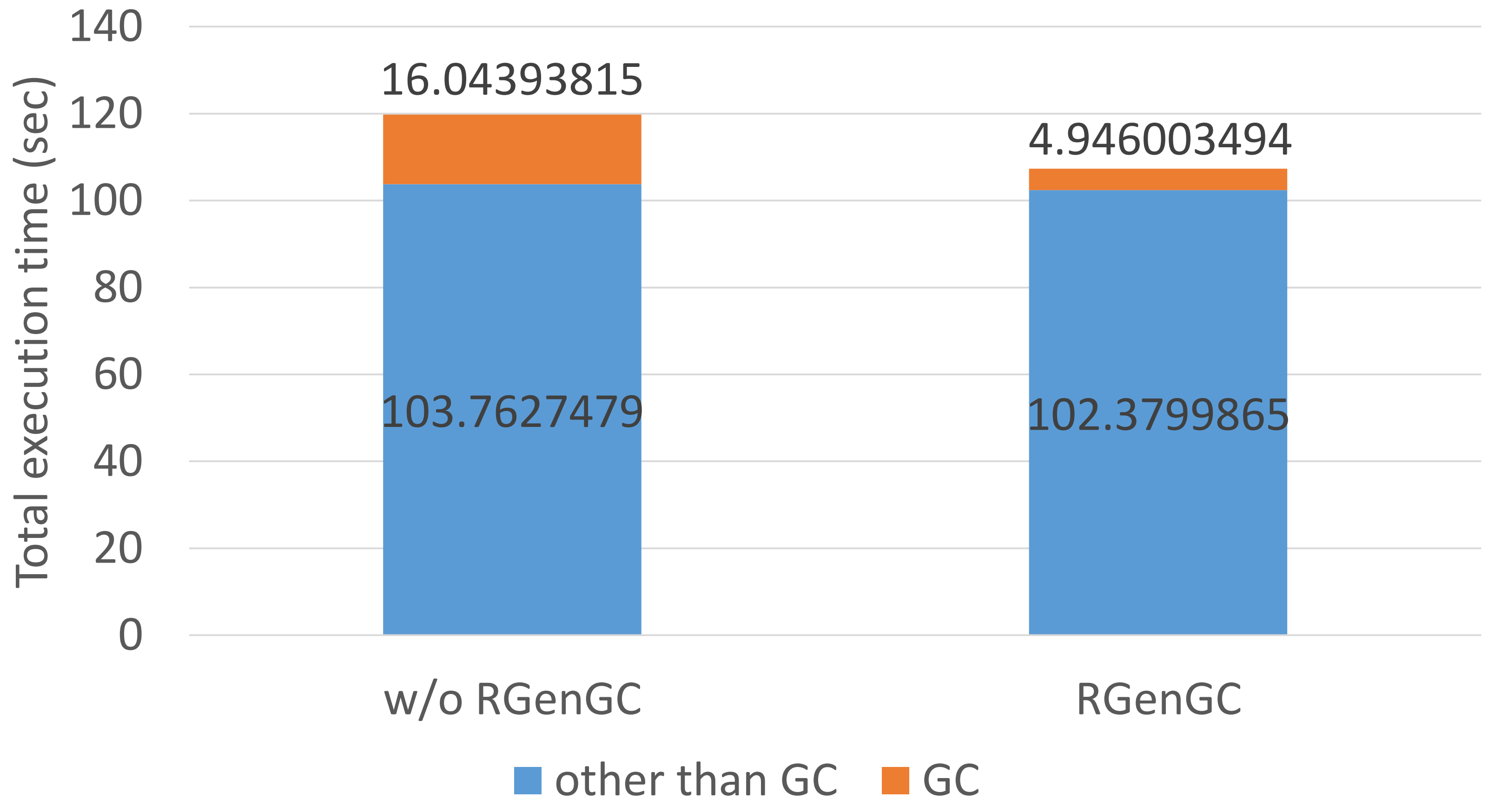
  → **No** (mostly) **compatibility issue** with C-exts
- Inserting WBs gradually
  - We can concentrate WB insertion efforts for major objects and major methods
  - Now, most of objects (such as Array, Hash, String, etc.) are WB protected
    - Array, Hash, Object, String objects are very popular in Ruby
    - Array objects using **RARRAY_PTR() change to WB unprotected** objects (called as Shady objects), so existing codes still works.

RGenGC
Performance evaluation (RDoc)



* Disabled lazy sweep to measure correctly.

RGenGC
Performance evaluation (RDoc)



* 12% improvements compare with w/ and w/o RGenGC

* Disabled lazy sweep to measure correctly.

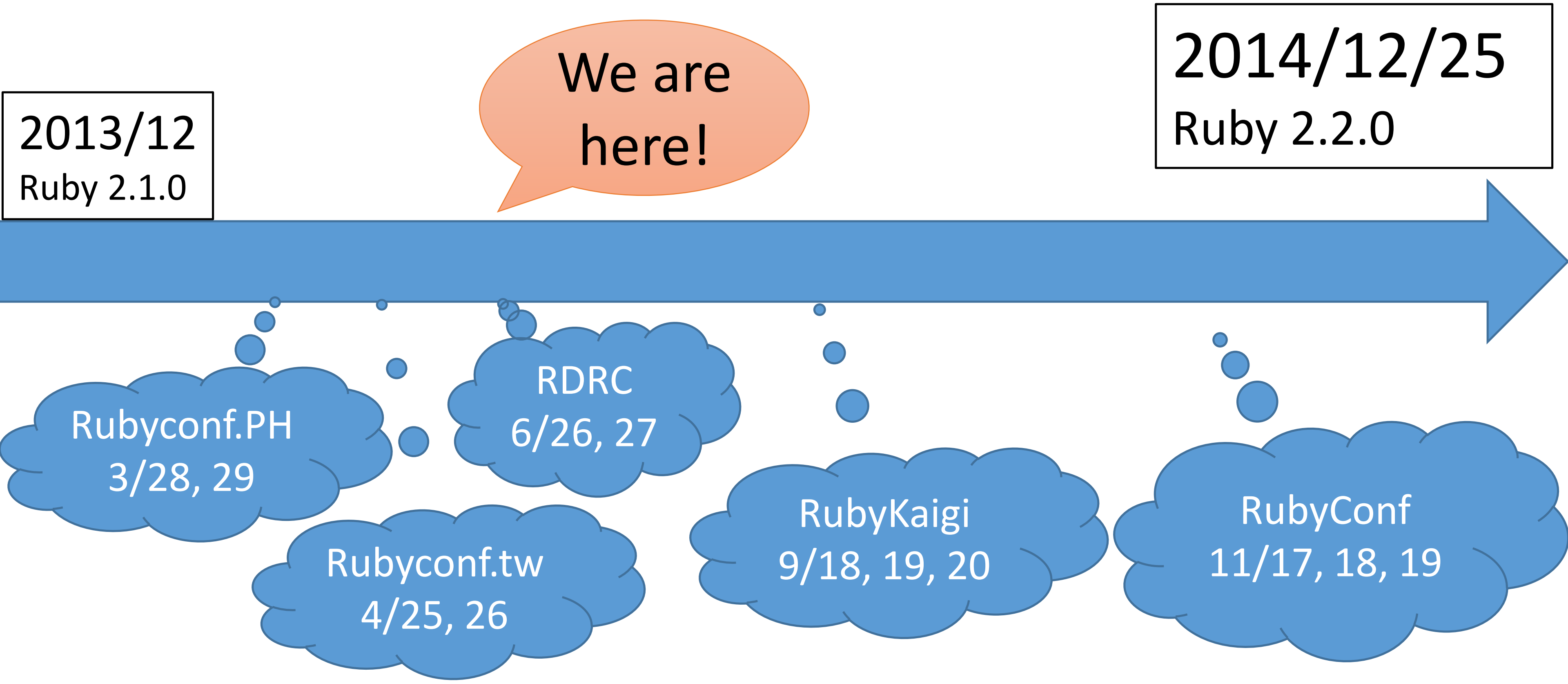
http://www.flickr.com/photos/adafruit/8483990604

