Towards Ruby 2.0: Progress of (VM) Internals

The results of “My Code”

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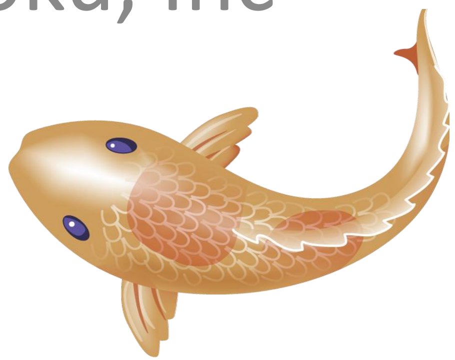


Agenda

- Background
- Finished work - Ruby 2.0 Internal Changes
  – Support Module#prepend
  – Introducing Flonum
  – New set_trace_func
  – Controllable asynchronous interrupts
  – Deep changes
- Remaining work - Ruby 2.0 Internal Features
  – Virtual machine changes
    - Enable “disabled-optimizing” options
    - Optimize “send” instruction
    - Change VM data structures
  – C APIs for “incomplete features”
- Future work – Dreams: After Ruby 2.0

Introduction

- Koichi Sasada
  - Heroku, Inc.
    - Heroku is a cloud application platform - a new way of building and deploying web apps.
    - No longer a professor ☺
  - One of CRuby committer
    - Full-time committer employed by Heroku, Inc.
    - Toward Ruby 2.0 (next release)
    - Matz is my boss.

Background
Brief History of Ruby Interpreter

1993 2/24
Birth of Ruby
(in Matz' computer)

1995/12
Ruby 0.95
1st release

1996/12
Ruby 1.0

1998/12
Ruby 1.2

1999/12
Ruby 1.4

2000/6
Ruby 1.6

2003/8
Ruby 1.8

2009/1
Ruby 1.9.0

2012/9
イマココ

2000 Book:
Programming Ruby

2004～
Ruby on Rails

Background
Ruby 2.0 Roadmap

2013/2/24
Ruby 2.0 Release
(20th anniversary)

2012/Sep
イマココ

2012/Aug
“Big-feature” freeze
(was invalidated?)

2012/Oct
Feature freeze

Quoted from “[ruby-core:40301]
A rough release schedule for 2.0.0”

Background
Ruby 2.0 Policy

- Compatibility
- Compatibility
- Compatibility
- Usability
- Performance

Finished work
Ruby 2.0 Internal Changes

Finished work
Ruby 2.0 Internal Changes

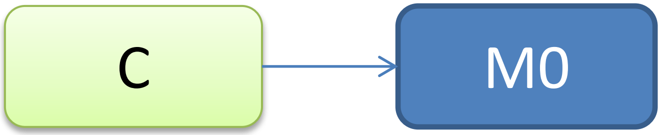
- Support Module#prepend
- Introducing Flonum
- New backtrace API “caller_locations”
- New set_trace_func related features
- Controllable asynchronous interrupts
- Deep changes

Module#prepend

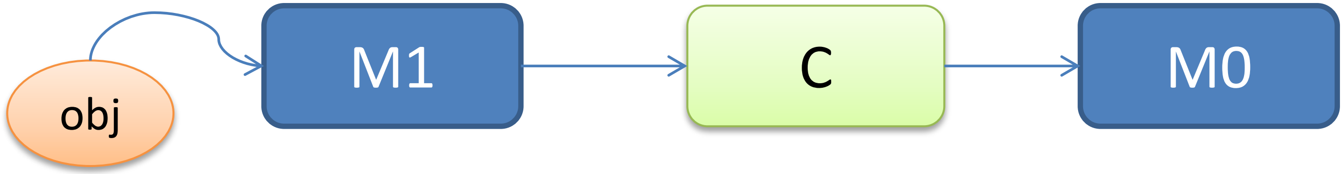
- Classes can include modules

```
module M; end
class C; include M; end
```

- The method search order is “Original -> Included module”

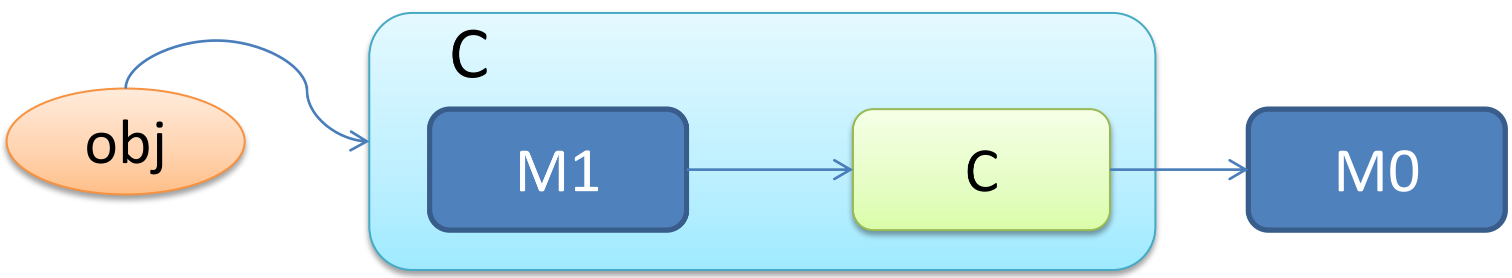


- Object#extend allow to put module, but it’s only extend an object



Module#prepend

- Module#prepend enables to extend the class which override original class



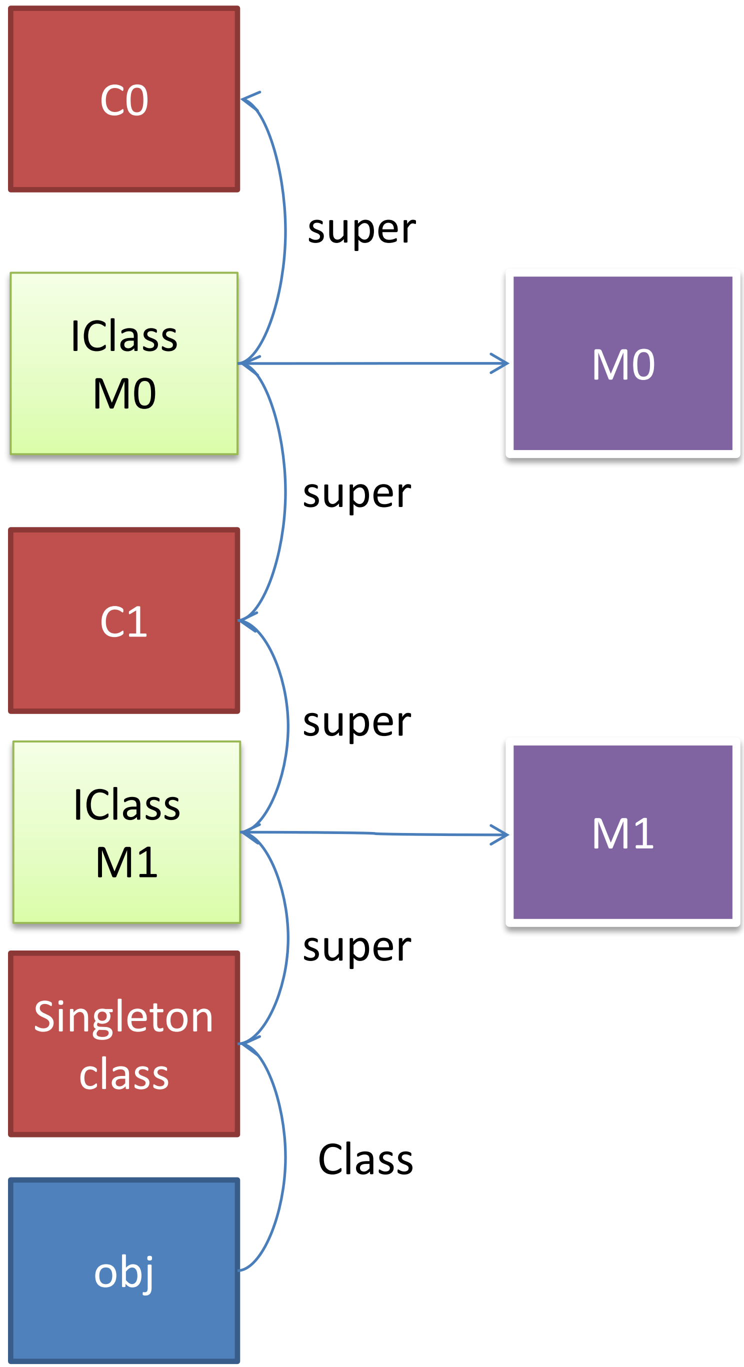
Module#prepend

- Example
  - Invoke specific procedure before/after the method invocation (“around”)

```
module EachTracer
  def each(*args)
    before_each
    r = super(*args) # call original
    after_each
    r
  end
end
class Array
  prepend EachTracer
  def before_each; p :befor_each; end
  def after_each; p :after_each; end
end
```

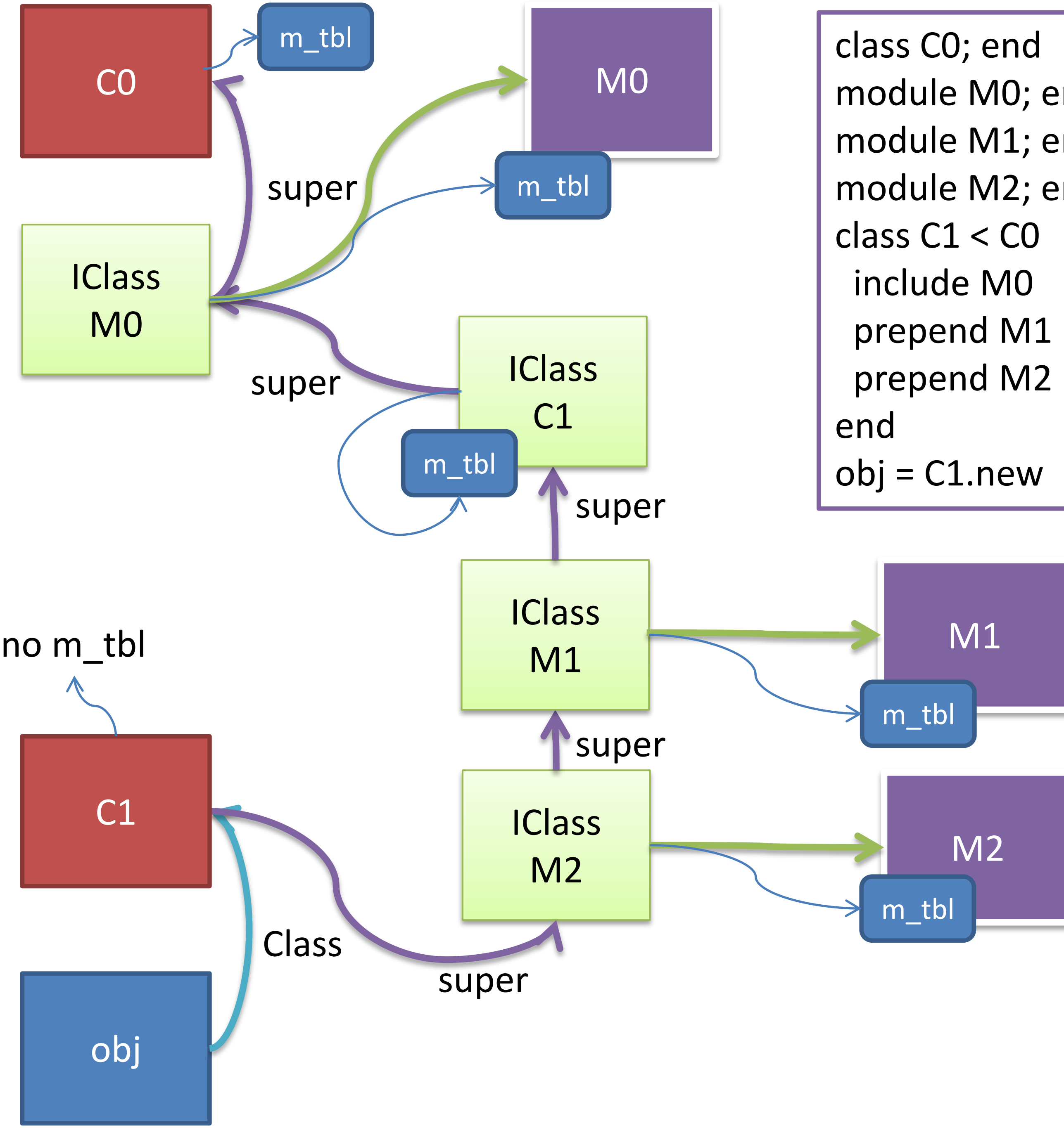
```
[1, 2, 3].each{|i| p i}

#=>
:befor_each
1
2
3
:after_each
```

Ruby 1.9 or before




```
class C0; end
module M0; end
module M1; end
class C1 < C0
  include M0
end
obj = C1.new
obj.extend M1
```

