Precompiling Ruby scripts
Myth & Fact

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Questions

Have you ever thought

Ruby
is slow?

Quick answer

- *Try __latest MRI__ contains optimized VM*
  - Ruby 1.9 and later implement VMs
  - Ruby 2.3 (Dec/2015) also includes many improvements
  - VMs are written by **Koichi Sasada**

Questions

Have you ever thought

Ruby's GC
is slow?

Quick answer

- *Try **Ruby 2.1** and later*
  - Generational and incremental techniques to increase throughput and to reduce GC pause time
  - GCs are implemented by **Koichi Sasada**

Questions

Have you ever thought

Ruby/Rails boot time is slow?

Quick answer

- *Check out this presentation :p*
- This presentation is by **Koichi Sasada**
  - A programmer living in Tokyo, Japan
  - Ruby core committer since 2007

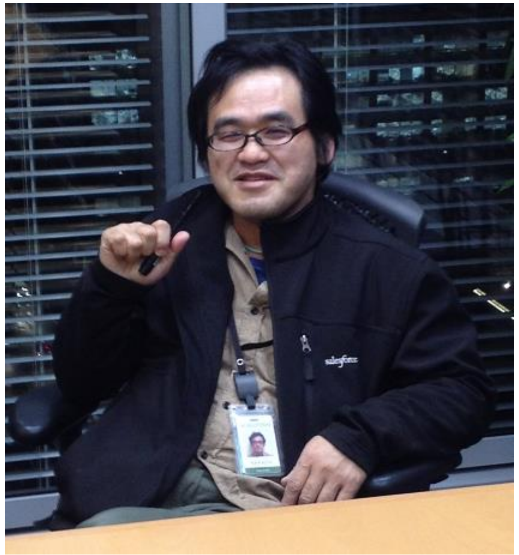
Ruby
PROGRAMMING
Language

Koichi is an Employee

Koichi is a member of Heroku Matz team

- Heroku employs three full time Ruby core developers in Japan named “Matz team”

Matz



Nobu

Koichi (ko1)

Mission of Heroku Matz’s team

Design Ruby language
and improve quality of MRI

Latest achievement: **Ruby 2.3**

Next challenge: **Ruby 2.4**

and **Ruby 3**

Feel free to ask about Ruby itself later

Back to “Question”

Have you ever thought

Ruby/Rails boot time is slow?

Myth

“If we have an AOT compiler, the boot time issue will be solved”

OK, let's try it.

Today’s talk is about:

- New feature of Ruby 2.3

  “Pre-compilation primitives”
- Yomikomu gem: what is and how to use it.
- Evaluation results includes redmine boot time

New feature of Ruby 2.3
“Pre-compilation primitives”

Compilers for interpreters

- JIT (just in time) compilers
  - Compile to more efficient code at runtime
  - Runtime statistics information are available

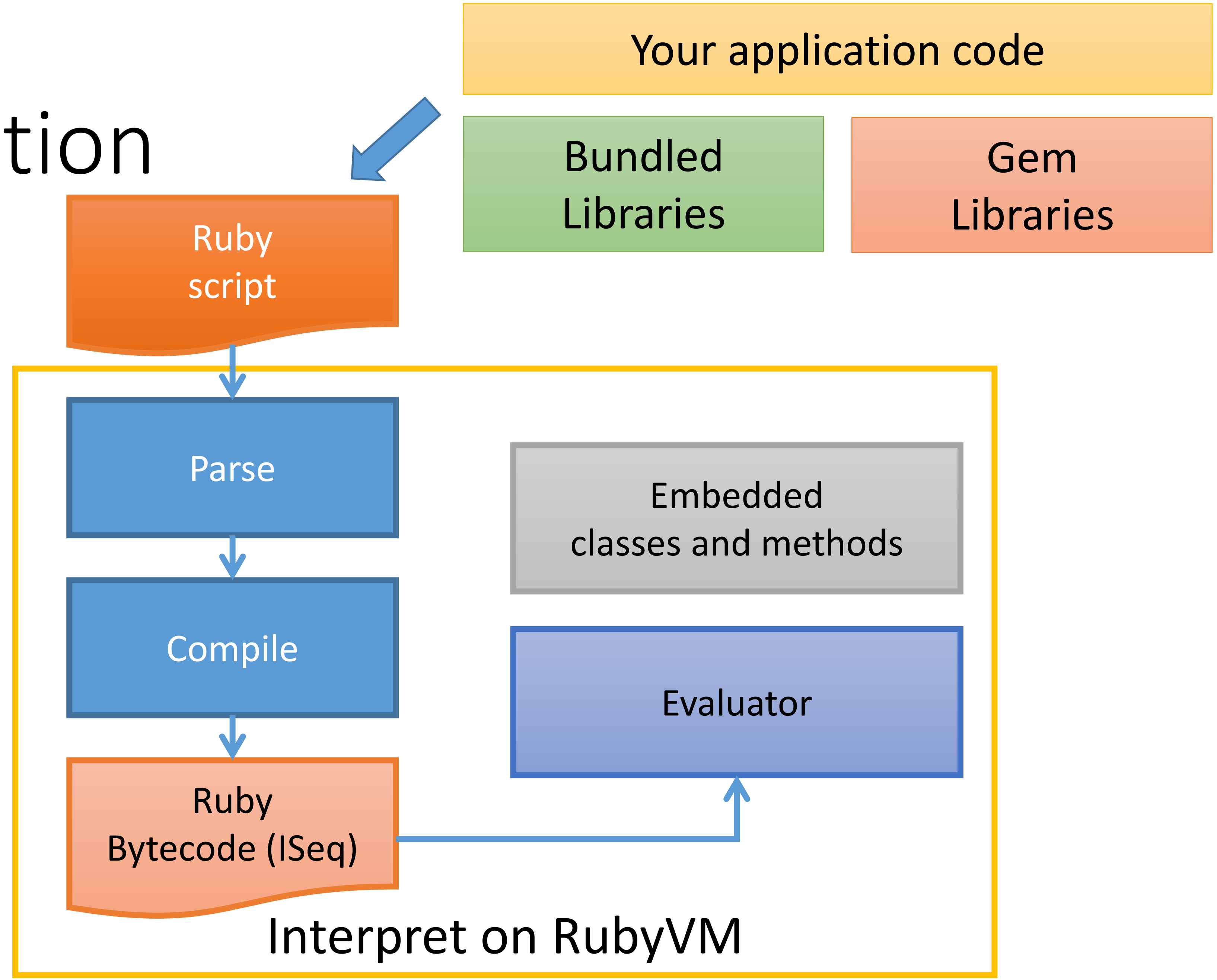
One goal of Ruby 3 !