“Ruby 2.2”.inspect #=> Next version

Schedule of Ruby 2.2

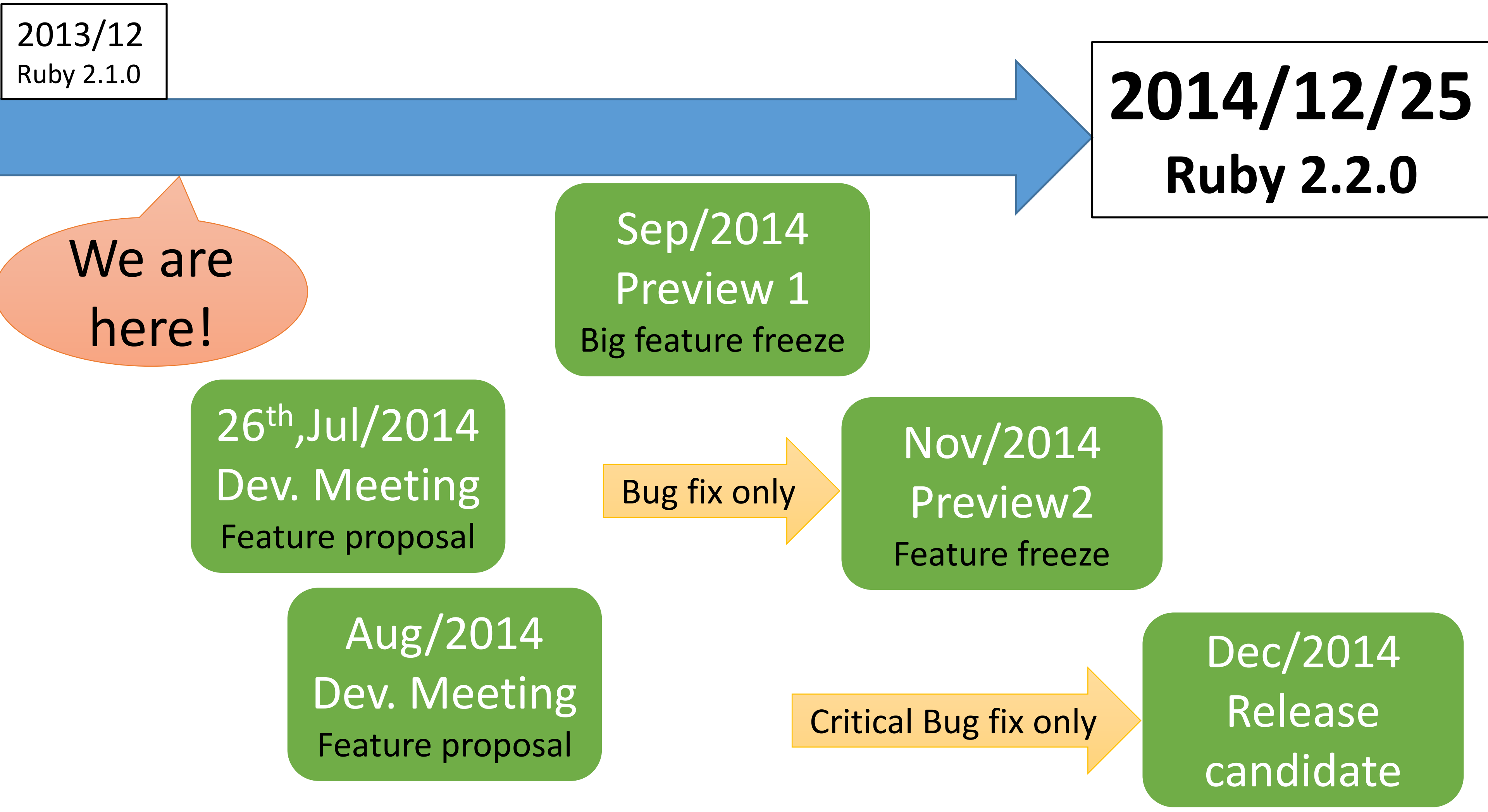
- Not published officially
- Schedule draft is available by Naruse-san
  - https://bugs.ruby-lang.org/projects/ruby-trunk/wiki/ReleaseEngineering22

Ruby 2.2 schedule



Events are important for EDD (Event Driven Development) Developers

Ruby 2.2 (rough) schedule



2.2 big features (planned)

- New syntax: not available now
- New method: no notable methods available now
- Libraries:
  - Minitest and test/unit will be removed (provided by bundled gem)

2.2 internal changes

- Internal
    - C APIs
        - Hide internal structures for Hash, Struct and so on
        - Remove obsolete APIs
    - GC
        - **Symbol GC (merged recently)**
        - **2age promotion strategy for RGenGC**
        - **Incremental GC** to reduce major GC pause time
    - VM
        - More sophisticated method cache

Symbol GC

- Symbols remain forever → Security issue
  - "n.times{|i| i.to_s.to_sym}"
    creates "n" symbols and they are never collected
- Symbol GC: Collect dynamically created symbols

http://www.flickr.com/photos/donkeyhotey/8422065722

Break

Ruby.inspect

https://www.flickr.com/photos/theloushe/4640871734/

Inspecting Ruby

- You may want to know “what happen?” on your application
- Ruby has many “inspecting” features to see applications behavior
    - Some features are supported only by MRI/CRuby

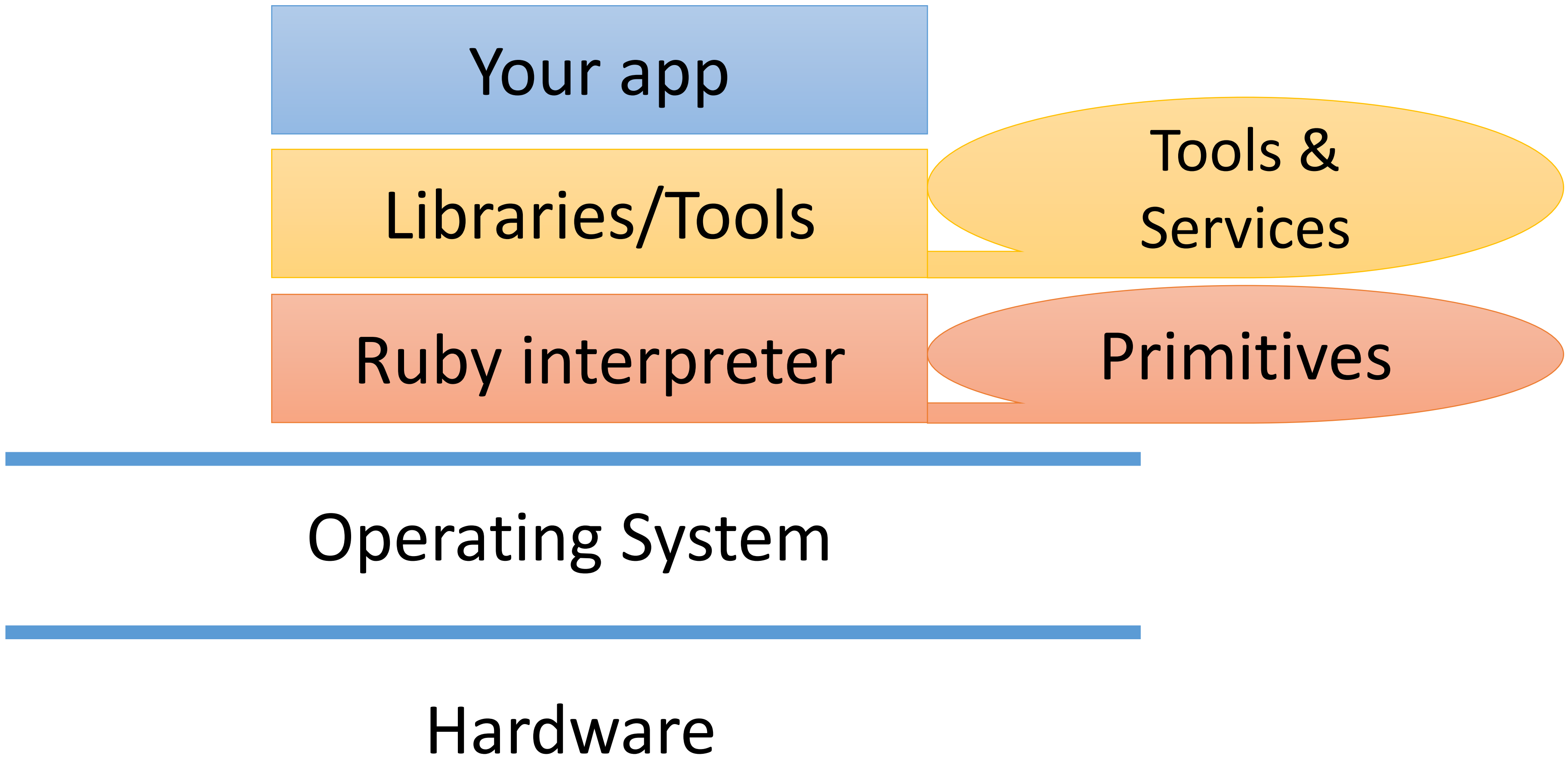
Why “inspect” is needed?

- Code reading
- Debugging
- Performance tuning
- Understanding Ruby’s implementation
- …

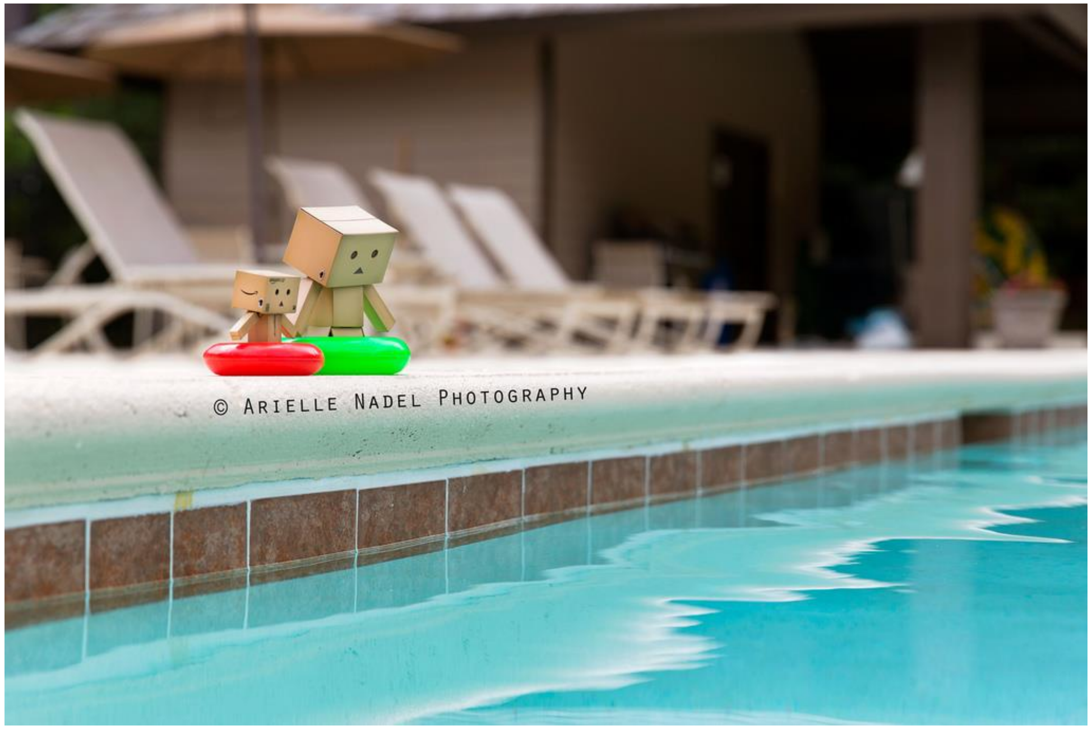
How to inspect your app?