After Ruby 2.0
Module#prepend

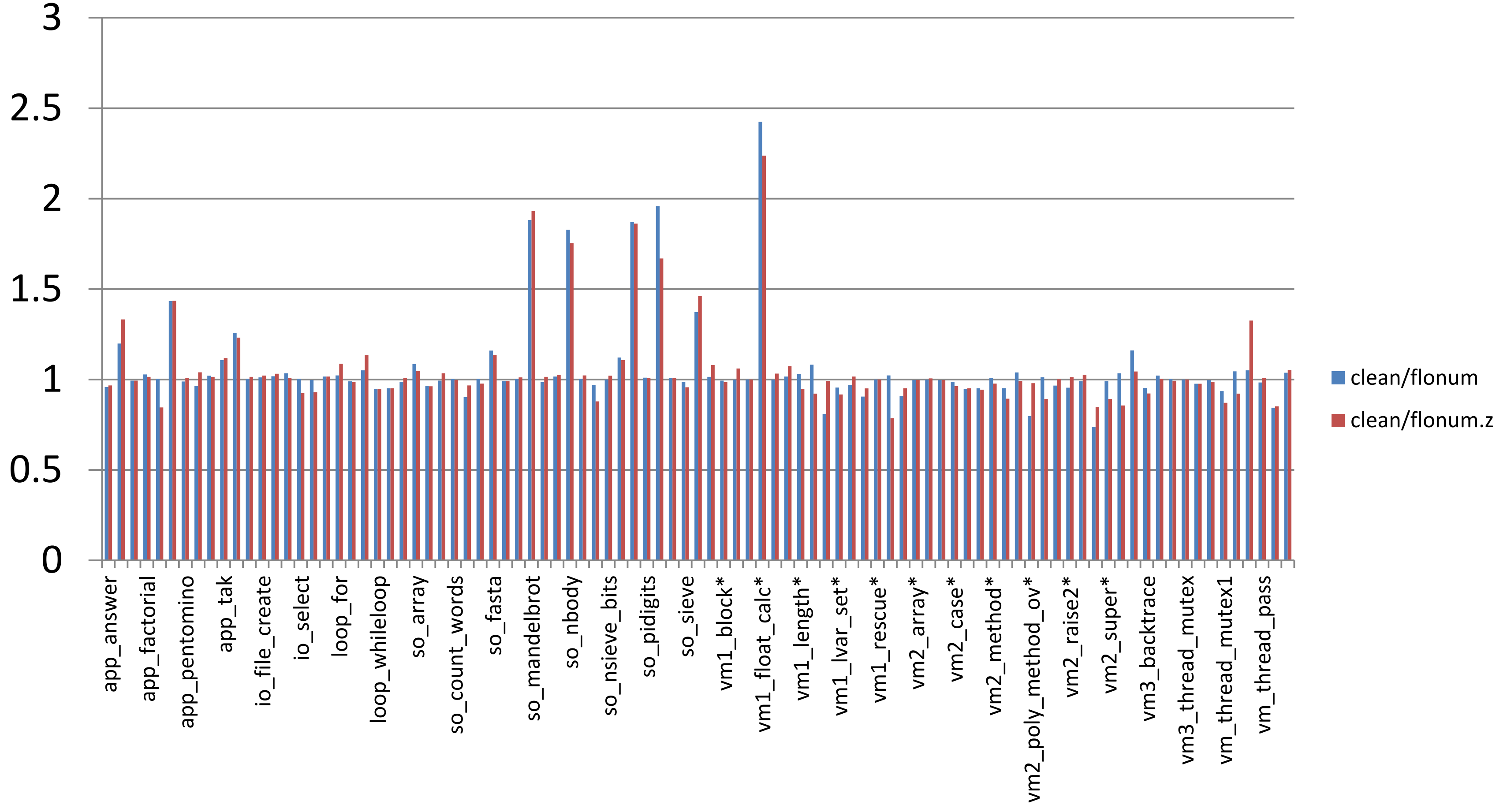



```
class C0; end
module M0; end
module M1; end
module M2; end
class C1 < C0
  include M0
  prepend M1
  prepend M2
end
obj = C1.new
```

Introducing Flonum
(only on 64bit CPU)

- Problem: Float objects are not immediate on Ruby 1.9
  - It causes GC overhead problem
- **To speedup floating calculation, represent Float object as immediate object**
  - Specified range Float objects are represented as immediate object (Flonum) like Fixnum
    - 1.72723e-77 < |f| < 1.15792e+77 (approximately) and +0.0
    - Out of this range and all Floats on 32bit CPU are allocated in heap
  - No more GCs! (in most of case)
  - Flonum and old Float are also Float classes
  - Proposed by [K.Sasada 2008]
  - On 64bit CPU, object representation was changed

Benchmark results



Flonum: Float in Heap (1.9 or before)

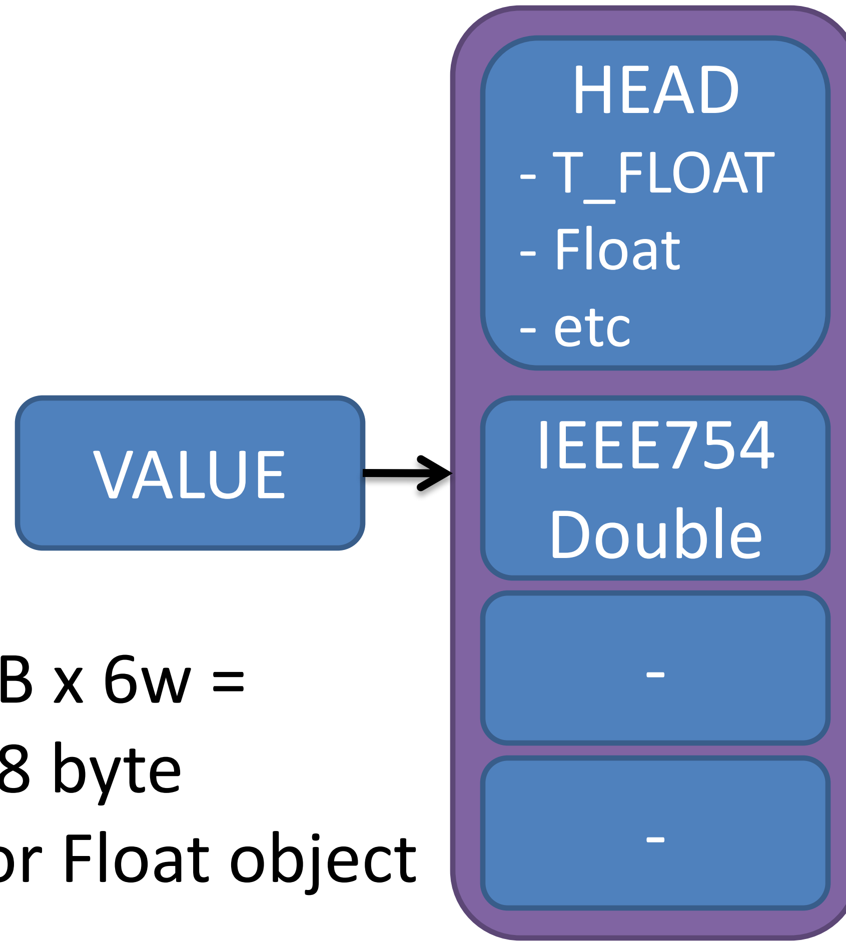
All of Float object

are allocated in heap

Data structure in heap

contains IEEE754/double

On 64bit CPU

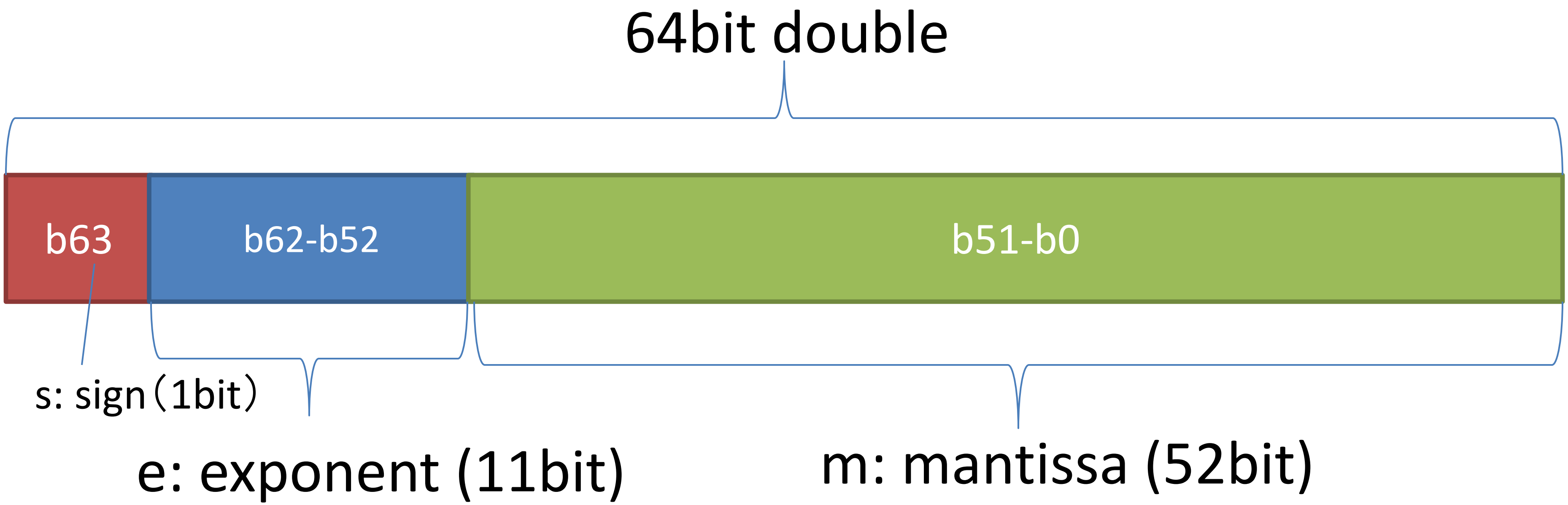


8B x 6w =

48 byte

for Float object

Flonum: Encoding
IEEE754 double floating number



$$-1^{s}2^{e-1024}m \quad \left(m = 1 + \sum_{i=0}^{51} \frac{b_i}{2^{52-i}}\right)$$

Flonum: Range

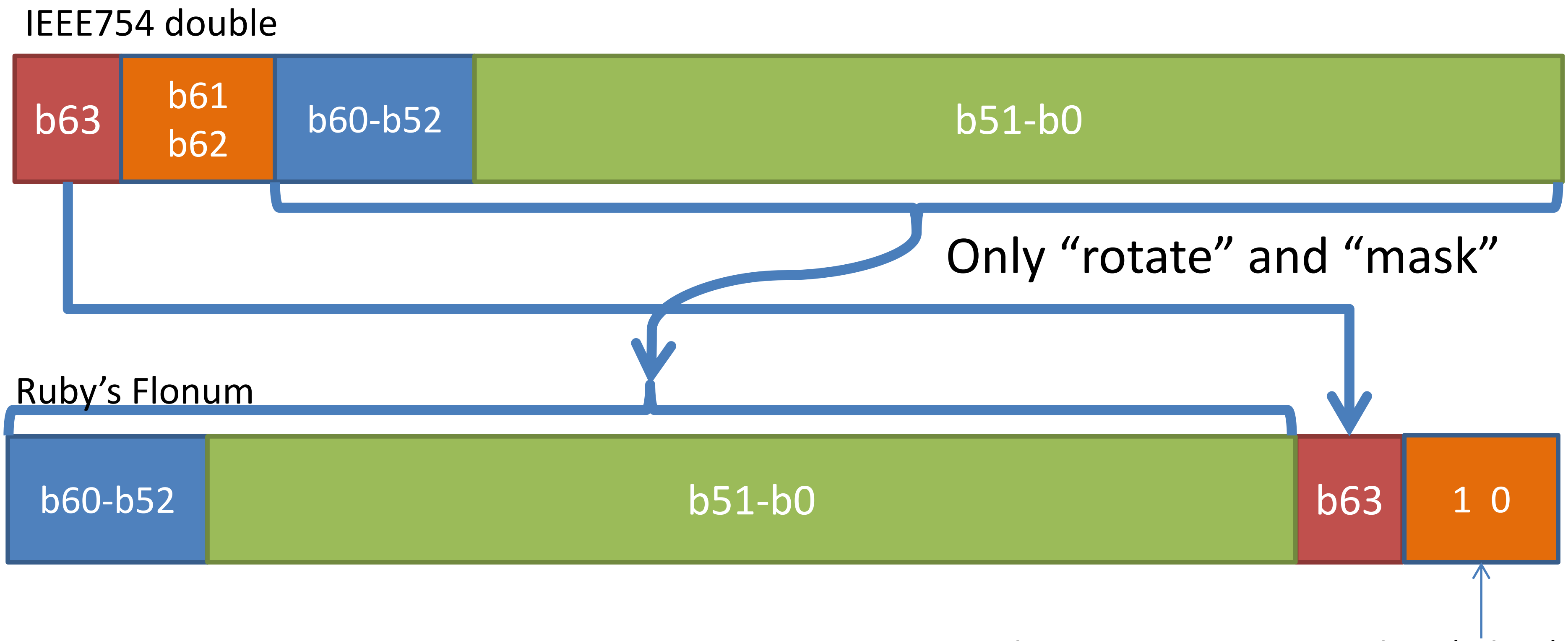
IEEE754 double

Check if e (b52 to b62) is with-in 768 to 1279, then it can be represent in Flonum.

This check can be done with b60-b62.