- AOT (ahead of time) compilers
  - Program to native machine code (like C, …)
  - Program to other languages code
    - Translate to C, Java, etc…
  - Program to persistent byte code (like Java, …)
    - RubyVM::InstructionSequence in Ruby’s case

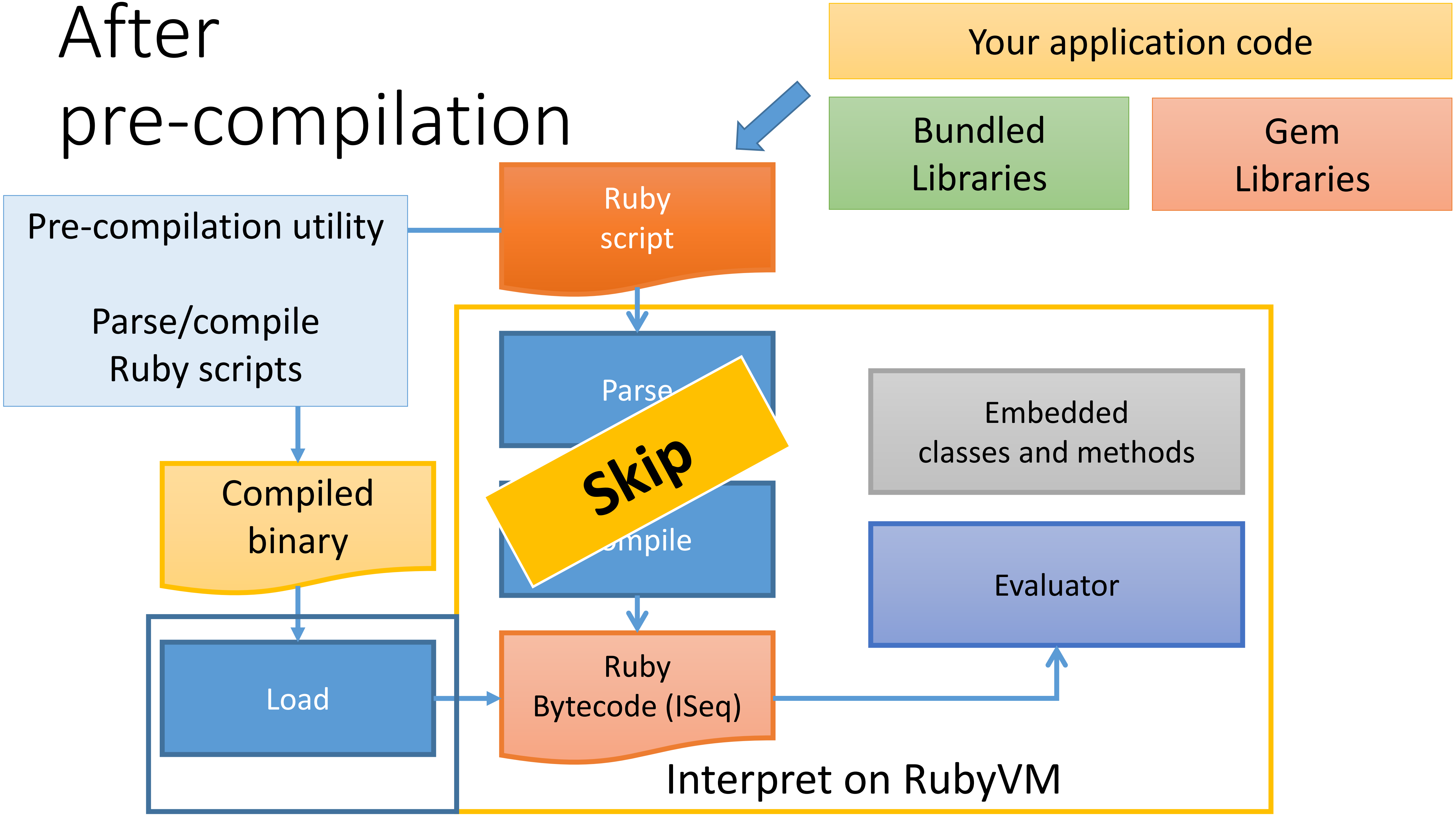
RubyVM::InstructionSequence or ISeq Ruby's bytecode