- Use “Tools and services” for Ruby
- Make tools with “Standard inspect features”
- Inspect Ruby process itself from outside

Inspection features on computer layers



Tools & Services



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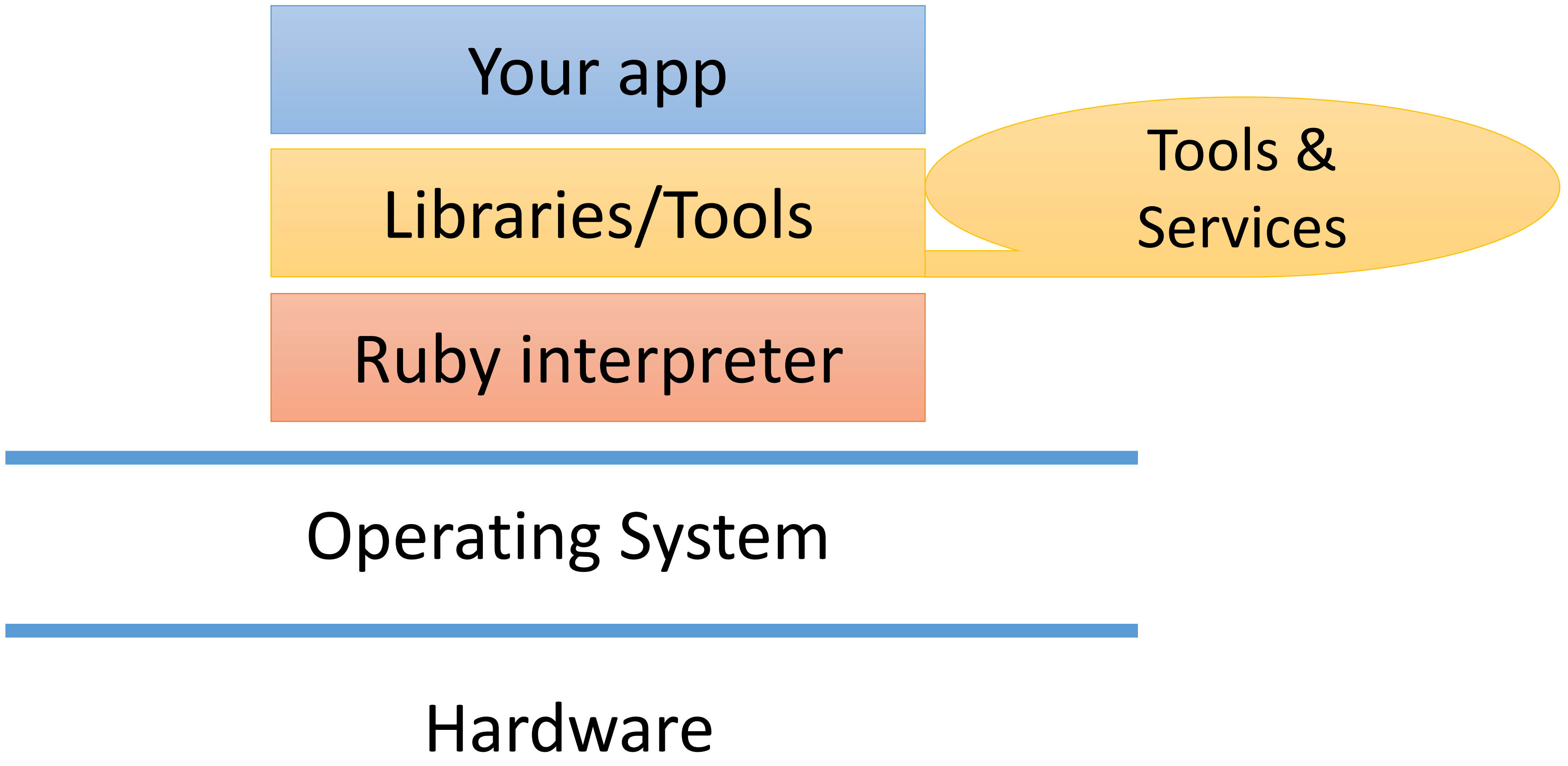
Tools & Services



Tools & Services

- Benchmarking
  - benchmark
  - benchmark/ips
- Profiling
  - [Time] ruby-prof (deterministic profiler)
  - [Time] perftools.rb, stackprof, rblineprof (sampling profilers)
  - [Memory] GCTracer, AllocationTracer, …
  - [Total] NewRelic
- Debugging
  - ruby-debug
  - byebug (2.0~)
  - tracer (standard library)

New Relic

- **"Dive into Ruby VM Stats with New Relic"** **http://blog.newrelic.com/2014/04/23/ruby-vm-stats/**
- **"Ruby VM measurements"** https://docs.newrelic.com/docs/ruby/ruby-vm-stats

IMPORTANT

You can use New Relic very easily on Heroku as an Add-on

Tools & Services

You can find manuals for tools!

Enjoy!

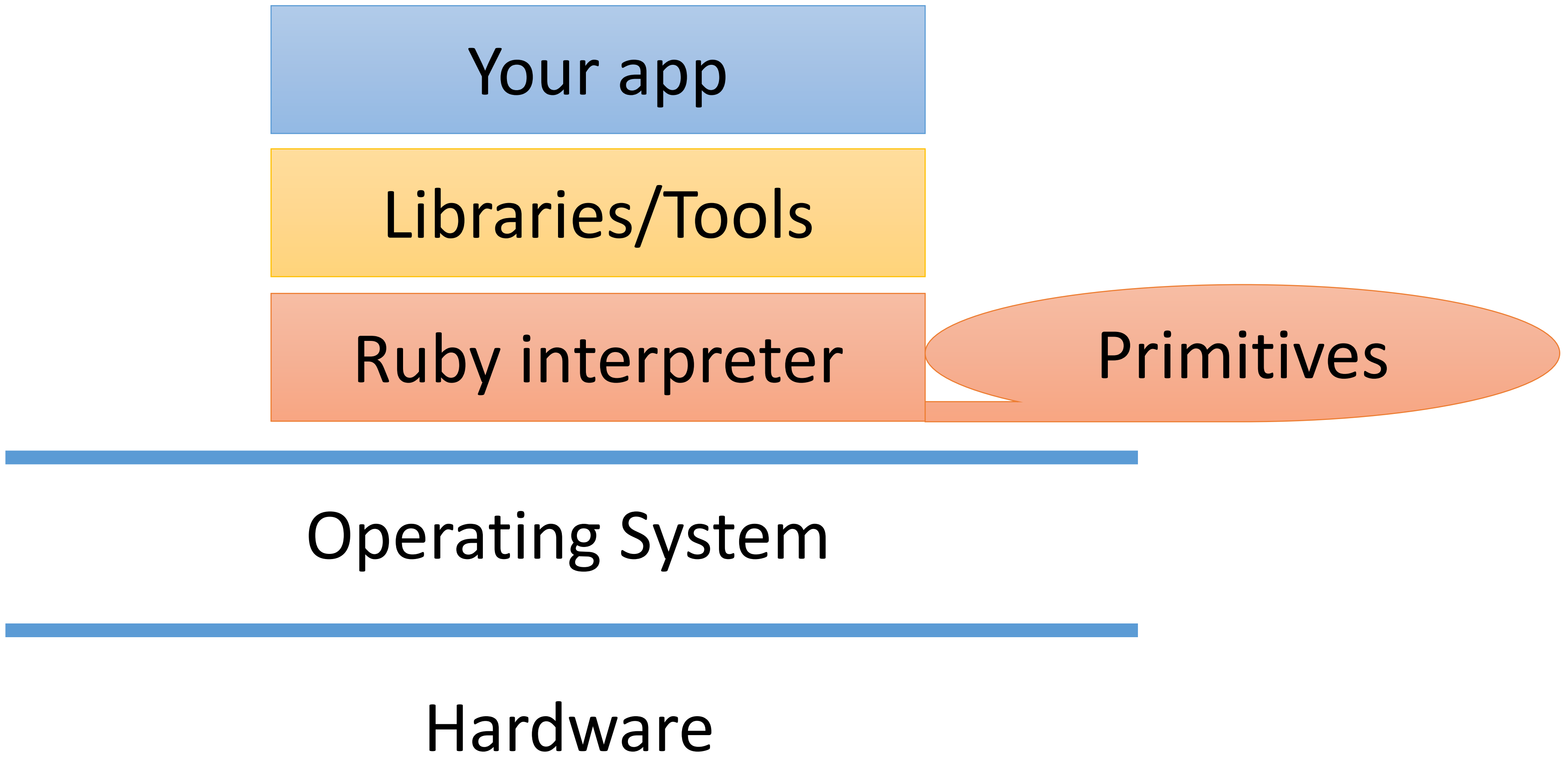
- "Debugging Ruby Performance" by Aman Gupta will help you to survey

https://speakerdeck.com/tmm1/debugging-ruby-performance

Ruby's Inspection primitives
How to make inspection tools?