(+0.0 (0x00) is special case to detect)

Flonum: Encoding



Flonum representation bits (2 bits)
#define FLONUM_P(v) ((v&3) == 2)

☆ +0.0 is special case (0x02)

Flonum: Object representation on VALUE

	Non Flonum	Flonum
Fixnum	...xxxx xxx1	...xxxx xxx1
Flonum	N/A	...xxxx xx10
Symbol	...xxxx 0000 1110	...xxxx 0000 1100
Qfalse	...0000 0000	...0000 0000
Qnil	...0000 0100	...0000 1000
Qtrue	...0000 0010	...0001 0100
Qundef	...0000 0110	...0011 0100
Pointer	...xxxx xx00	....xxxx x000

New backtrace API “caller_locations”

- Problem: caller() returns an array of strings
- **Introduce “caller_locations”**
  - Returns an array of object which has methods such as “lineno”, “path”, etc
  - caller_locations(0)[0].path #=> “foo.rb”
  - caller_locations(0)[0].lineno #=> 23
- Boost creating backtrace speed by internal changes

  → Speedup exception creation

New “set_trace_func”

- Problem: set_trace_func is not flexible and slow
- **TracePoint API**
  - TracePoint.trace(events) do block end
  - Specify “events” to invoke
  - Add new events (block_enter, etc)
- **New C APIs**
  - Rewrite all trace_func related code and enable lightweight probes for profilers
  - x2~ faster for “very lightweight” probes

Controllable asynchronous interrupts

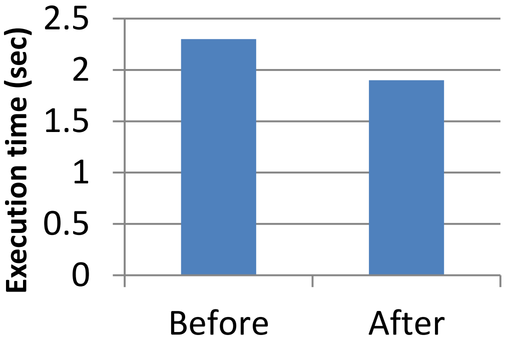
- Problem: Can not make safe program with Async-interrupts such as TimeoutError
- **Thread#control_interrupt(hash) do block end**
  - hash contains exception classes as keys and symbols represents 3 states as values
    - immediate: interrupt immediately
    - on_blocking: interrupt only when before blocking
    - never: never interrupt
  - Async interrupts specified by hash are masked in block

Controllable asynchronous interrupts

```
# example: Guard from TimeoutError
require 'timeout'
Thread.control_interrupt(TimeoutError => :never) {
  timeout(10){
    # TimeoutError doesn't occur here
    Thread.control_interrupt(TimeoutError => :on_blocking) {
      # possible to be killed by TimeoutError
      # while blocking operation
    }
    # TimeoutError doesn't occur here
  }
}
```

Deep changes

- Remove “finish” frame from control frames
- Unify “lfp” and “dfp” into “ep”
  - Reduce time of creating method frame (control frame) is important than reduce time of accessing local variables
- Call “allocation function” directly
  - Lightweight object allocation
  - miniruby -I./lib -rbenchmark -e 'GC.disable;Benchmark.bm {|x|x.report{10_000_000.times{Object.new}}}‘ #=>



Remaining tasks for Ruby 2.0

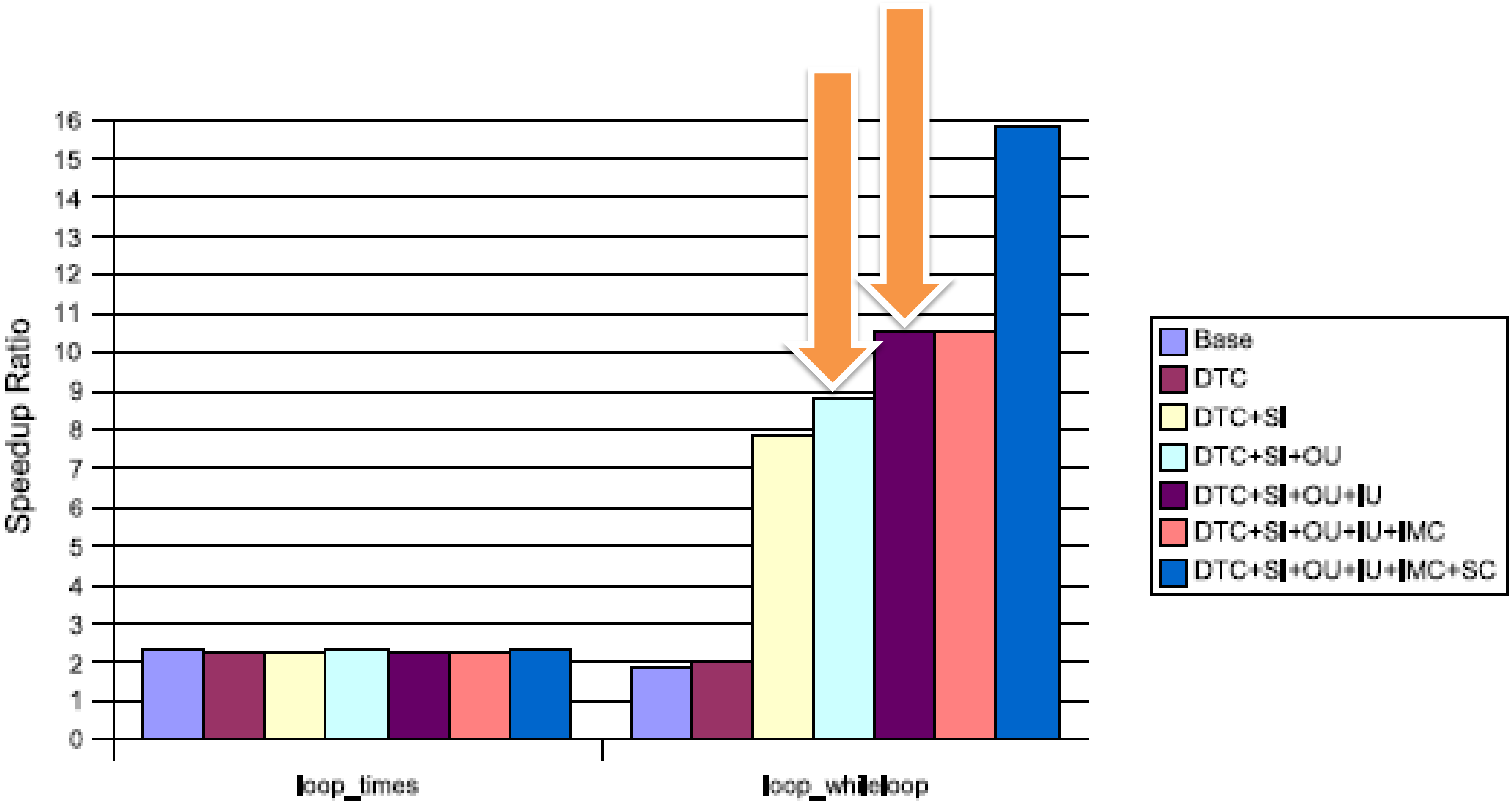
Remaining works
Ruby 2.0 Internal Features

- Virtual machine changes
  - Enable “disabled-optimizing” options
  - Optimize “send” instruction
  - Change VM data structures
- More supports for Profiler/Debugger
- C APIs for “incomplete features”

Virtual machine changes
Enable “disabled-optimizing” options

- Operand/Instruction unification
  - Unify instruction and specific operand and make additional instructions
  - Macro instructions
- Tail-call optimization?
  - Eliminate method frame if the call is tail-call
  - To avoid stack overflow
  - I prefer auto expanding VM stack than it

Unification result

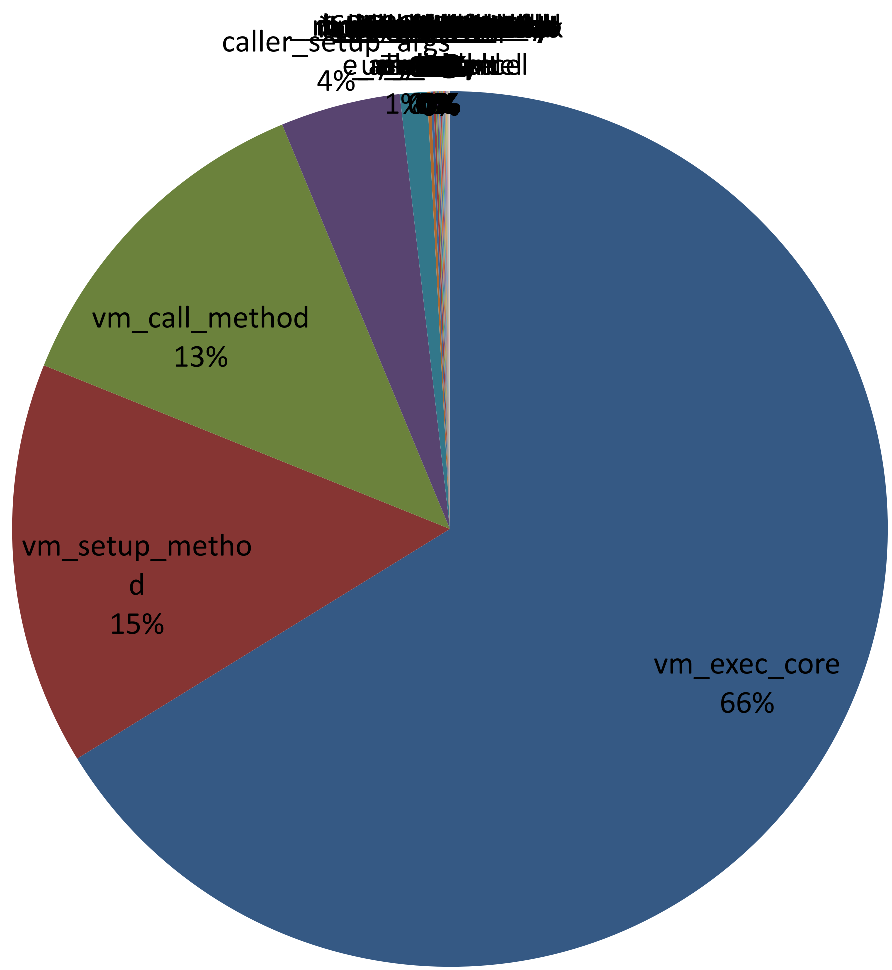


Virtual machine changes
Optimize "send" instruction

Ruby is OO language

→ Everything are methods

→ Optimizing Method call is important

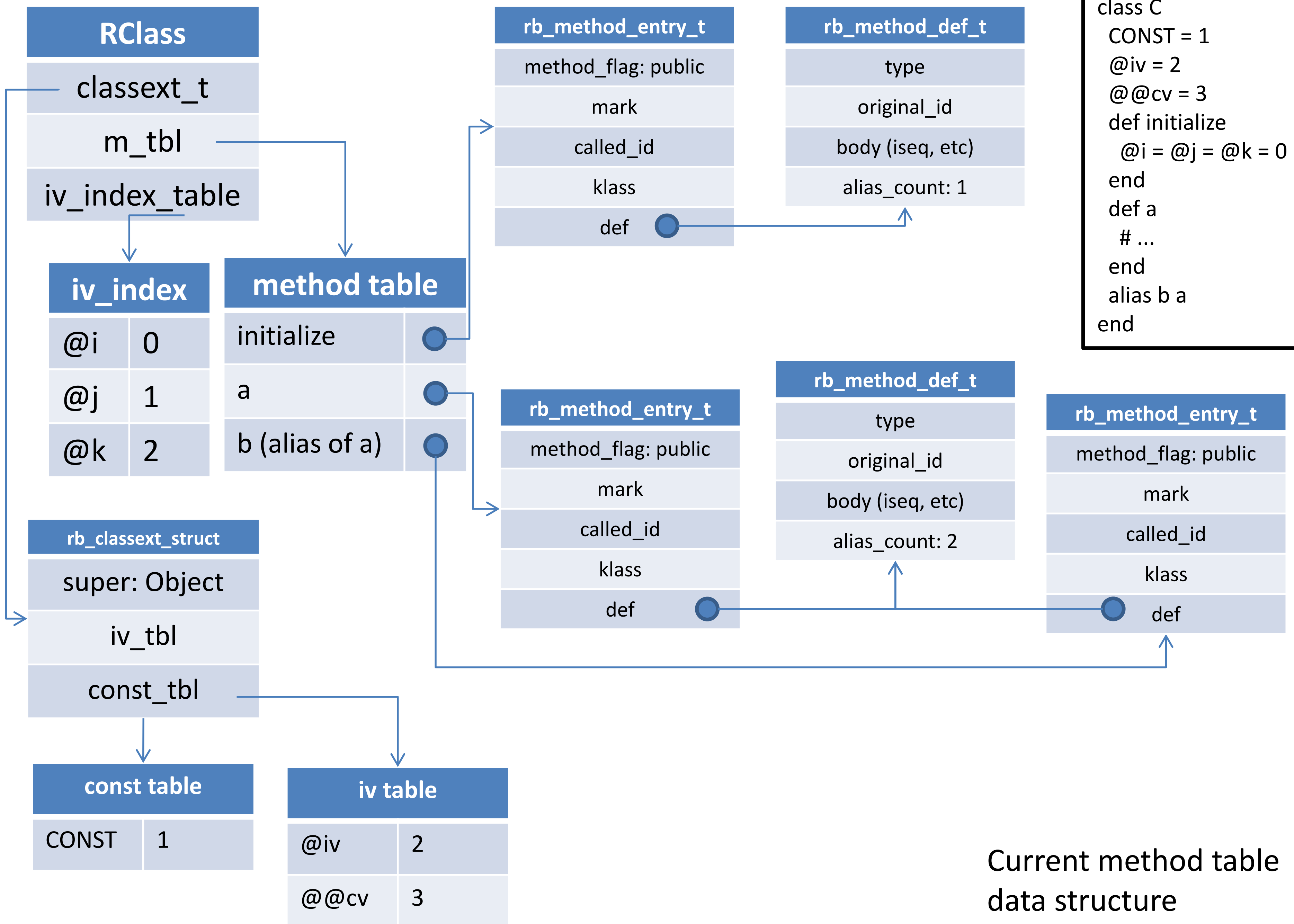


Virtual machine changes Optimize “send” instruction

- Inline cache
  - More sophisticate cache invalidation protocol
  - Cache checking results such as visibilities, number of parameters and so on
  - Direct C function call path
- Compilation (future work)
  - JIT compilation **only for** “send” instruction is feasible / cost effective
  - Need to consider about maintenance