- All of Ruby programs are compiled to ISeqs
- MRI makes ISeqs at boot time

Before pre-compilation



After pre-compilation



Purpose of pre-compilation

- Fast boot
- Reduce memory consumption
- Migrate compiled code to other nodes

Purpose of pre-compilation
Goal of this time

- Fast boot
- Reduce memory consumption
- Migrate compiled code to other nodes

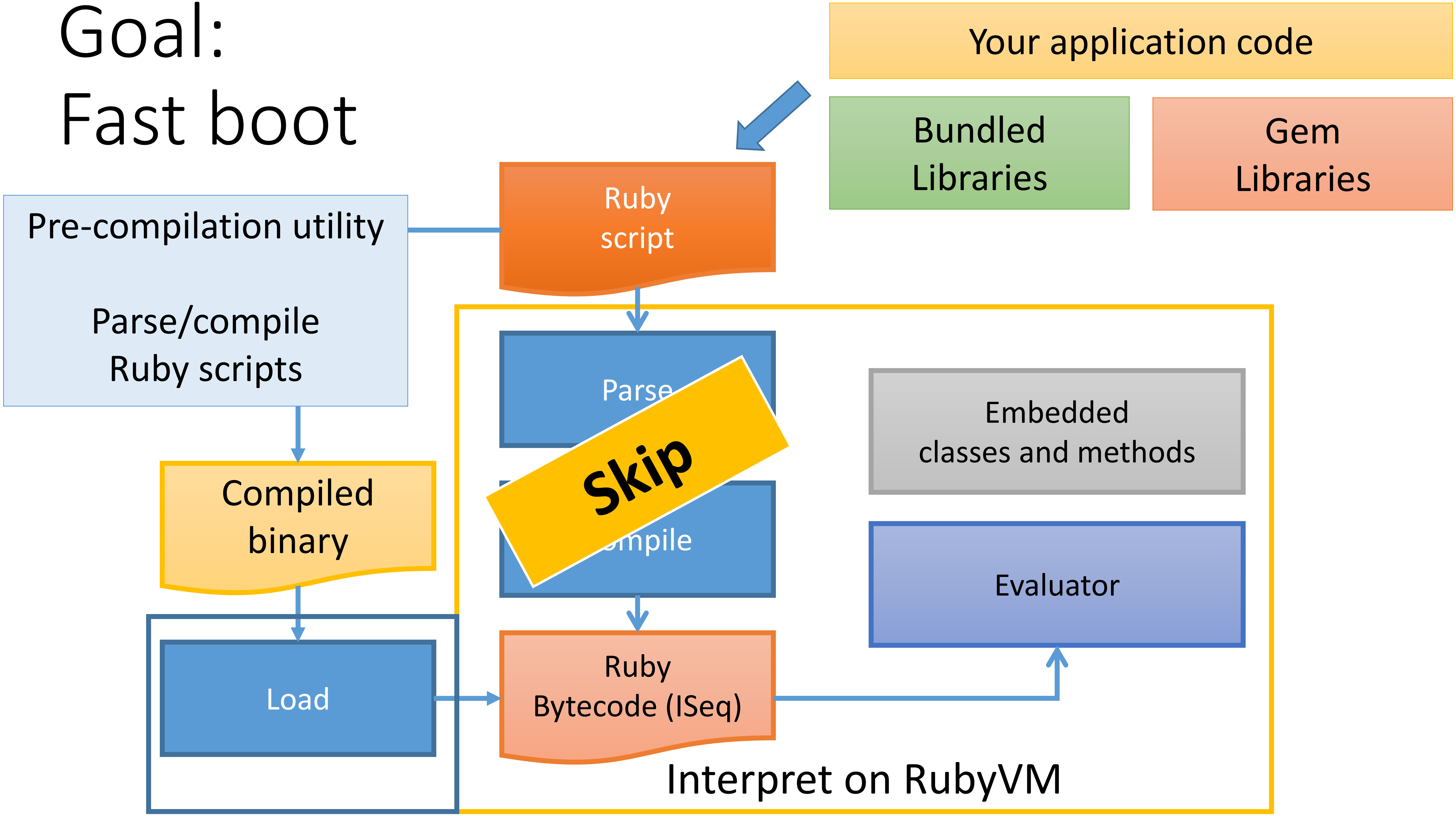
Out of scope

No portable binary support

No verification at loading time

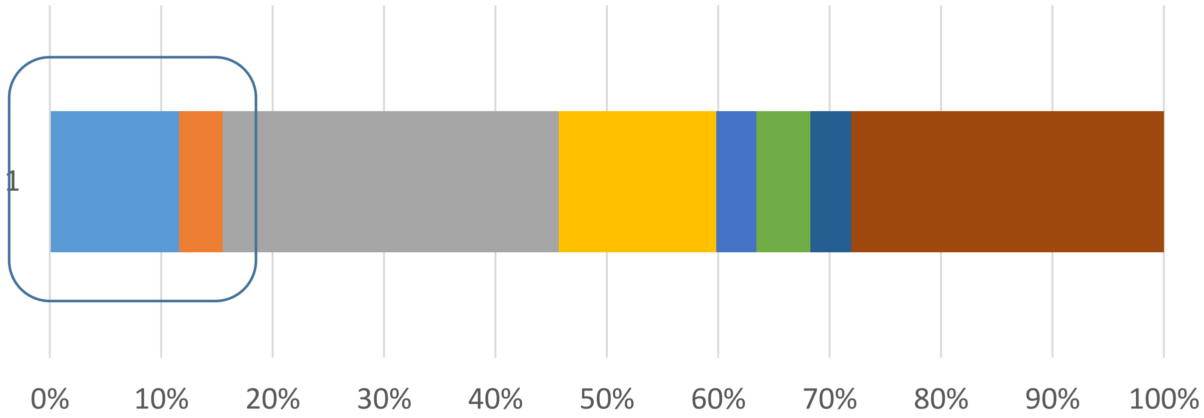
[Because we can’t not trust binaries by others]

Goal: Fast boot



Goal: Memory consumption
Current issue

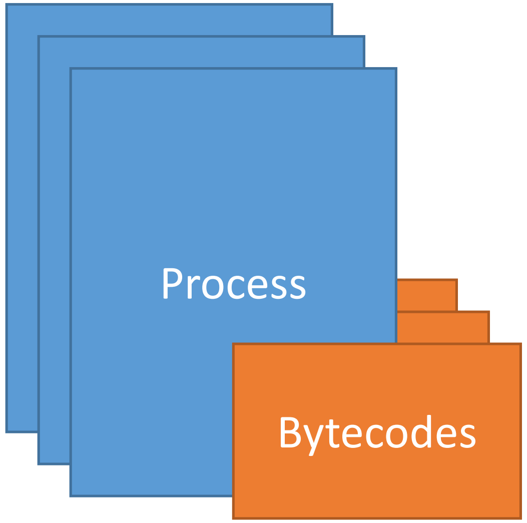
ISeq consumes 15% (20MB) on simple Rails app



	1
🟦 iseq_setup@compile.c	15,595,764
🟧 rb_iseq_new_with_opt@iseq.c	5,231,136
⬜ heap_assign_page@gc.c	40,518,400
🟨 st_init_table_with_size@st.c	18,994,480
🟦 rb_str_buf_new@string.c	4,817,252
🟩 st_update@st.c	6,578,736
🟦 onig_region_resize@regexec.c	4,891,968
🟫 others	37,676,810

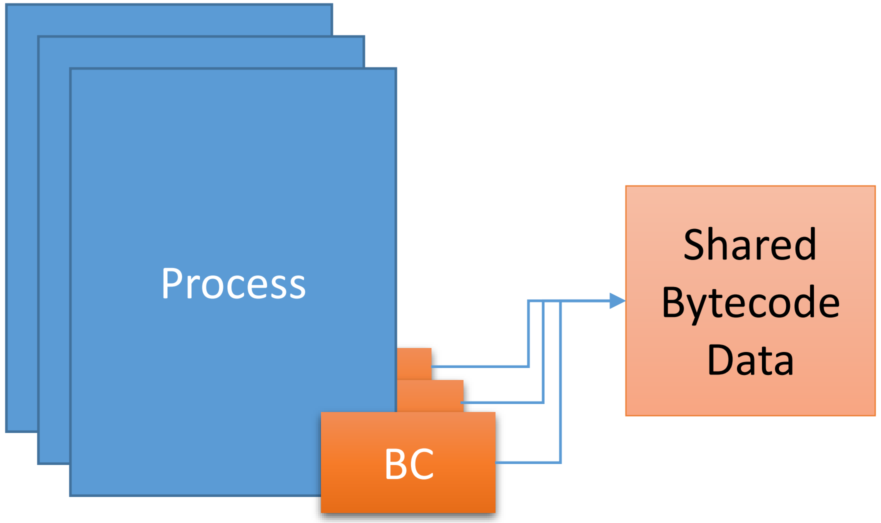
Purpose: Memory consumption
Current issue on multi-processes