https://www.flickr.com/photos/fiddleoak/6691220069/

Inspection features on computer layers



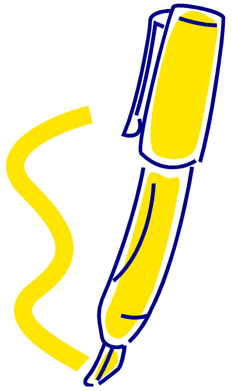
Ruby’s Inspection primitives

- Show object
- Reflections
- Statistics
- Tracing

Show objects Kernel#p and pp library

- Debug print
  - Kernel#p(obj): print result of “obj.inspect”
  - pp: print pretty printed result
  - Both print onto STDOUT
  - You can modify Object#inspect for better representation
- Everyone love to use ☺
  - Traditional “printf” debug

Show objects
Kernel#p and pp library



- Tips
  - Use p() method with keyword argument

```
foo=[1, 2]; bar={a: 1, b: ['bar']}
p foo: foo, bar: bar
#=> {:foo=>[1, 2],
         :bar=>{:a=>1, :b=>["bar"]}}
```

  - PP.pp(obj, STDERR) prints onto STDERR, not STDOUT

Show objects ObjectSpace::dump(obj)

- Dump the contents of a ruby object as JSON
  - Not for serializing, but for seeking internal "implementation specific" information
- ObjectSpace::dump_all() dumps all objects and relations
  - It will help us to find out memory leak (unexpected relation to prevent GC collection)
- Introduced from Ruby 2.1

Reflections

https://www.flickr.com/photos/cbpphotos/11934804573

Reflections

- Stack trace
  - caller, caller_locations
  - Thread#backtrace, Thread#backtrace_locations
- Access variables
  - Object#instance_variable_get(name)
  - Binding#local_variable_get(name)
  - Kernel#global_variable_get(name)
  - Module#class_variable_get(name)
  - Module#const_get
- Definitions
  - #source_location, #arity, #parameters for Method and Proc objects
- Last weapon
  - Kernel#eval, Object#instance_eval, …

Getting stack trace
caller, caller_locations

- caller() returns Backtrace strings array.
  - like ["t.rb:1:in `<main>'"]
- caller_locations() retuns OO style backtrace information
  - caller_locations(0).each{|loc|
    p "#{loc.path}:#{loc.lineno}“}
  - No need to parse “backtrace” string!

Getting more rich trace
debug_inspector gem

- Binding information for each frame
  - General version of caller_binding
  - https://github.com/banister/debug_inspector

Accessing variables

- Object#instance_variable_get(name)
- Binding#local_variable_get(name)
- Kernel#global_variable_get(name)
- Module#class_variable_get(name)
- Module#const_get

Getting definitions

- Method#source_location, Proc#source_location
- Method#arity, Proc#arity
- Method#parameters, Proc#parameters

Evil eval

- eval series
  - Kernel#eval, Binding#eval
  - Object#instance_eval
  - Module#module_eval
- Can do everything
  - Accessing any variable (getting and setting)
  - Evaluate any expression
  - Strong, but dangerous

Statistics

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Statistics features

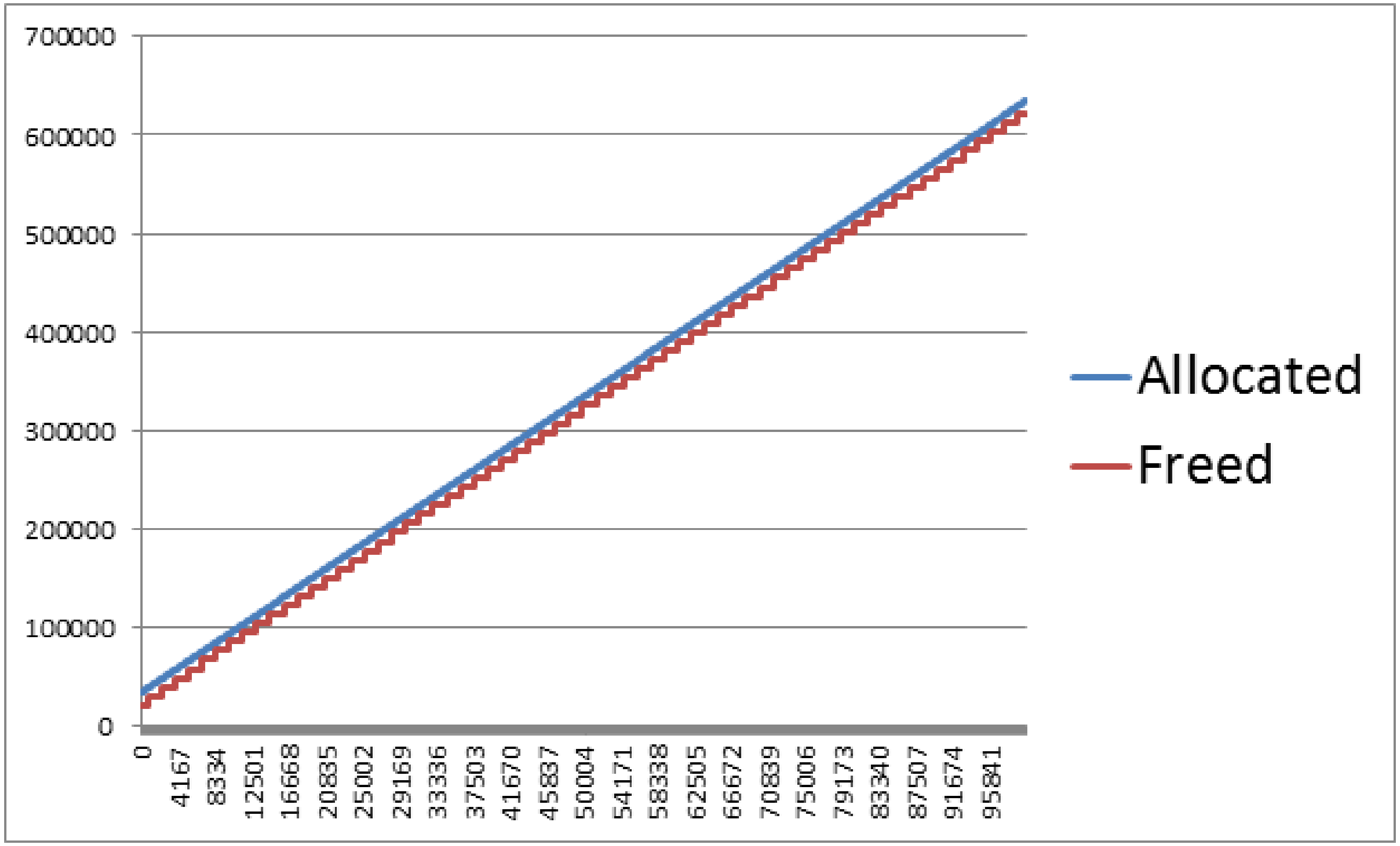
- GC.stat for GC (memory management)
- ObjectSpace::count_objects

Statistics information

GC.stat returns “current information of GC”