Virtual machine changes
Change VM data structures

- Reconstruct rb_control_frame_t
  - make it small to boost pushing new frames
- Introduce rb_code_context_t to represent code context (iseq + cref + method info + ...)
- Re-arrange boot sequence to make it easy for application embedded usage



Current method table data structure

Current ISeq data structure

catch table entry

- type
- iseq
- start, end: trap range
- cont, sp: continue info

inline cache entry

- key:
  - vmstat
  - class
- value (union):
  - value
  - method
  - index

line info entry

- position (この PC は)
- line_info (何行目)

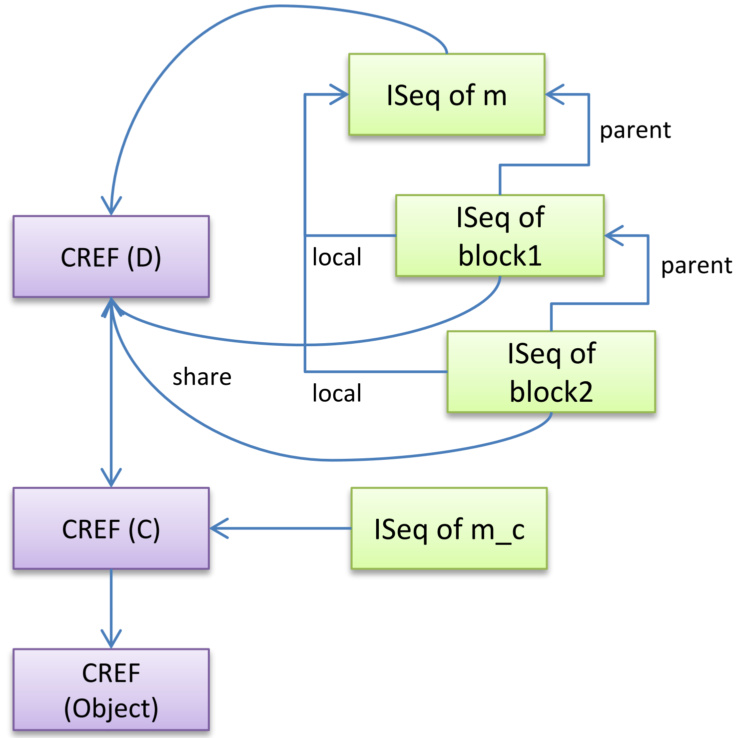
cref stack entry

- visibility
- class
- next (link)

ISeq

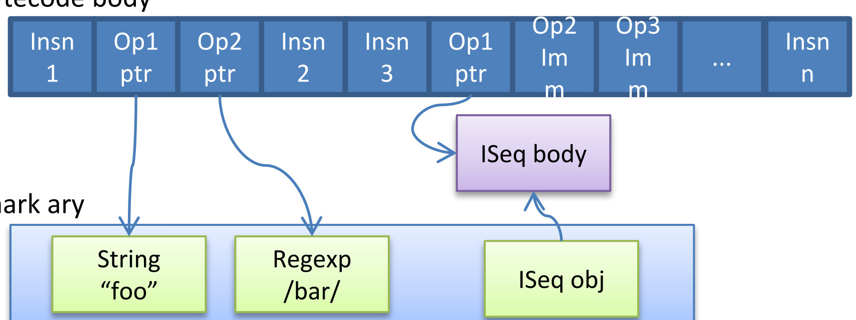
static data:
- name
- filename
- arg info
- bytecode body
- ← catch_table entries
- ← line info entries
- local_table (ID *)
- stack_max
- parent_iseq (直近の親)
- local_iseq (lfp 指し先)
- mark ary

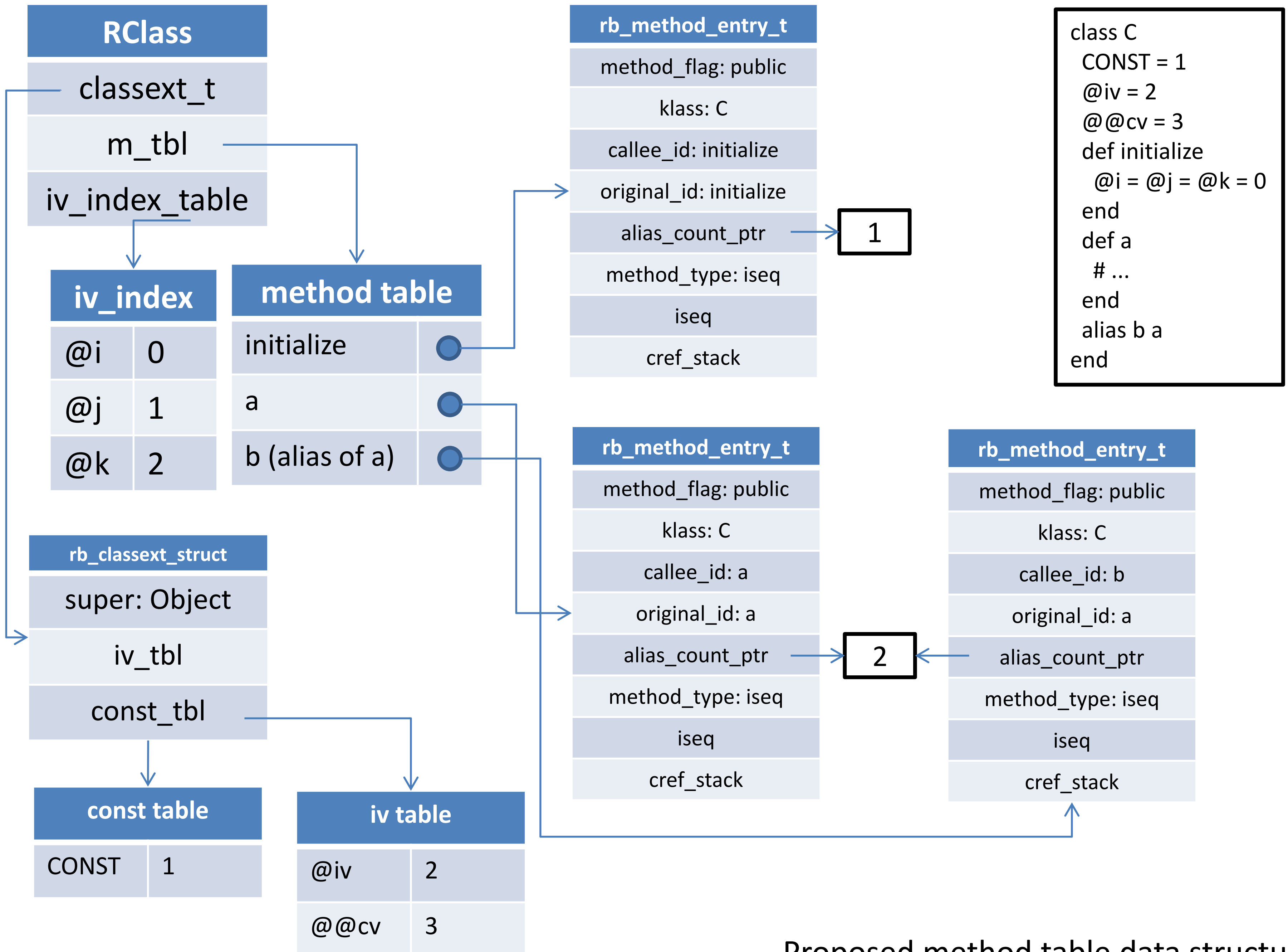
dynamic data:
- self
- orig
- ← inline cache entries
- klass (def したクラス)
- ← cref_stack
- defined_id (define_method されたときのid)



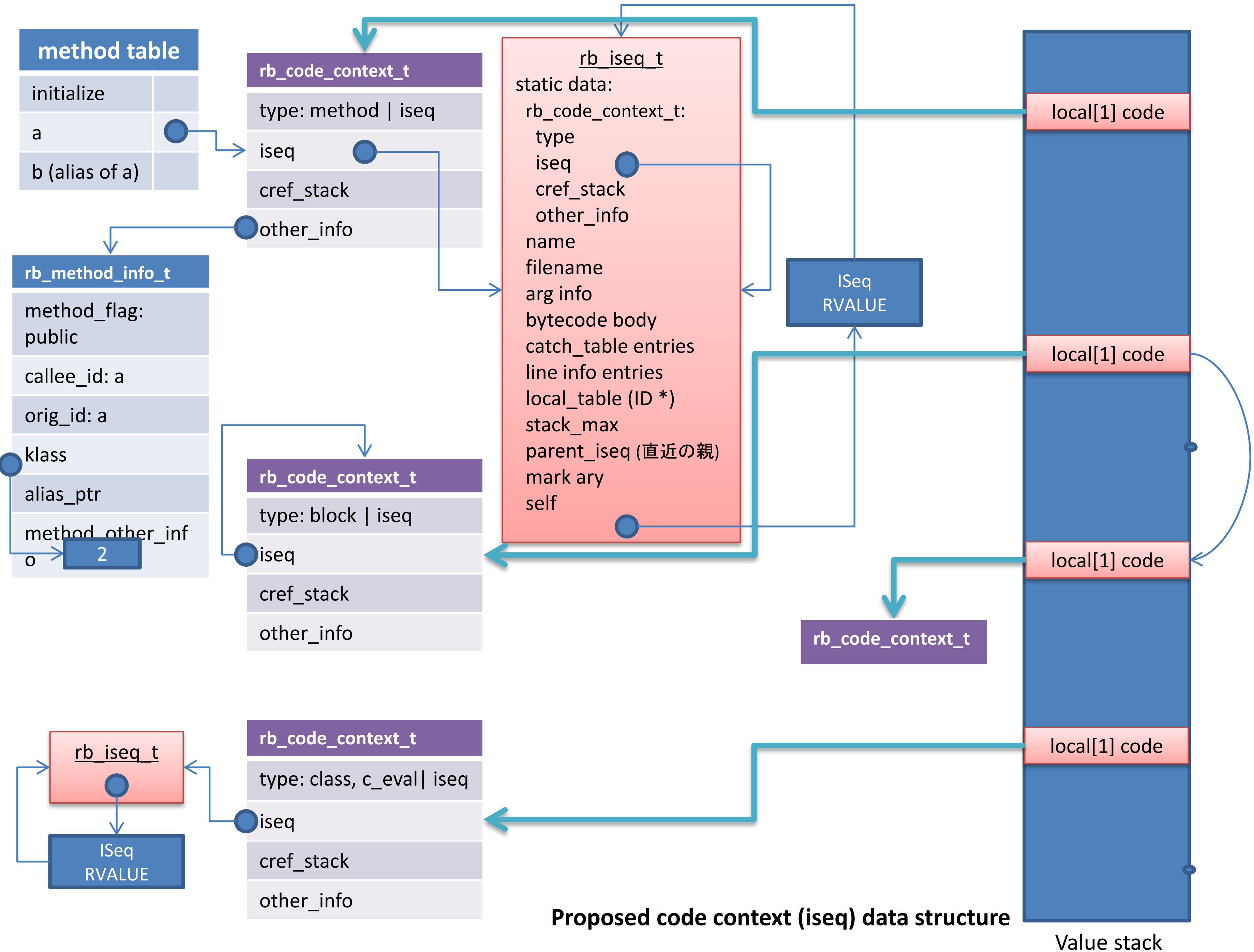

```
class C
 class D
  def m
   1.times{
     # block1
     1.times{
       # block2
     }
   }
  end
 end

 def m_c
 end
end
```