Actual



Independent BCs

Expected



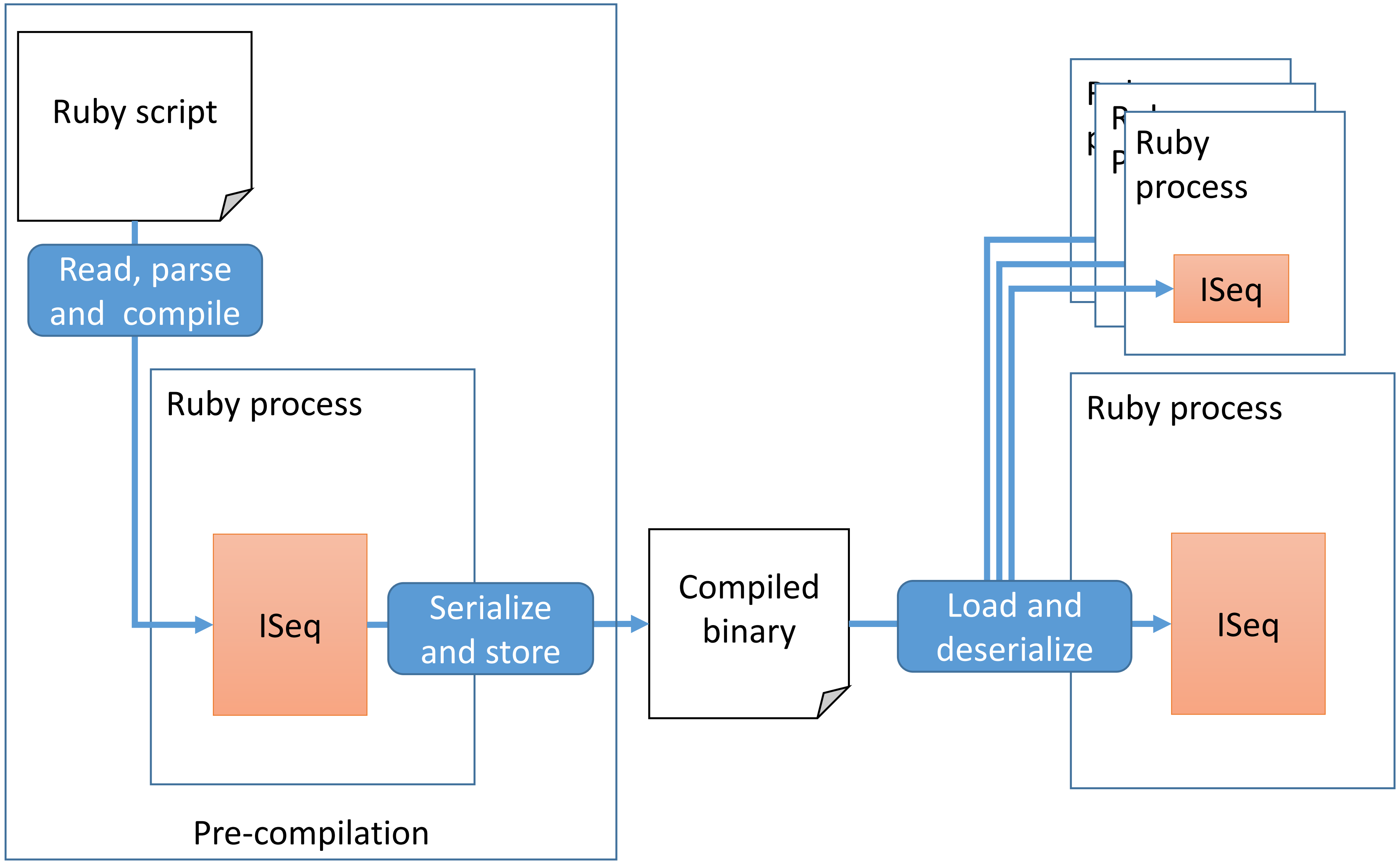
(Partialy) Shared BCs

Design and implementation of primitives on Ruby 2.3

We need two components

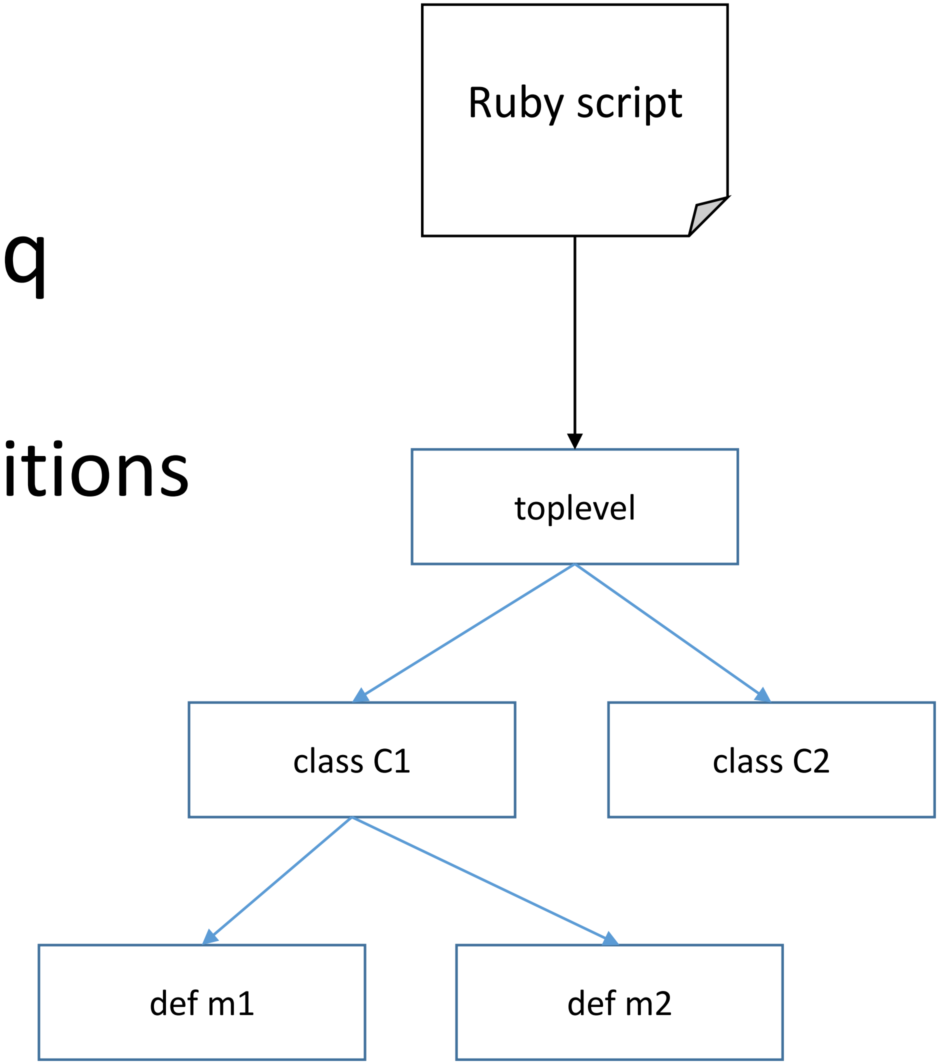
1. Serializer and deserializer for ISeq
2. Utility to control AOT compilation
   - When to compile scripts and load them?
   - Where/How to store compiled binaries?