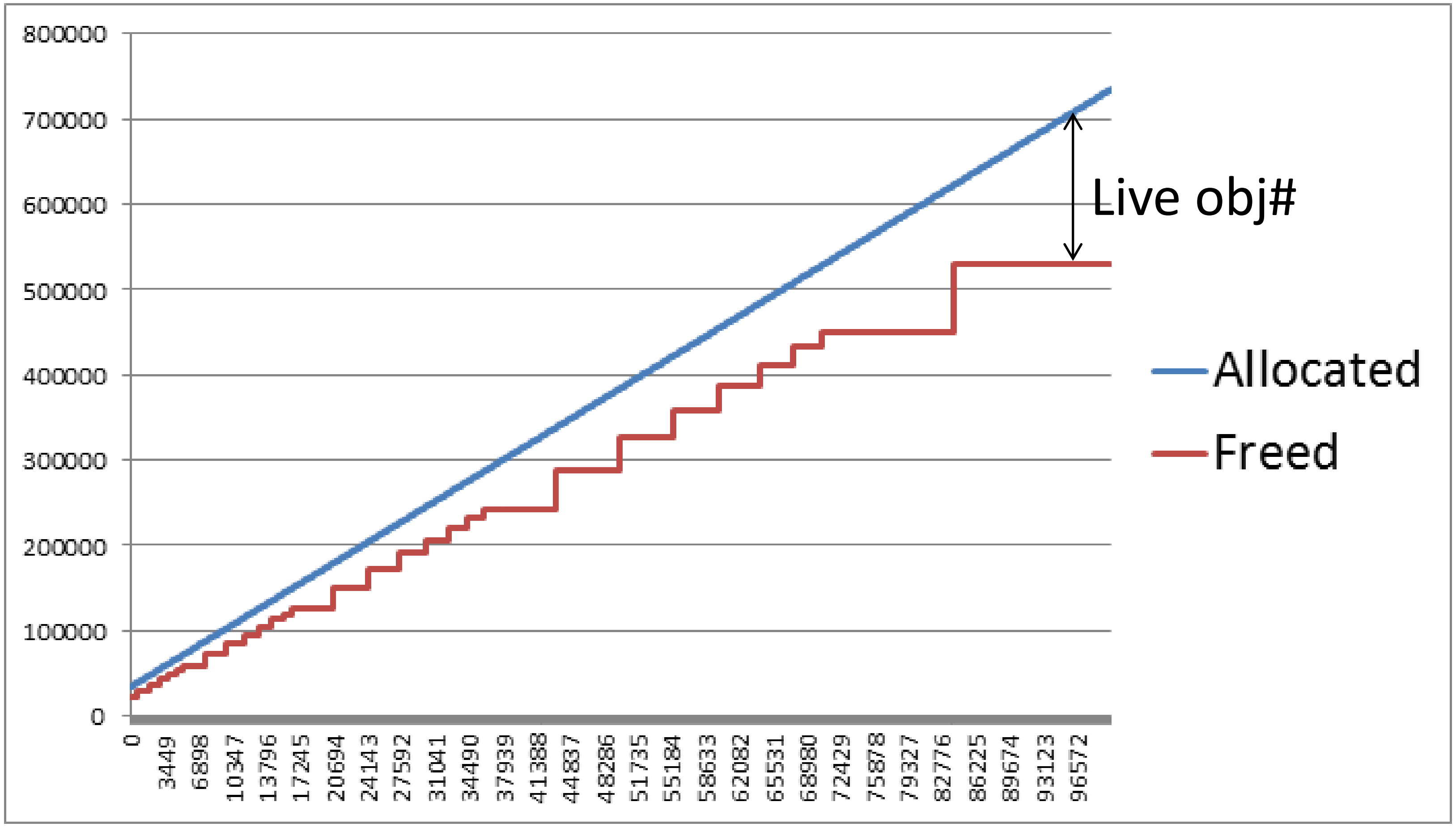
- Counts
  - :count=>2, # GC count
  - :minor_gc_count=>2, # minor GC count
  - :major_gc_count=>0, # major GC count
- Current slot information
  - :heap_live_slot=>6836, #=> # of live objects
  - :heap_free_slot=>519, #=> # of freed objects
  - :heap_final_slot=>0, #=> # of waiting finalizer objects
  - total_slots = heap_live_slot + heap_free_slot + heap_final_slot
- Statistics
  - :total_allocated_object=>7674, # total allocated objects
  - :total_freed_object=>838,# total freed objects
  - Current living objects = total_allocated_object - total_freed_object

GC.stat example: normal program



```
100_000.times{|i| ""; # Generate an empty string
h = GC.stat
puts "#{i}¥t#{h[:total_allocated_object]}¥t#{h[:total_freed_object]}"}
```

GC.stat example: Leakey behavior



```
ary = []
100_000.times{|i| ary << "" # generate an empty string and store (leak)
h = GC.stat
puts "#{i}¥t#{h[:total_allocated_object]}¥t#{h[:total_freed_object]}"}
```

Statistics information
ObjectSpace::count_objects

- ObjectSpace::count_objects returns counts for each type

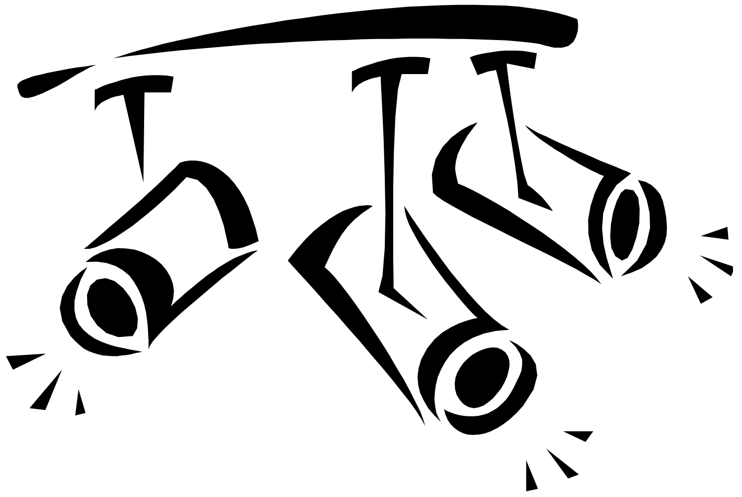
  Example:

  ```
  p ObjectSpace::count_objects
  #=>
  {:TOTAL=>30235, :FREE=>1226, :T_OBJECT=>60, :T_CLASS=>513, :T_MODULE=>24
  , :T_FLOAT=>7, :T_STRING=>9527, :T_REGEXP=>68, :T_ARRAY=>1718, :T_HASH=>8
  9, :T_STRUCT=>1, :T_BIGNUM=>5, :T_FILE=>21, :T_DATA=>1013, :T_MATCH=>26, :
  T_COMPLEX=>1, :T_NODE=>15904, :T_ICLASS=>32}
  ```

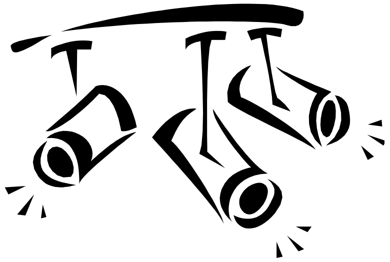
- Sister methods
  - ObjectSpace::count_objects_size in ‘objspace’ lib

Tracing

- TracePoint
- DTrace
- Object allocation tracing
- Trace object relations



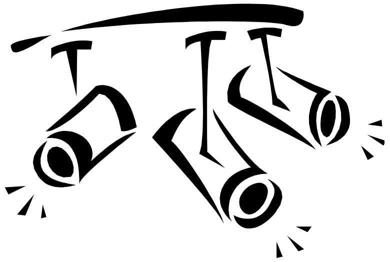
TracePoint



- Track Ruby’s execution
  - Insert tracing points by block
  - Introduced from Ruby 2.0
  - Lightweight OO-style version of “set_trace_func” method

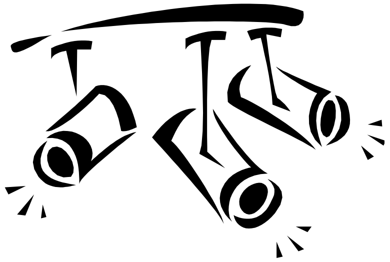
```
# old style
set_trace_func(lambda{|ev,file,line,id,klass,binding|
  puts “#{ev} #{file}:#{line}”
}

# new style with TracePoint
trace = TracePoint.trace{|tp|
  puts “#{tp.event}, #{tp.path}:#{tp.line}”
}
```

TracePoint
Advantages



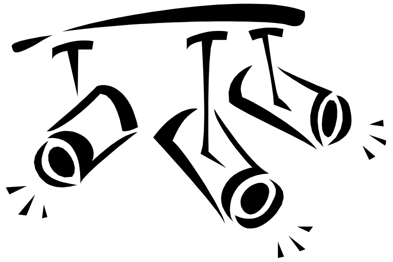
- Advantage of TracePoint compare with set_trace_func
  - OO style
  - Easy enable and disable
  - **Lightweight**
    - Creating binding object each time is too costly
  - Event filtering

TracePoint
Traceable events



- Same as set_trace_func
  - line
  - call/return, c_call/c_return
  - class/end
  - raise
- New events (only for TracePoint)
  - thread_begin/thread_end
  - b_call/b_end (block start, block end)

TracePoint
Filtering

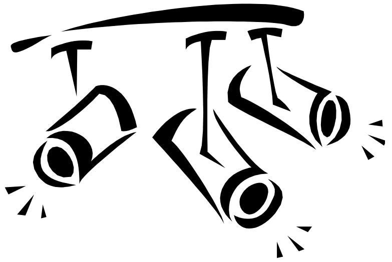


- TracePoint.new(events) only hook “events”
  - “set_trace_func” track all events
  - Example:

    TracePoint.new(:call, :return){…}

- Aliases
  - a_call -> call, c_call, b_call
  - a_return -> return, c_return, b_return