Bytecode body

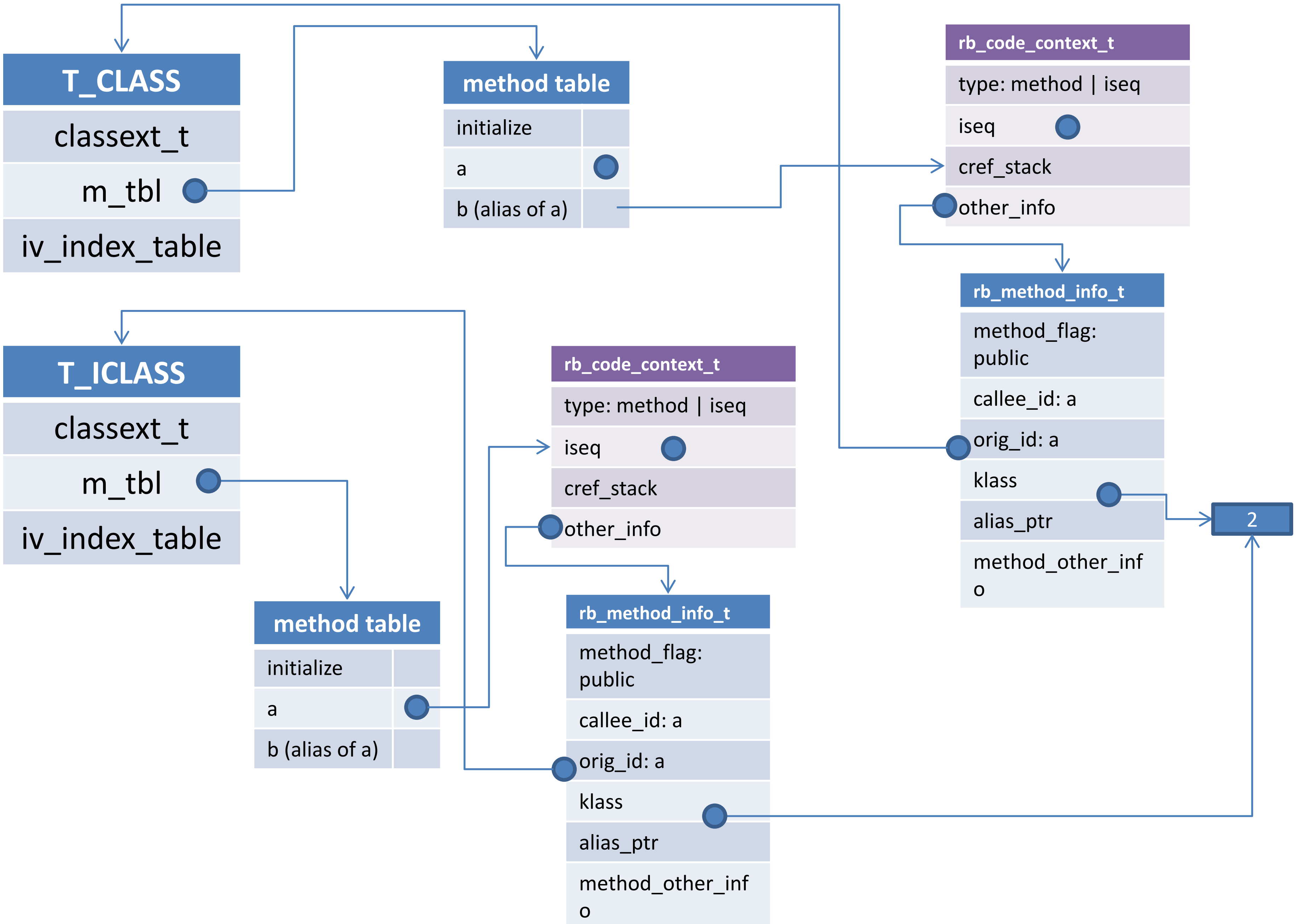




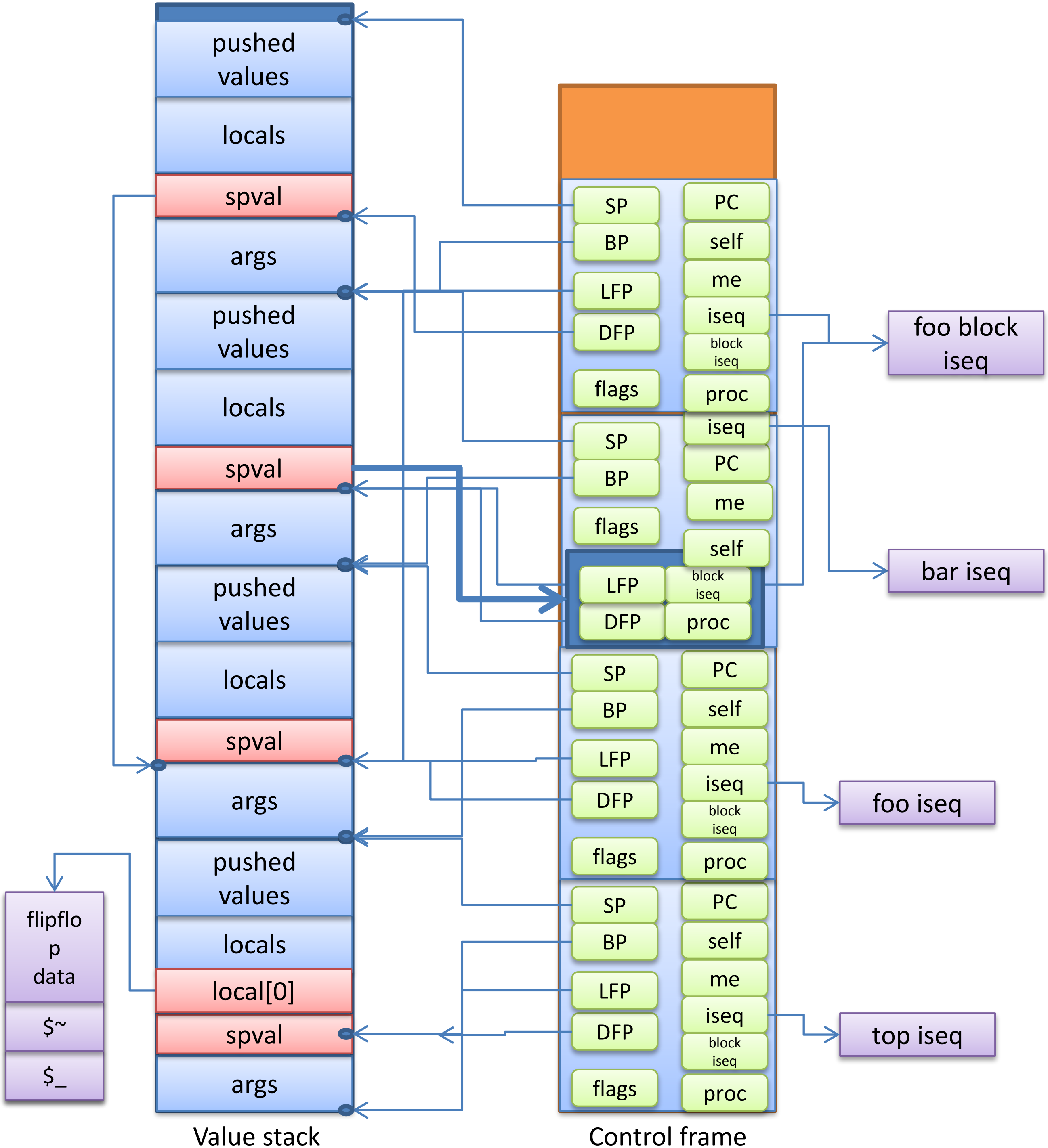
Proposed method table data structure



Proposed code context (iseq) data structure


T_CLASS
classext_t
m_tbl
iv_index_table
method table
initialize
a
b (alias of a)
rb_code_context_t
type: method | iseq
iseq
cref_stack
other_info
rb_method_info_t
method_flag: public
callee_id: a
orig_id: a
klass
alias_ptr
method_other_info
2
T_ICLASS
classext_t
m_tbl
iv_index_table
method table
initialize
a
b (alias of a)
rb_code_context_t
type: method | iseq
iseq
cref_stack
other_info
rb_method_info_t
method_flag: public
callee_id: a
orig_id: a
klass
alias_ptr
method_other_info

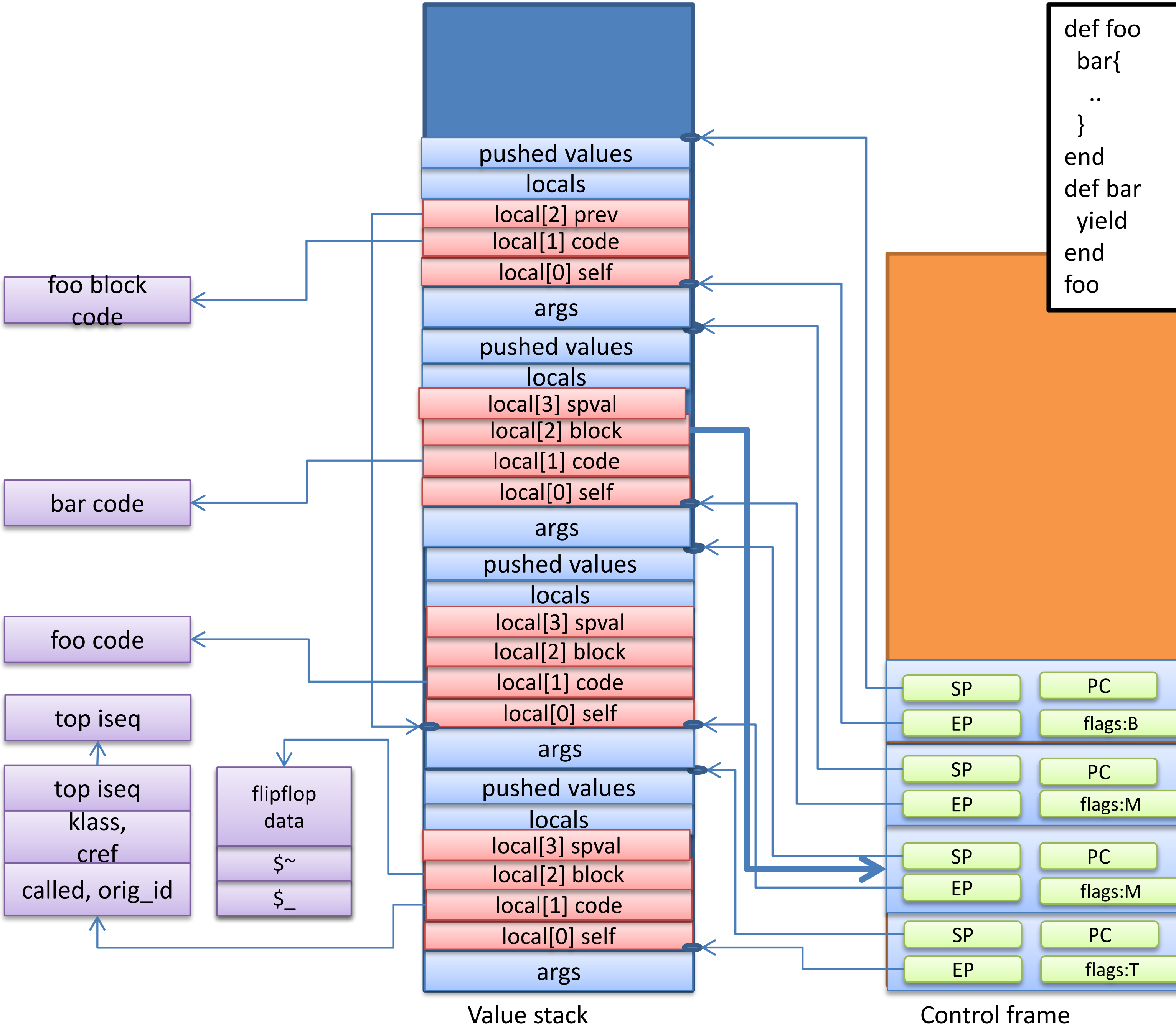
Current VM stacks structure

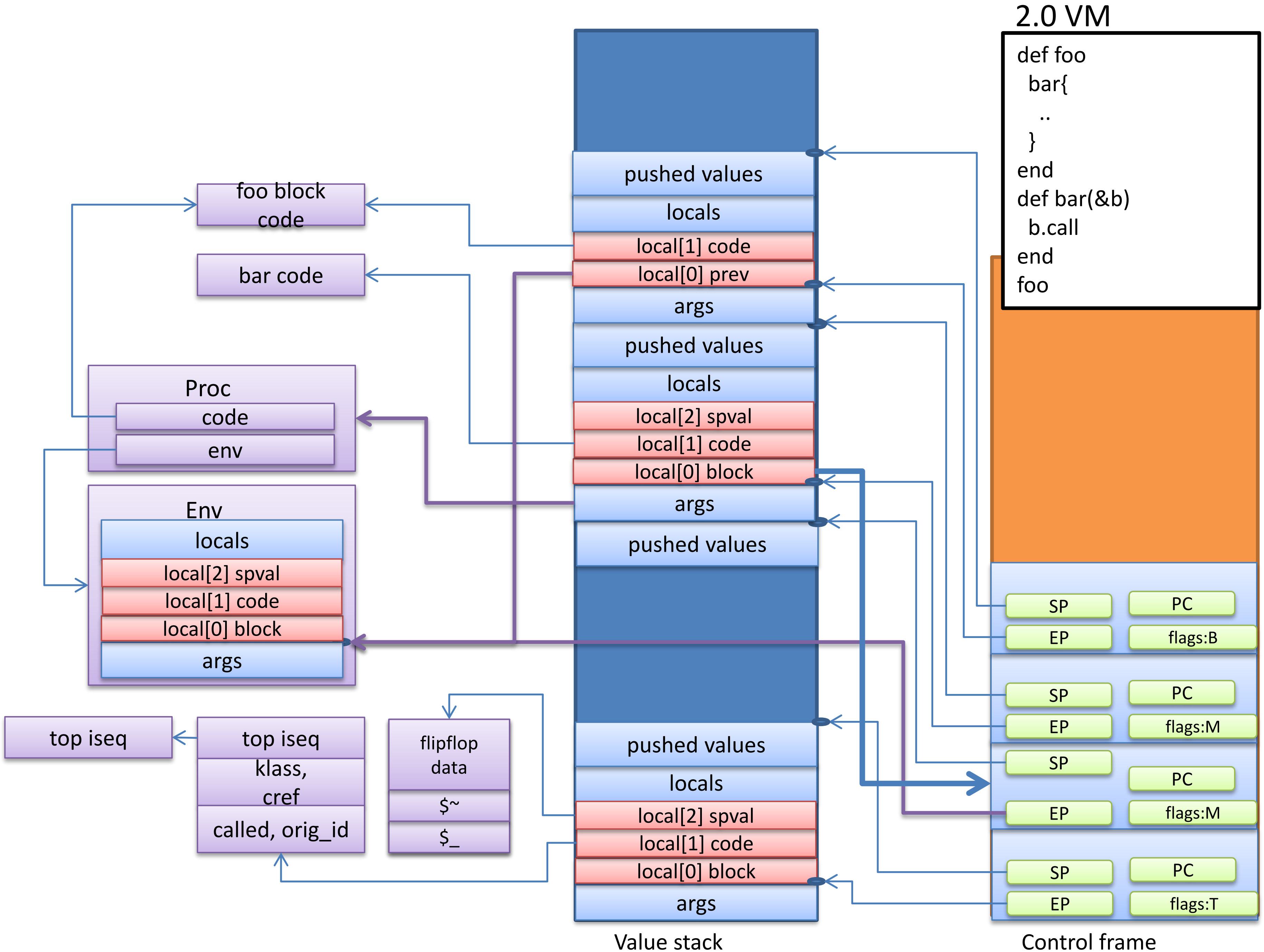



```
def foo
  bar{
    ..
  }
end
def bar
  yield
end
foo
```