Serializer and deserializer of ISeq

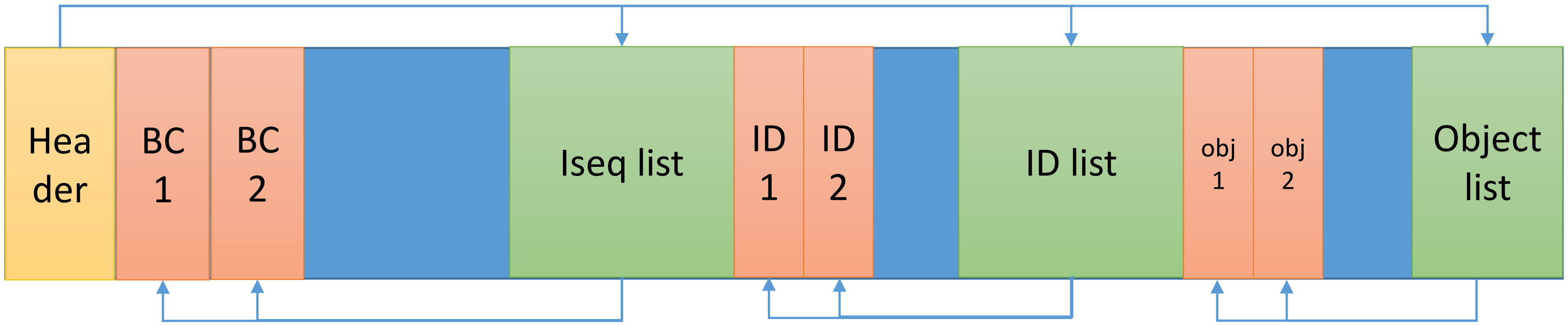


(background)
ISeq is a tree

- Basically, each scope has own ISeq
  - A top-level has class expressions
  - Class expression has method definitions
  - Method definition has blocks
  - Block has blocks, …
  - Other bytecode blocks
    - ensure, rescue, …
  - And other exceptional cases



Specify compiled binary data format



- Iseq (BC), ID, Objects are pointed by index of each lists in each data
- Referred objects are serialized
- **Dump machine dependent data (can’t migrate compiled code)**
- No verifier (because this file is not for migrations)

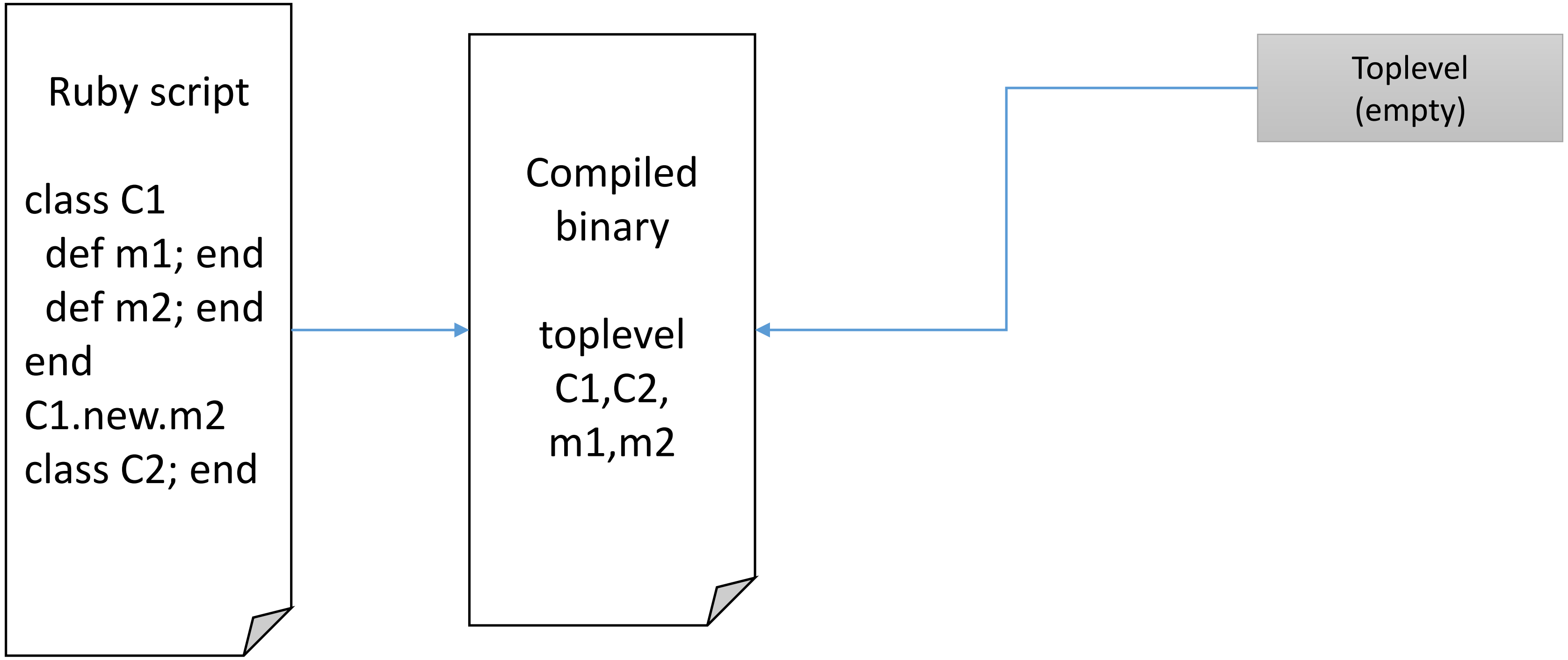
Optimization technique
Lazy loading

Lazy loading

- Do not load all of ISeq at once
  - Load ISeq if needed
  - Similar to “autoload” method