TracePoint
Event information



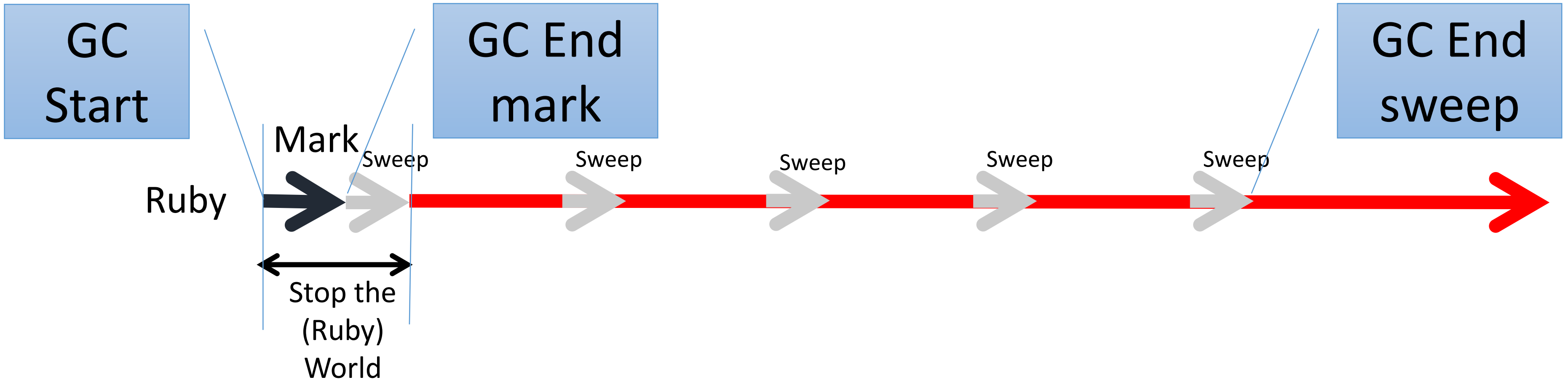
- Same as set_trace_func
  - event
  - path, lineno
  - defined_class, method_id
  - binding
- New event info
  - return_value (only for retun, c_return, b_return)
  - raised_exception (only for raise)

TracePoint
Internal events

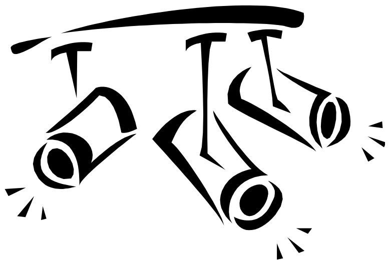
- Added events
  - RUBY_INTERNAL_EVENT_NEWOBJ
    - When object is created
  - RUBY_INTERNAL_EVENT_FREEOBJ
    - When object is freed
  - RUBY_INTERNAL_EVENT_GC_START
    - When GC is started
  - RUBY_INTERNAL_EVENT_GC_END_MARK
    - When marking of GC is finished
  - RUBY_INTERNAL_EVENT_GC_END_SWEEP
    - When sweeping of GC is finished

TracePoint
Internal events

- Timeline



DTrace



- Solaris, MacOSX FreeBSD and Linux has DTrace tracing features
- Ruby interpreter support some events
- See https://bugs.ruby-lang.org/projects/ruby/wiki/DTraceProbes

Object allocation tracing

- ObjectSpace::trace_object_allocations
  - Trace object allocation and record allocation-site
    - Record filename, line number, creator method's id and class
    - Implemented by TracePoint with internal events NEWOBJ/FREEOBJ
  - Usage:

```
ObjectSpace.trace_object_allocations{ # record only in the block
   o = Object.new
   file = ObjectSpace.allocation_sourcefile(o)   #=> __FILE__
   line = ObjectSpace.allocation_sourceline(o) #=> __LINE__ -2
}
```

Trace objects relations

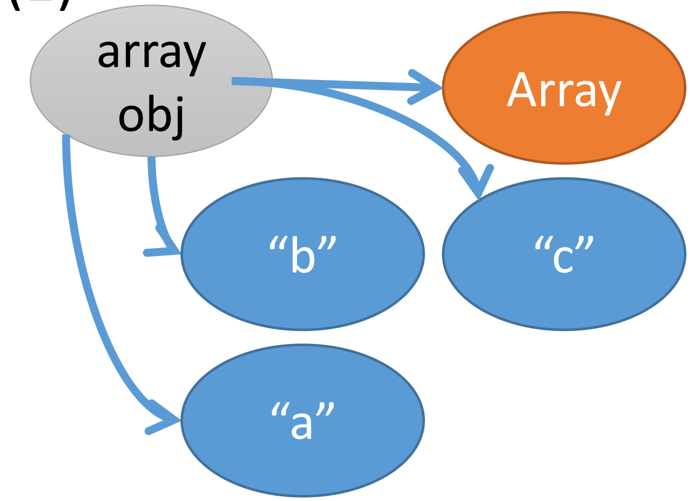
- ObjectSpace.reachable_objects_from(obj) returns directly reachable objects
  - Examples:

    (1) When obj is [“a”, “b”, “c”], returns [Array, “a”, “b”, “c”]

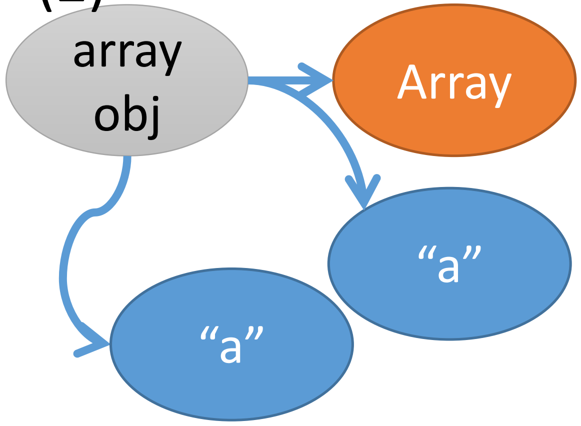
    (2) When obj is [“a”, “a”], returns [Array, “a”, “a”]

    (3) When obj is [a = “a”, a], returns [Array, “a”]

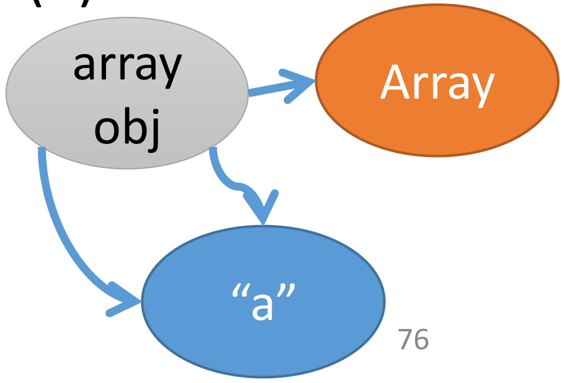
(1)



(2)

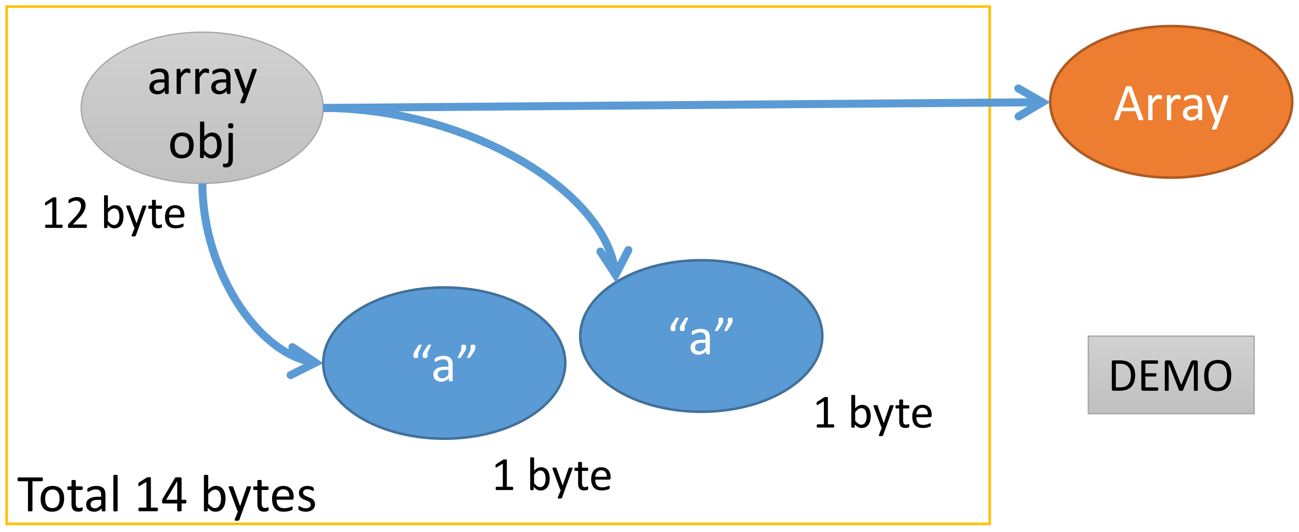


(3)



Trace objects relations

- You can analyze memory leak. ... Maybe.
- Combination with ObjectSpace.memsize_of() (introduced at 1.9) is also helpful to calculate how many memories consumed by obj.



(this is fake example)

Trace objects from root

- ObjectSpace.reachable_objects_from_root -> hash
  - Return all reachable objects from root.
  - You can get all objects graph in the heap.
  - ObjectSpace::dump_all() is implemented with this method.