2.0 VM

```
def foo
  bar{
    ..
  }
end
def bar
  yield
end
foo
```





2.0 VM
def foo
bar{
..
}
end
def bar(&b)
b.call
end
foo
foo block code
bar code
Proc
code
env
Env
locals
local[2] spval
local[1] code
local[0] block
args
top iseq
top iseq
klass, cref
called, orig_id
flipflop data
$~
$_
pushed values
locals
local[1] code
local[0] prev
args
pushed values
locals
local[2] spval
local[1] code
local[0] block
args
pushed values
pushed values
locals
local[2] spval
local[1] code
local[0] block
args
Value stack
SP
PC
EP
flags:B
SP
PC
EP
flags:M
SP
PC
EP
flags:M
SP
PC
EP
flags:T
Control frame

C APIs for “incomplete features”

- Discussion about several features are not completed
  - “require” framework
  - Instrumentation framework
  - …
- Strategy: Introduce “C APIs” secretly and experiment new features in gem

Future work
Dreams: After Ruby 2.0

- Compilation
- Parallel execution
- Pluggable features

Student's research: CastOff

A performance improvement tool for ruby1.9.3

(1) Use from ruby script

Programmer

```
require 'cast_off'
CastOff.compile(
    Klass,
    :Method,
    binding,
    TypeInfo)
…
```

- Compile Klass#Method
- Load compiled binary
- Run faster

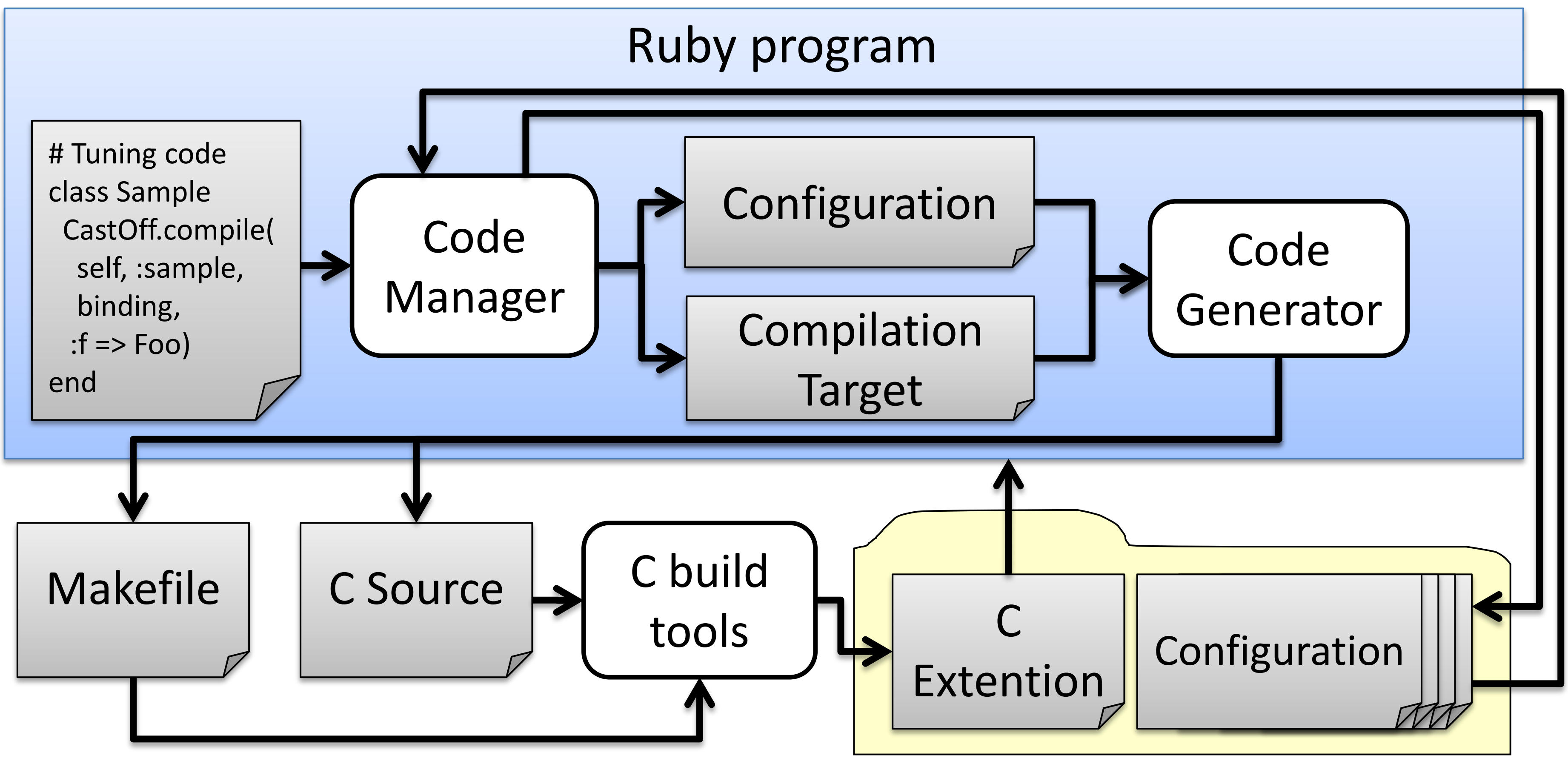
(2) Use from command line

Programmer

```
$ CastOff "program"
```

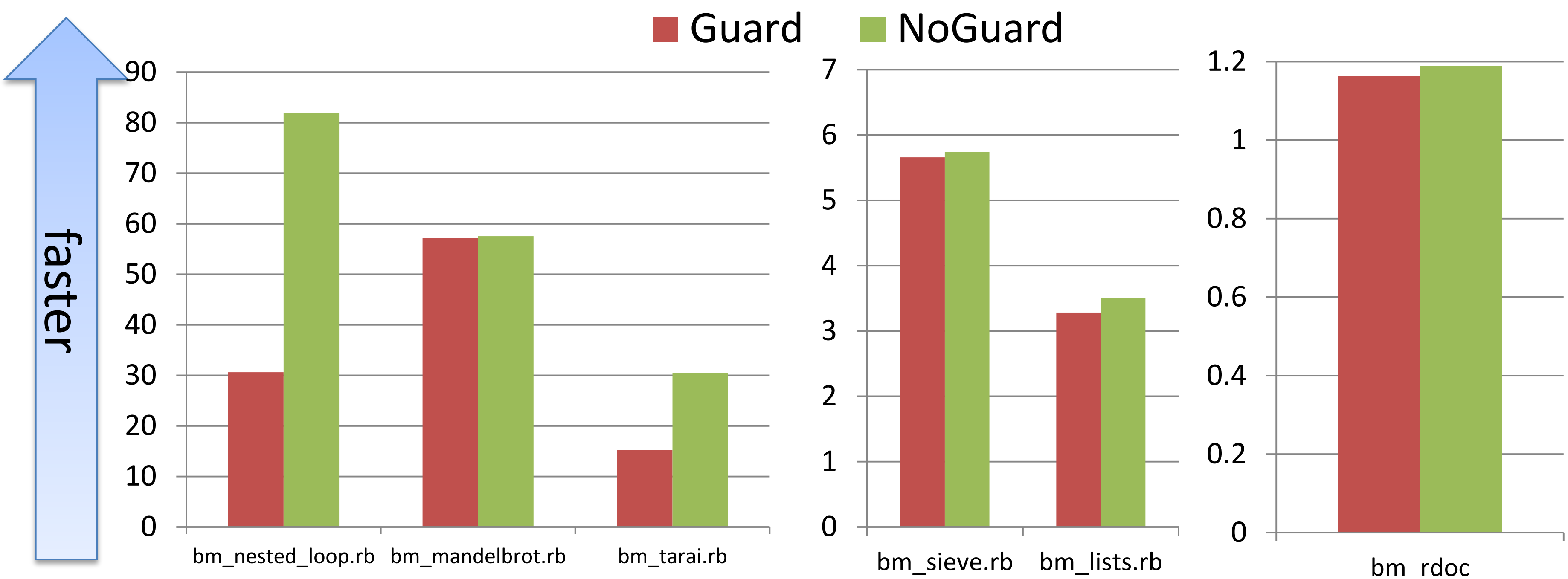
- Run and Profile "program"
- Compile methods in "program"
- Run faster

Compilation flow



Performance improvements

Execution time ratio（CRuby 1.9.3 / CastOff）



Parallel Execution

- Run threads in parallel (JRuby, MacRuby, …)
  - Good: Well known approach
  - **Bad: Difficult to make safe/correct multi-threaded programs**
    - **Many tragedy (in Java, etc.)**
  - Bad: Difficult to make efficient implementation with fine-grain lock
- Parallel processes (dRuby, …)
  - Good: No need to implement
  - Bad: Marshal overheads

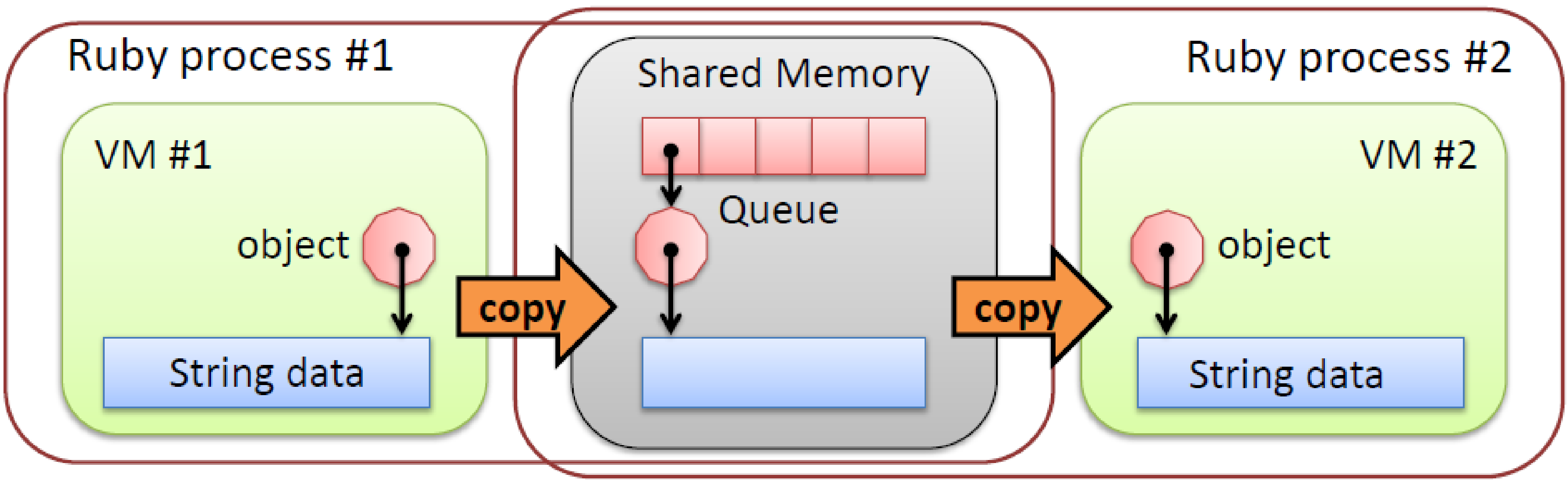
Support friendly
Coarse-grained parallel computing

- Encourage Multi-process
  - Traditional well-known approach
  - Toward advanced dRuby
- Multi-VM
  - VMs in one process
  - Light-weight communication

Student's reseach

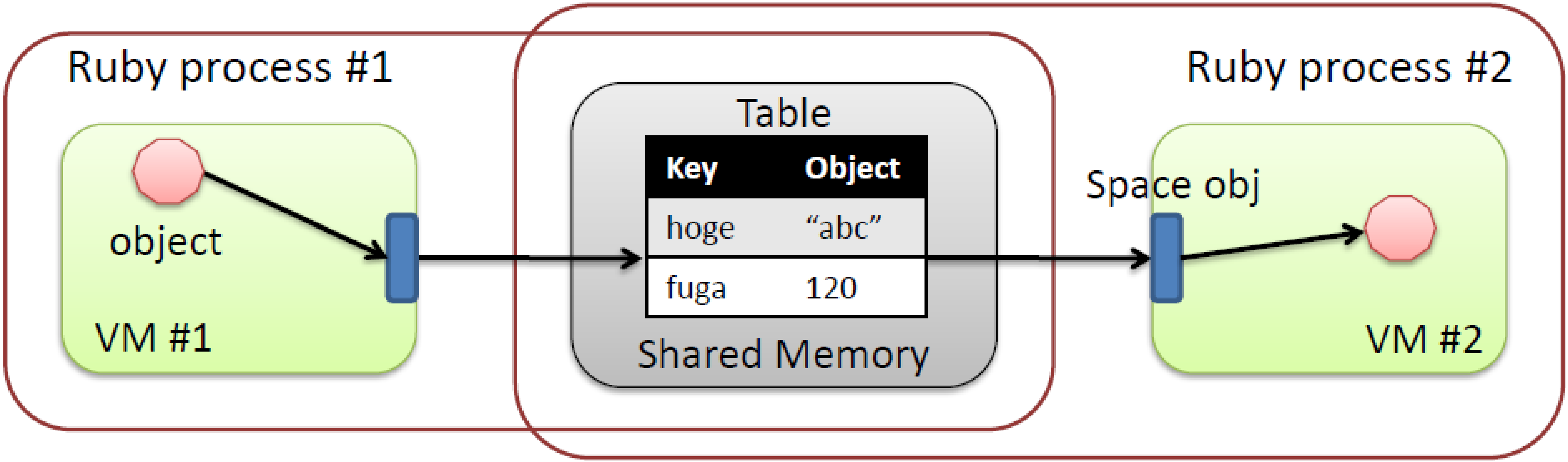
Tunnel: Inter-process communication w/shared memory