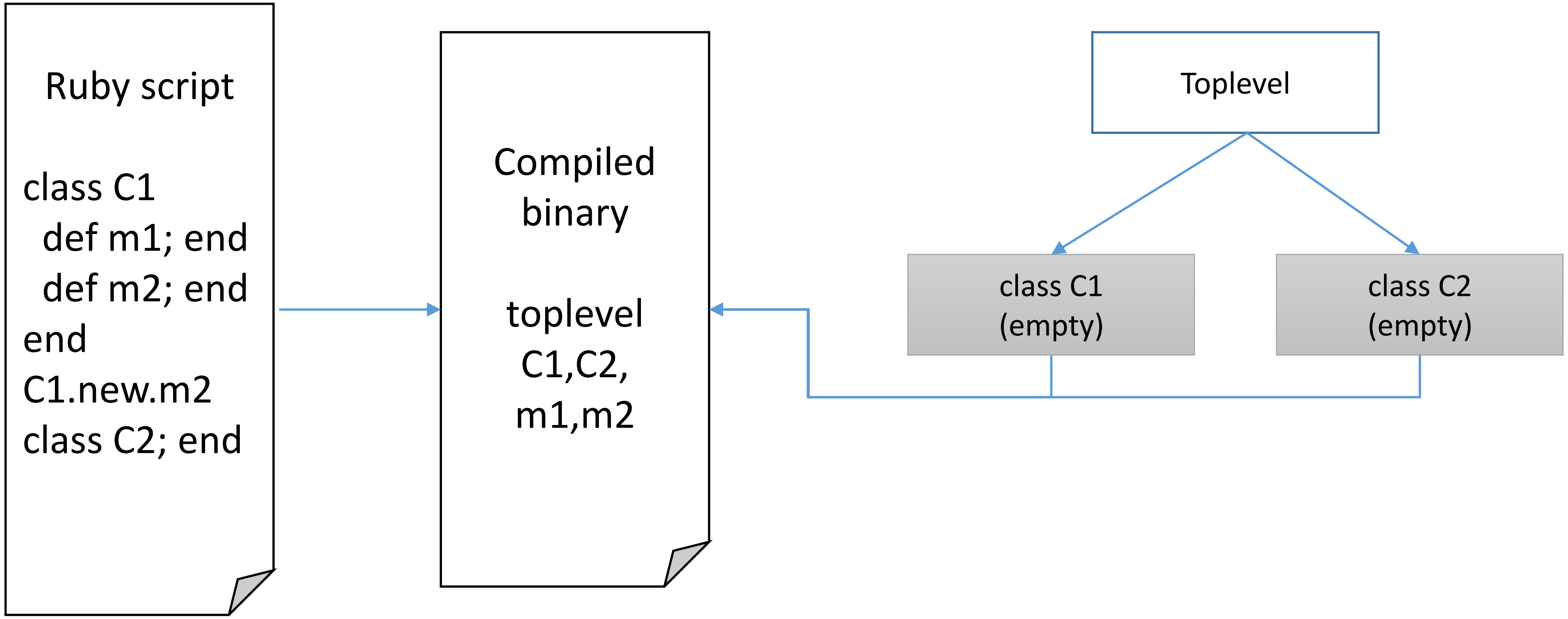
Technique
Lazy loading

(1)Load and make an empty toplevel ISeq



Technique
Lazy loading

(2) Load toplevel ISeq and make empty C1, C2 ISeqs and evaluate toplevel ISeq



Ruby script

```
class C1
  def m1; end
  def m2; end
end
C1.new.m2
class C2; end
```

Compiled binary

toplevel
C1,C2,
m1,m2

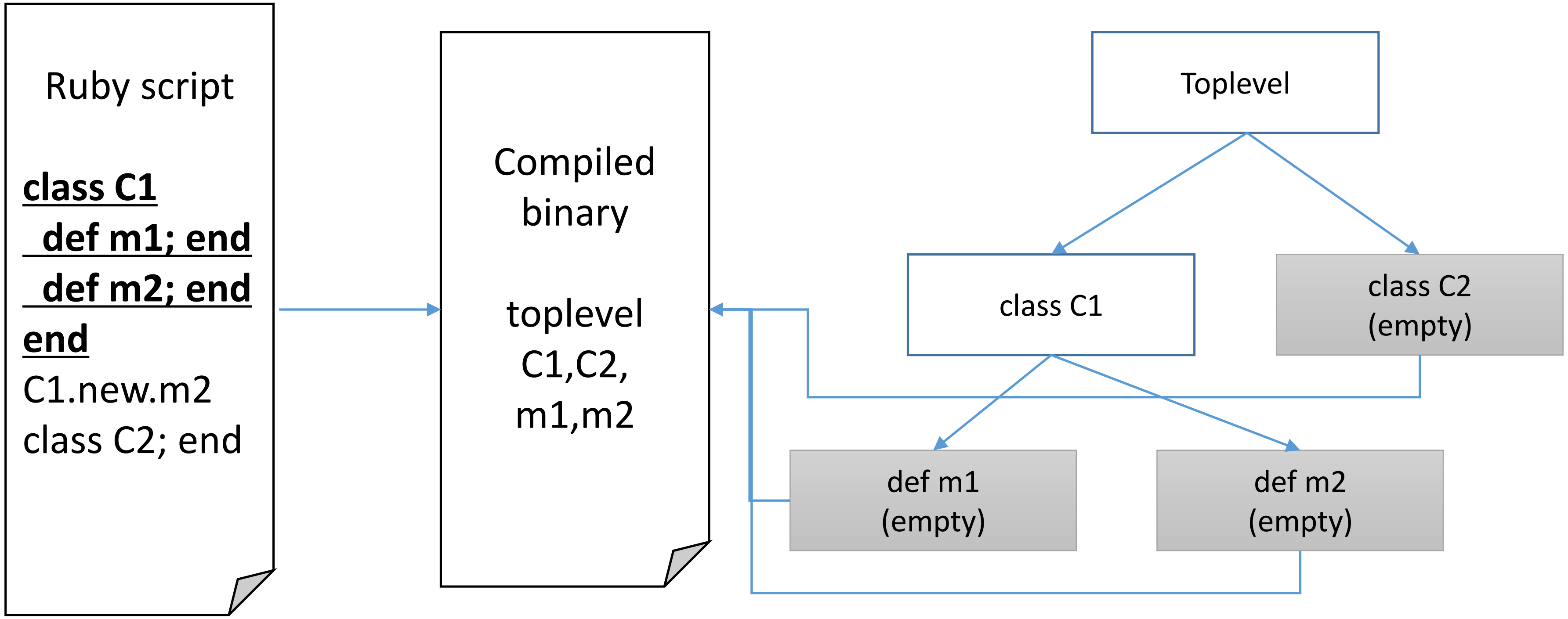
Toplevel

class C1
(empty)

class C2
(empty)