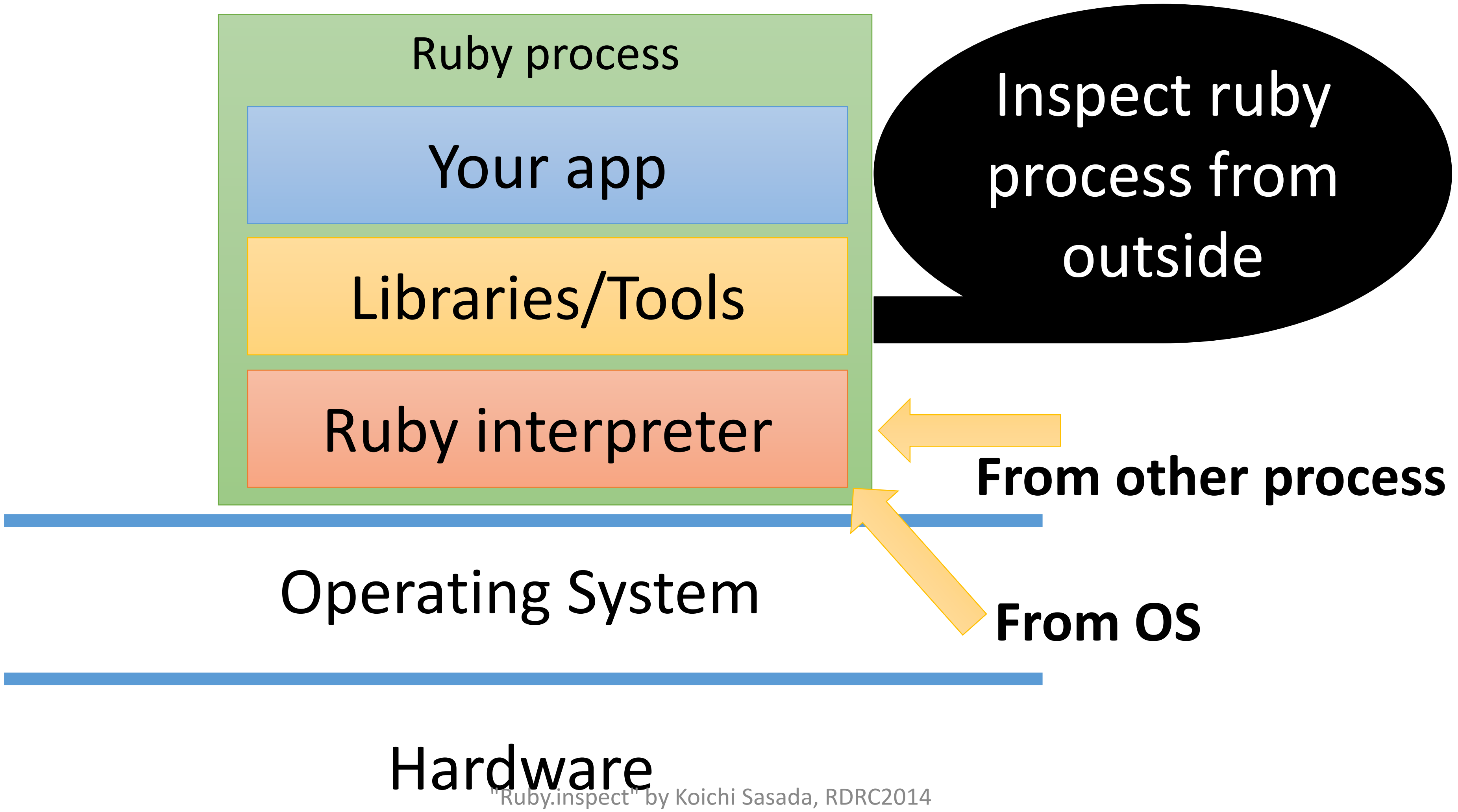
Make tools!!

- Example: combination of GC.stat and TracePoint
  - ObjectSpace::trace_object_allocation
  - gc_tracer: GC behavior
  - allocation_tracer: Allocation tracing
- You can make your own tools if you need!!

Inspect from outside

https://www.flickr.com/photos/justin_case/2842104135

Inspection features on computer layers



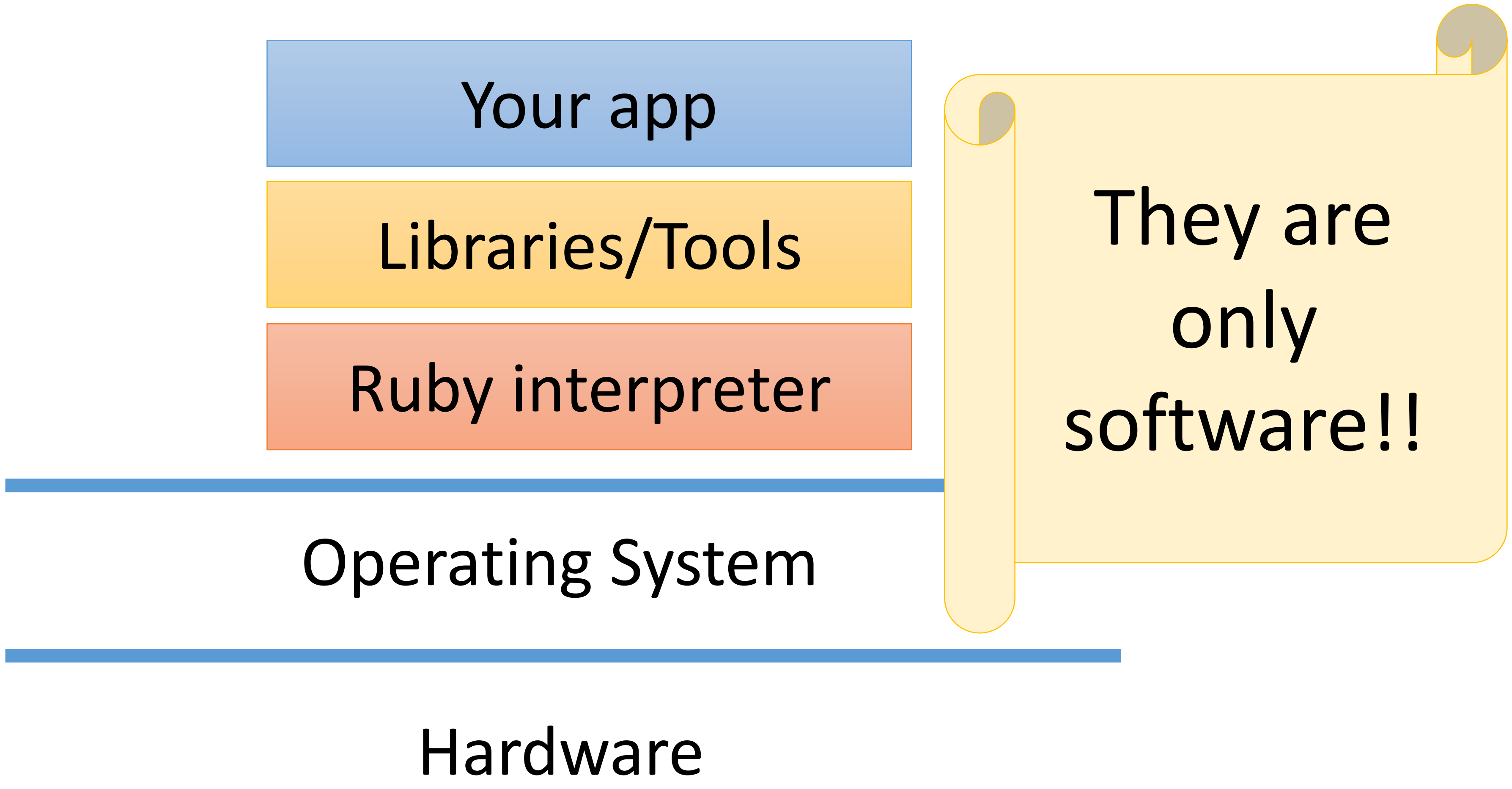
Inspect from outside

- System level tracing
  - strace (system call tracer)
  - Dtrace, systemtap, … (with Ruby’s dtrace support)
- System level profilers
  - Valgrind (massif for memory usage)
  - prof, proftools, …
- System level debugger
  - gdb

Advanced inspection

https://www.flickr.com/photos/usnavy/5958545513

Inspection features on computer layers

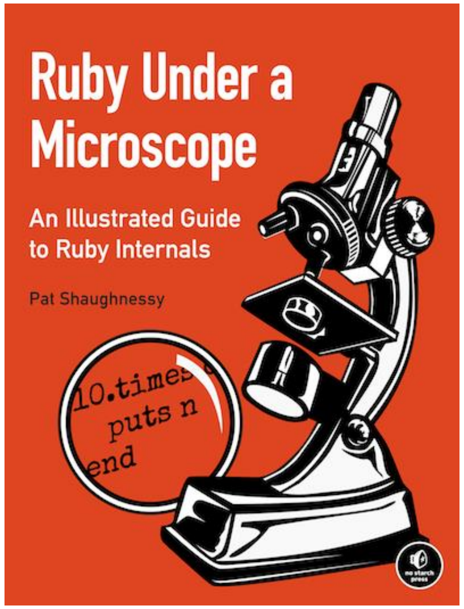


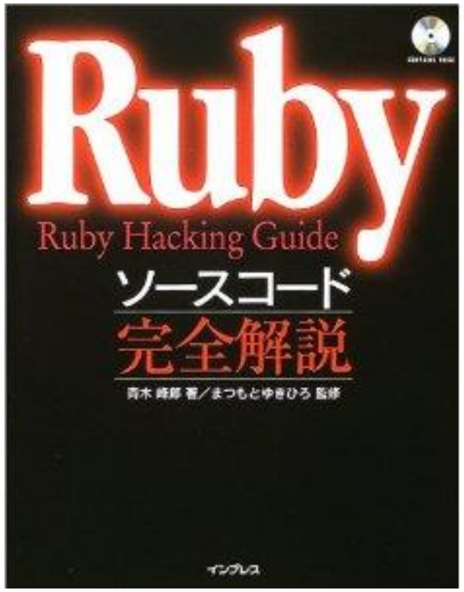
You can modify software

- Modify inspection tools
  - Most of tools are placed on github
- Modify Ruby interpreter
  - Make an C extension libraries with C-APIs
    - Some tools are written as C-extensions
  - Modify Ruby interpreter written in C
- Modify operating systems and system software layers