- Object transfer w/ shared memory

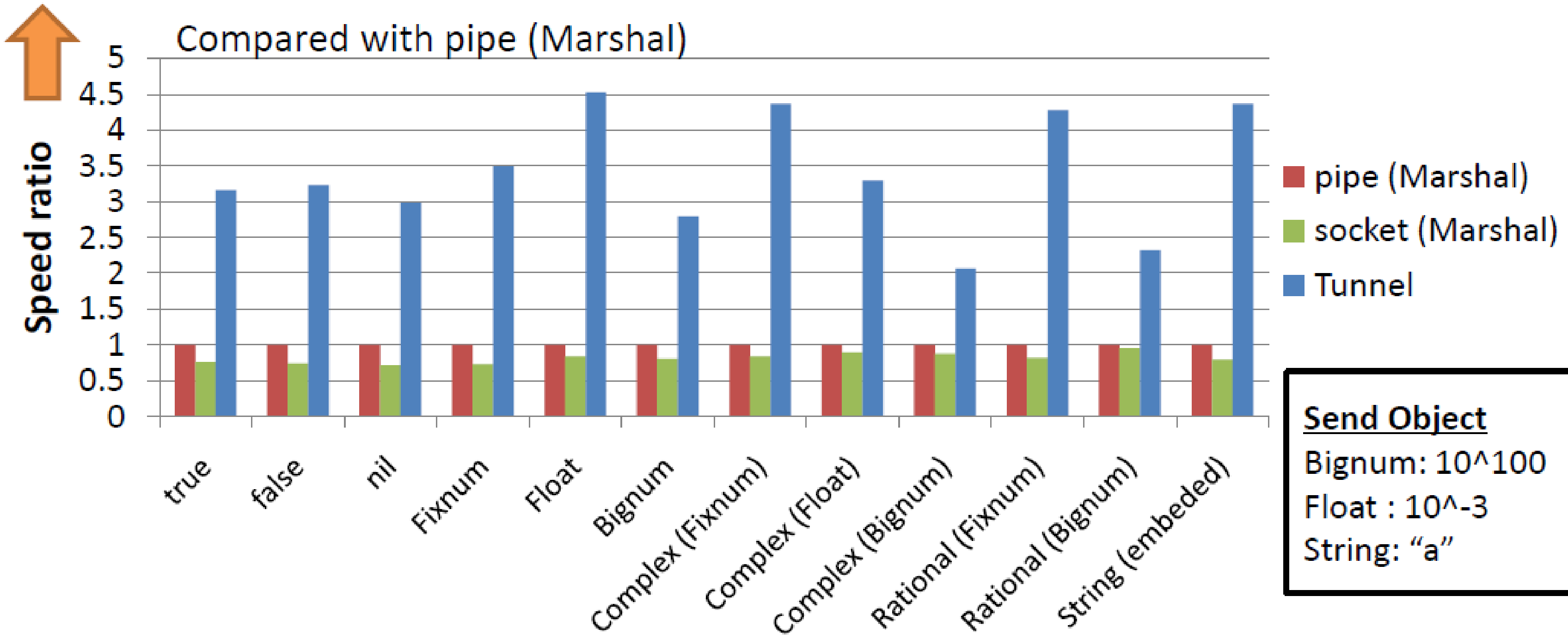


Student reserch (cont.)
Space: Inter-process
Space w/shared memory

- Shared space between ruby processes
  - Similar to Linda/Rinda



Evaluation of Tunnel

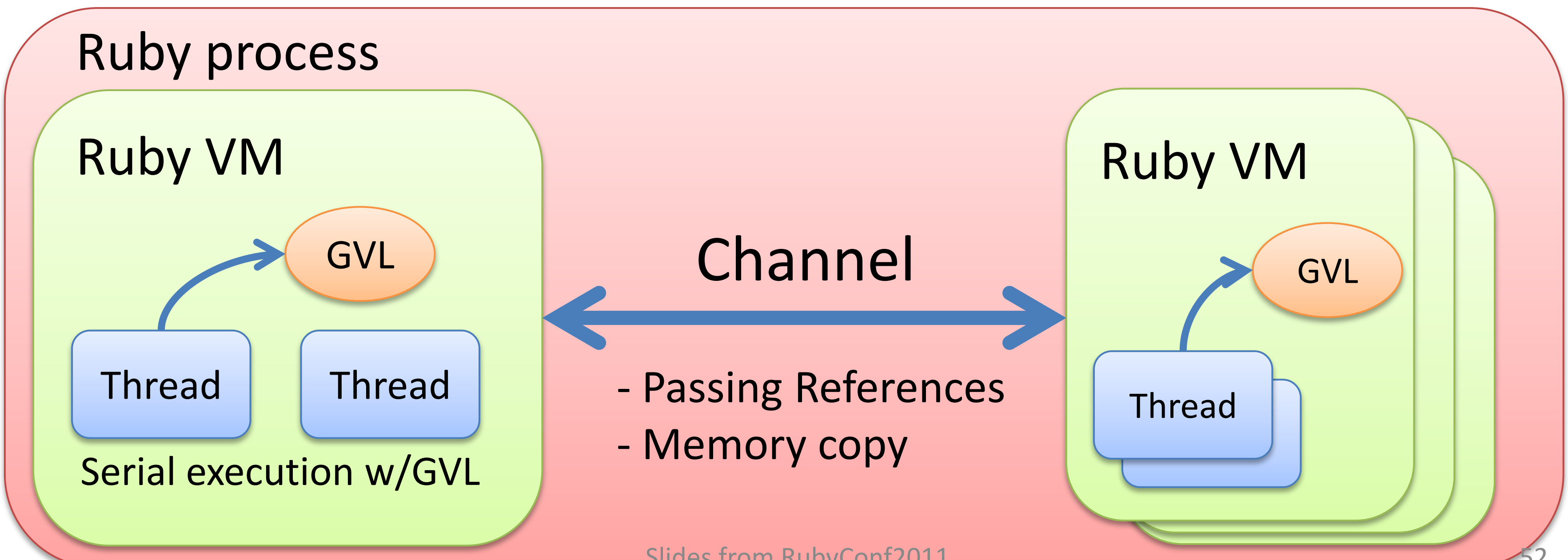


Send Object
Bignum: 10^100
Float : 10^-3
String: “a”

Parallel Execution
MVM

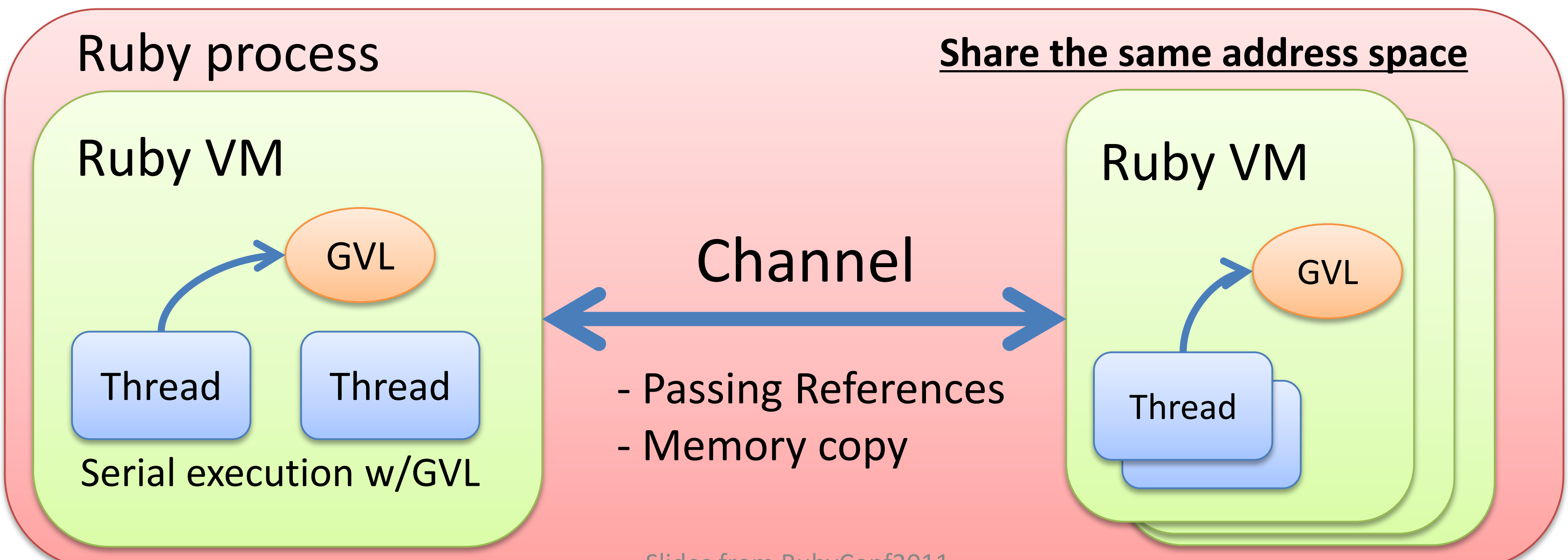
Parallel Execution Multiple-VM (MVM) on Ruby

- Multiple VMs in one process
  - VMs are completely isolated (Each VM has an independent object space (heap))
  - VMs run in **parallel**
    - Each VM has own GVL (w/o fine grained lock)



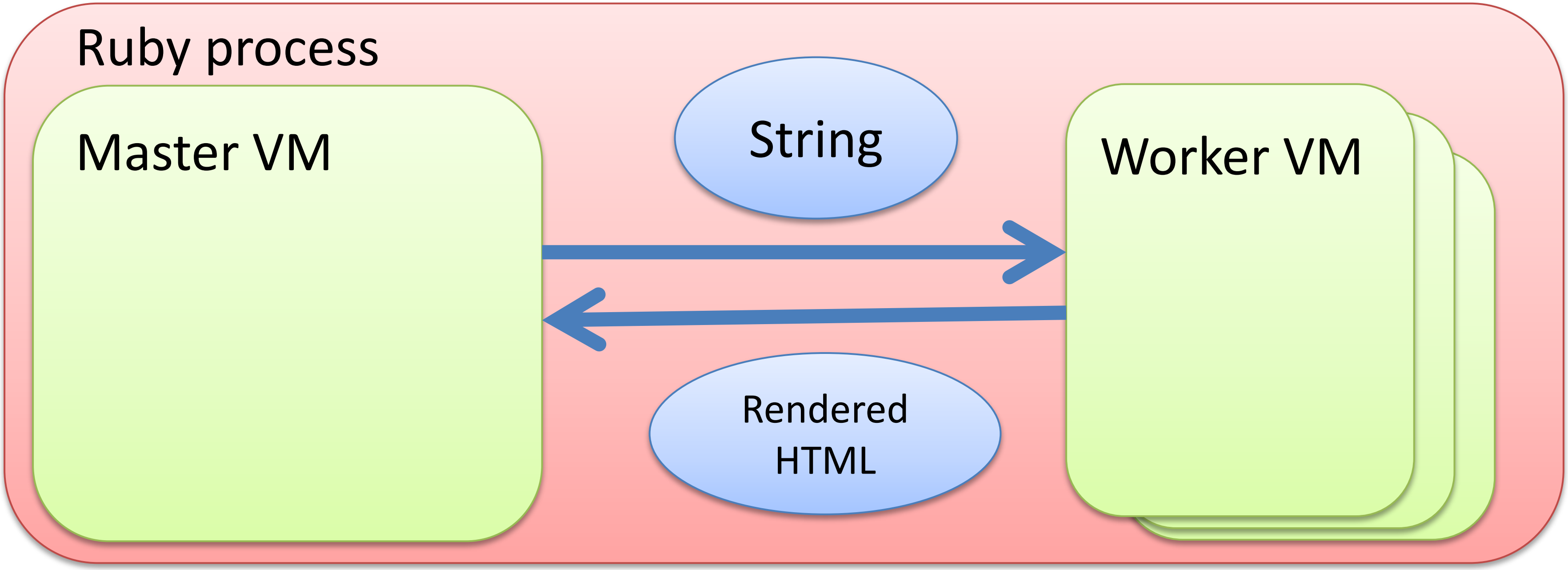
Our Approach
Multiple-VM (MVM) on Ruby

- Channel: Inter-VM Communication mechanism
  - The only way to communicate with other VMs
  - Simply passing references or copying memory in the same address space