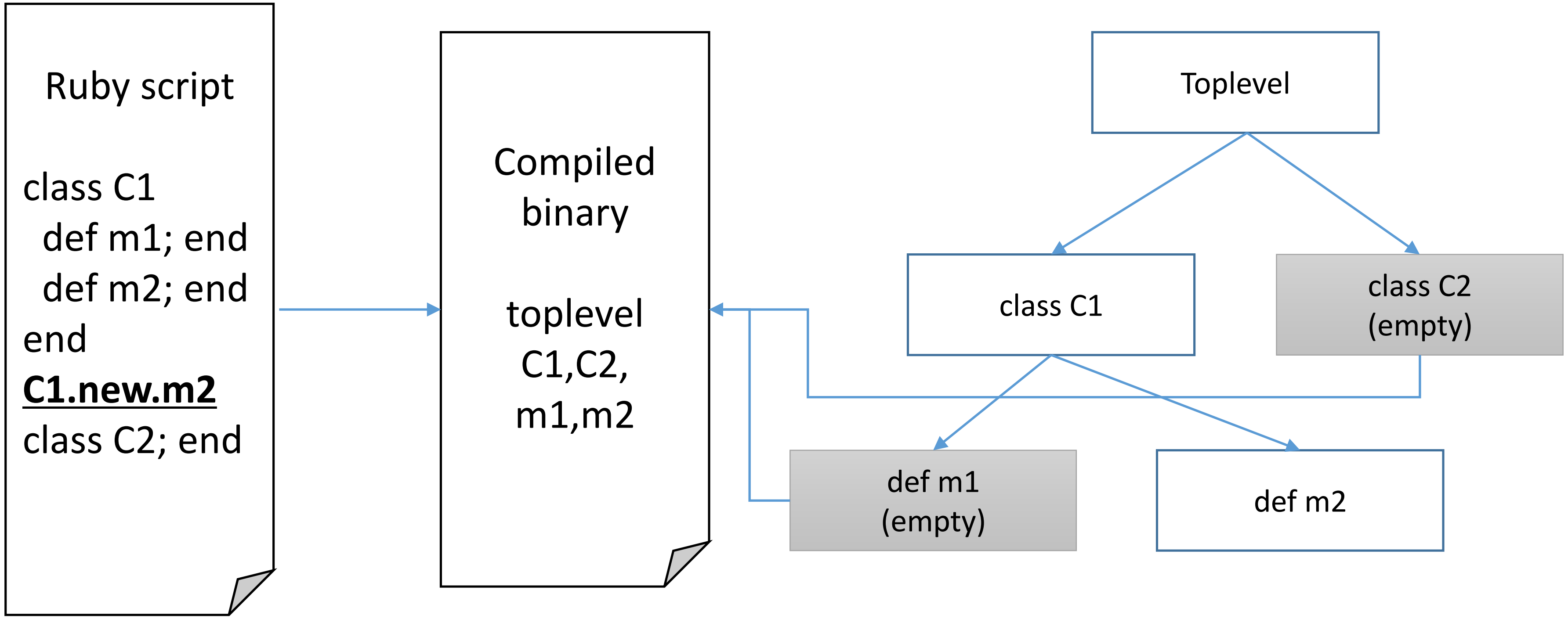
Technique
Lazy loading

(3) Load C1 and evaluate C1
Define m1 and m2 with empty ISeqs



Technique
Lazy loading

(4) Load m2 and invoke m2



Ruby script

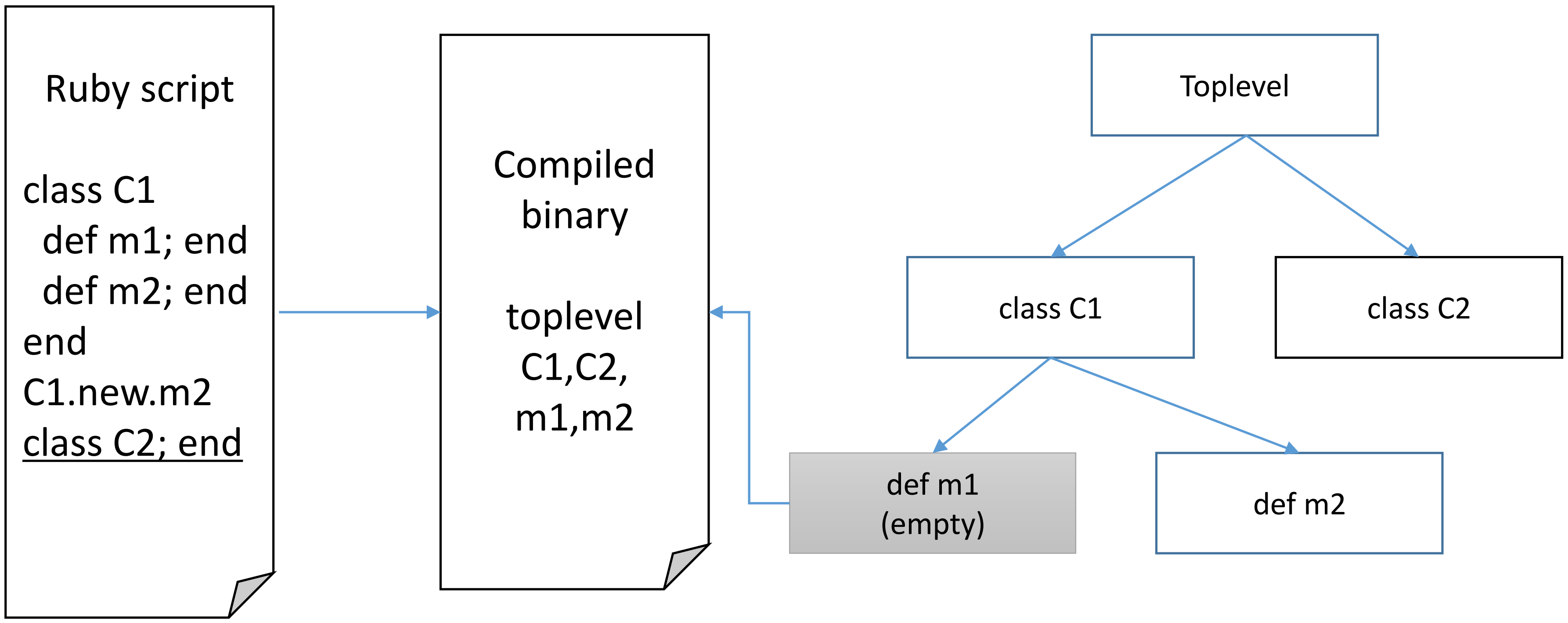
```
class C1
  def m1; end
  def m2; end
end
C1.new.m2
class C2; end
```

Compiled binary

toplevel
C1,C2,
m1,m2

Technique
Lazy loading

(4) Load C2 and evaluate C2



Ruby script

```
class C1
  def m1; end
  def m2; end
end
C1.new.m2
class C2; end
```

Interface
API and Tools

How to store compiled binary?

- Compile timing
  - Use compiler explicitly
    - C/Java/… compilers
  - Loading time
    - Rubinius (*.rbc), Python (*.pyc), …
- Location of compiled binary
  - A file in the same directory of *.rb files
  - A file in a special directory
  - DB

So many options!