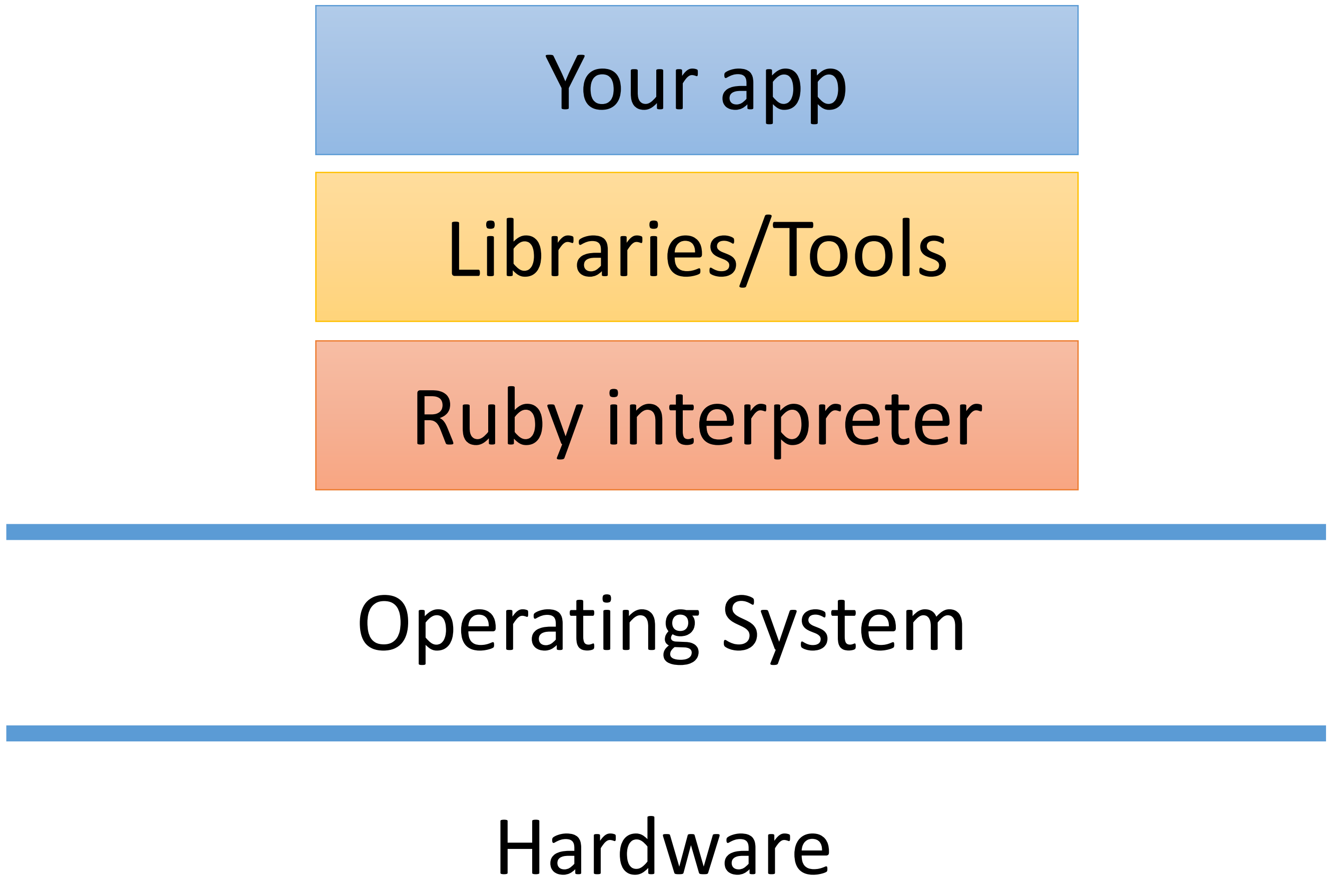
Hacking Ruby

- “Ruby Under a Microscope”
  - By Pat Shaughnessy
  - http://patshaughnessy.net/ruby-under-a-microscope
- “Ruby Hacking Guide”
  - By Minero Aoki, written in Japanese
  - English translation: http://ruby-hacking-guide.github.io/

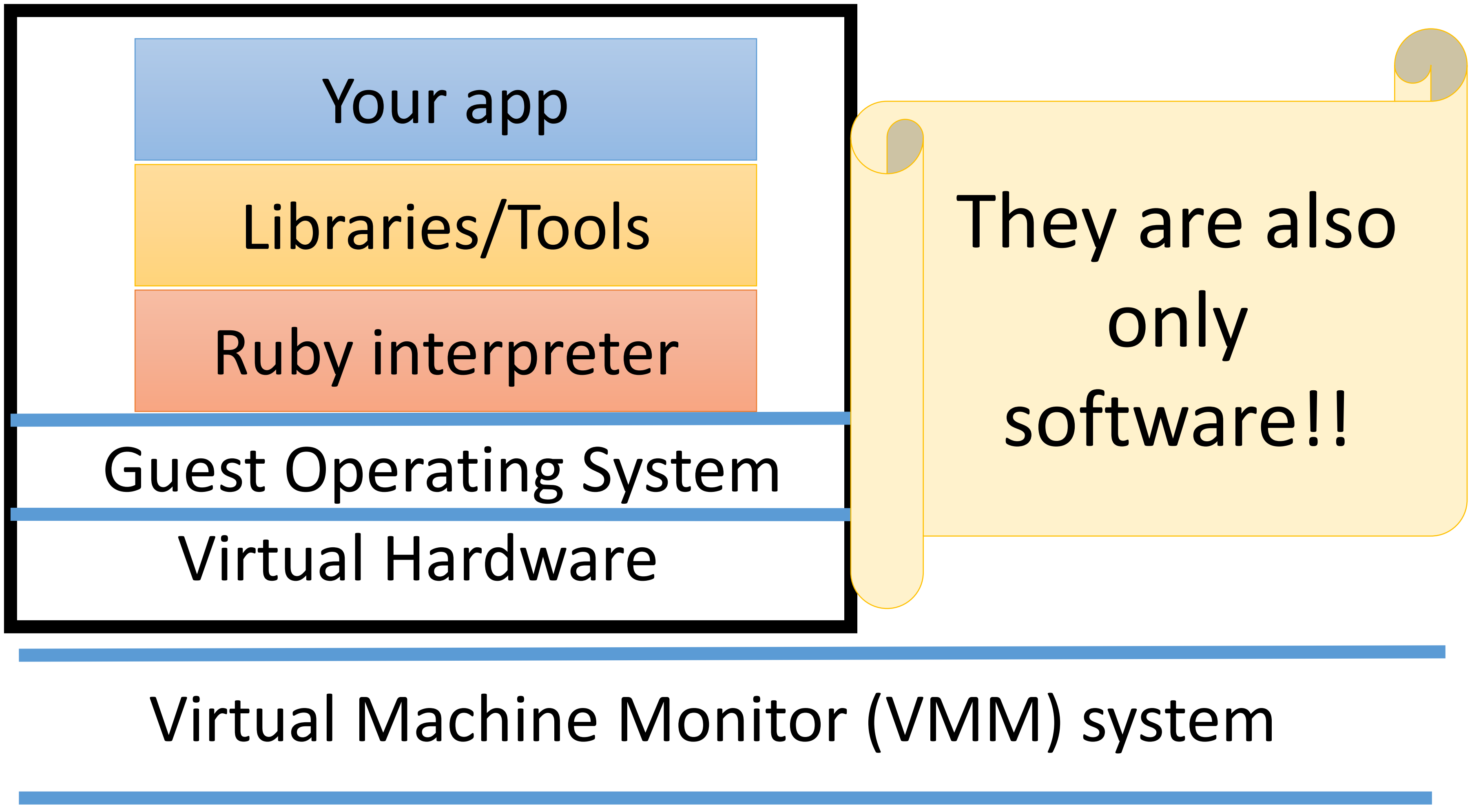




Advanced computer layers



Advanced computer layers



Real Hardware

Important idea: Understanding Lower-layers

- Understanding computer layers and lower-layers helps your understanding of your application
  - Which information we can inspect
  - What happen on the computer
- Ruby hides computers details, but understanding details will help you
  - This is why "Computer science" study is important
  - Or try to ask lower-layer professionals ☺
- Balance is matter between higher-layers and lower-layers

Today’s Message

Become
a Low-level
engineer
(somtimes)

Talk.inspect

Summary of this talk

- Introduction of Ruby 2.1, 2.2
- How to inspect your application behavior
  - With tools & services
  - Make a tools by inspection primitives
  - Inspection from outside
- Knowing "low-level" helps you
- Happy hacking

"Ruby.inspect"
Thank you for your attention

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