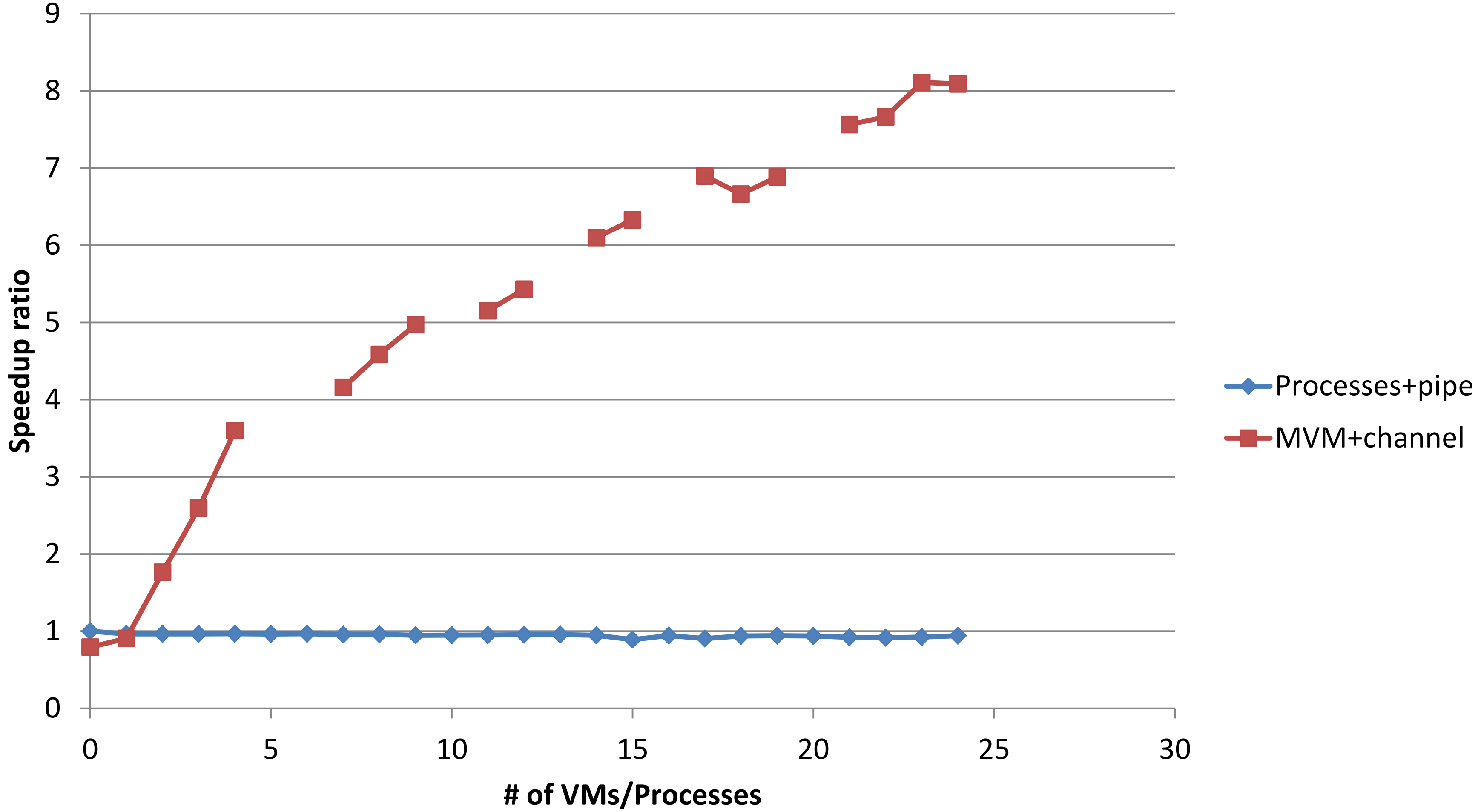


Evaluation
HTML rendering app

- Master dispatch string to worker and worker returns rendered HTML.

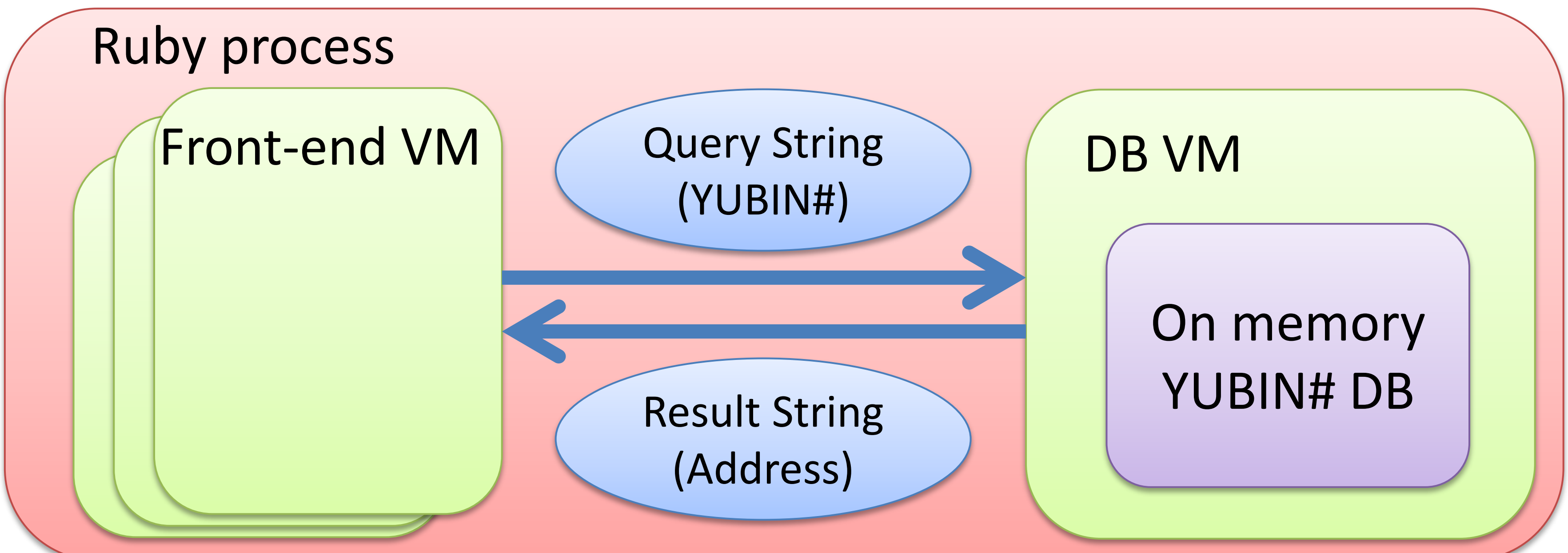


Evaluation
HTML rendering app



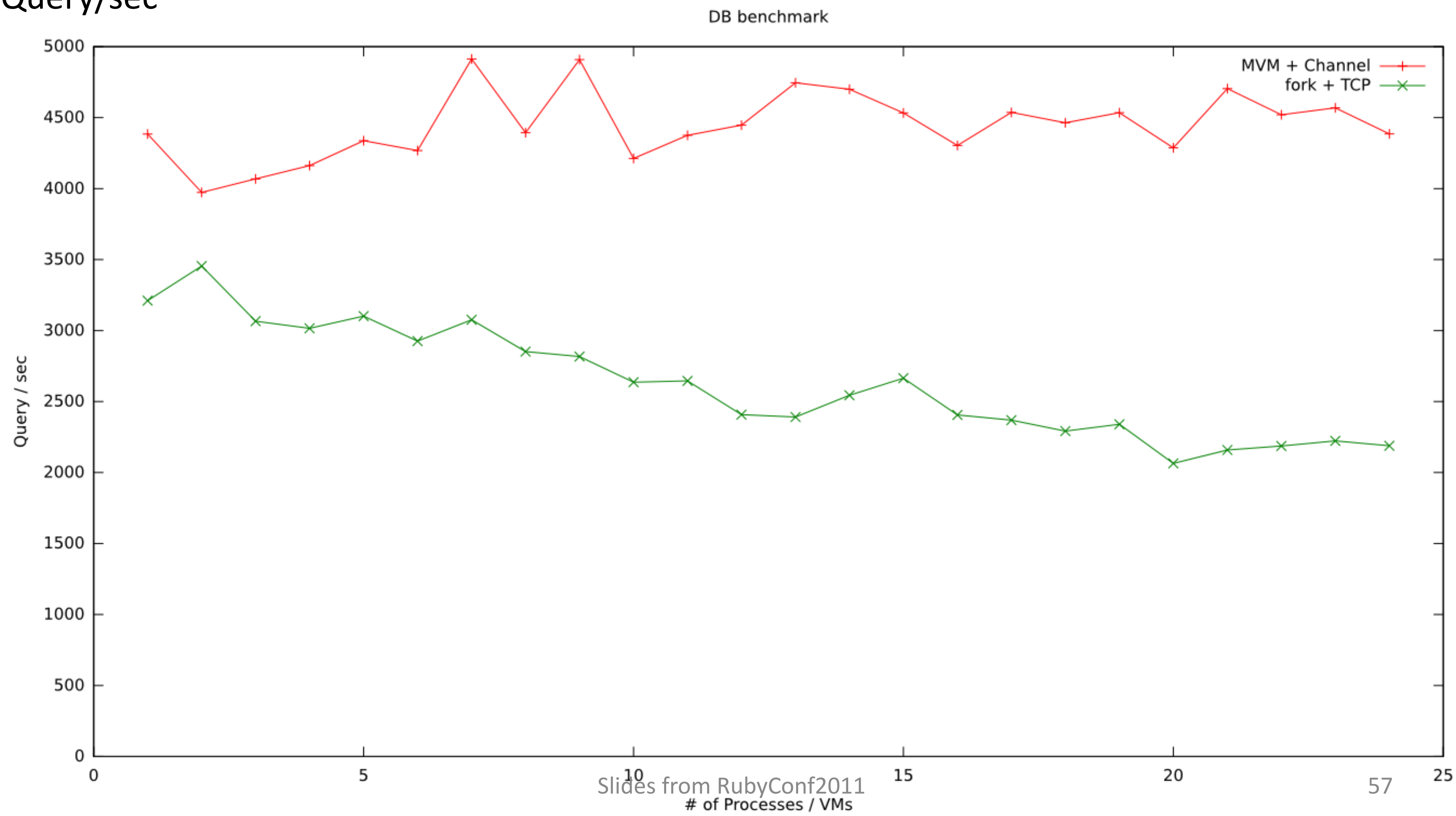
Evaluation
DB app

- Benchmark assuming web application
- Several front-end VMs and one DB VM
- YUBIN-Number (zip-code) DB on memory
- Using **dRuby** (w/MVM) framework



Evaluation
DB app

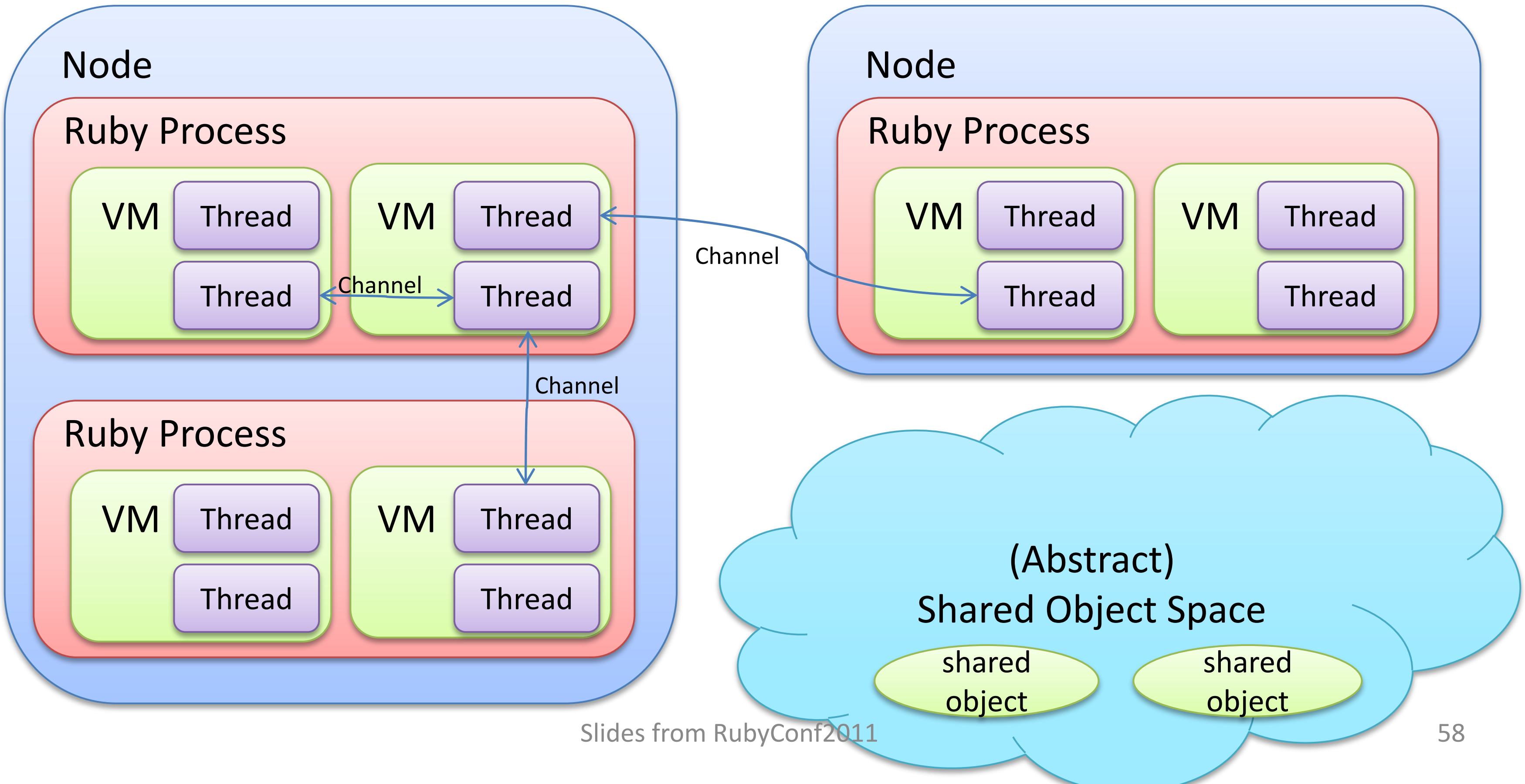
Query/sec



Slides from RubyConf2011

Future work on MVM/Parallel

- Extend this communication channel between inter-process (w/ shared memory), inter-node
- Migratable Ruby activity (threads, blocks (closures) and so on)



Summary

- Finished work - Ruby 2.0 Internal Changes
- Remaining work - Ruby 2.0 Internal Features
- Future work – Dreams: After Ruby 2.0

We will release Ruby 2.0 next year!

Don’t miss it!

Thank you!

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