Current (our) solution
Provides primitive APIs

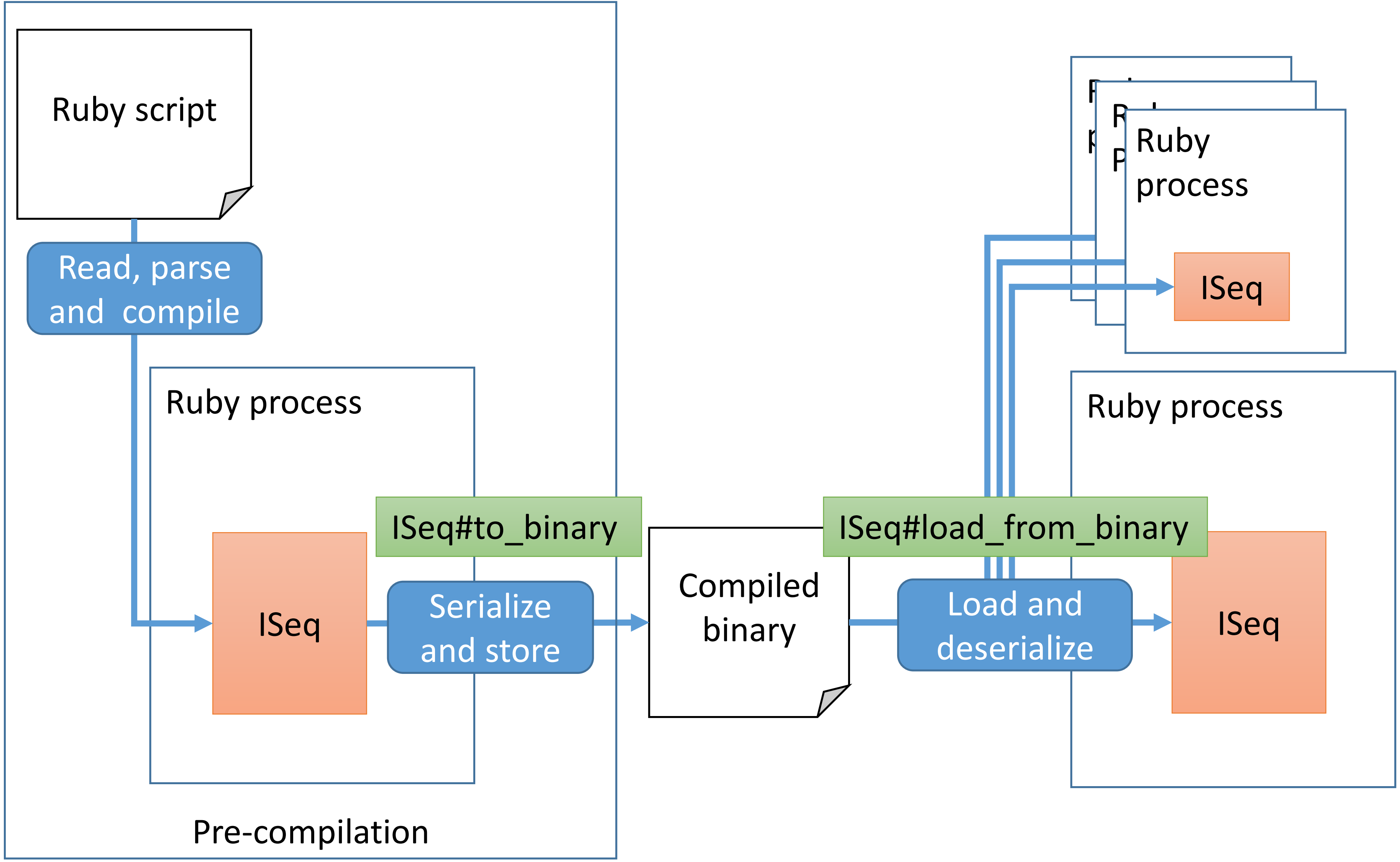
- Serialize and de-serialize APIs
- Loading API

You can try to make your own pre-compilation controller

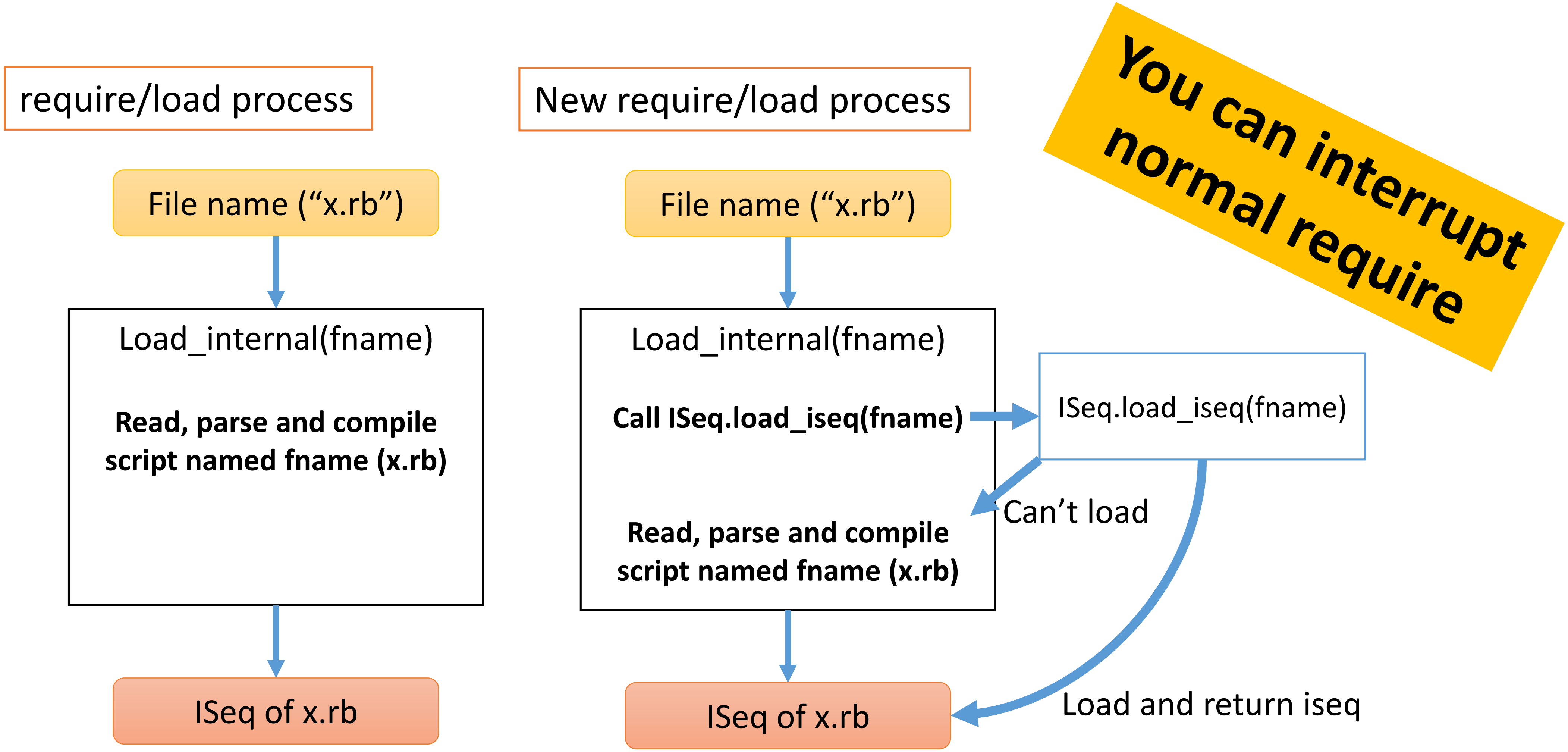
Current implementation
Primitive APIs

- Serialize and de-serialize APIs
  - RubyVM::InstructionSequence#to_binary
  - RubyVM::InstructionSequnece.load_from_binary(binary)
- Loading API
  - RubyVM::InstructionSequence.load_iseq
    - Call this method at every loading time (if defined)
    - This method should return nil or loaded ISeq

Store serialized program and load



Using ISeq.load_iseq



require/load process

File name (“x.rb”)

Load_internal(fname)

Read, parse and compile script named fname (x.rb)

ISeq of x.rb

New require/load process

File name (“x.rb”)

Load_internal(fname)

Call ISeq.load_iseq(fname)

ISeq.load_iseq(fname)

Can’t load

Read, parse and compile script named fname (x.rb)

Load and return iseq

ISeq of x.rb

You can interrupt normal require

Current implementation APIs (again)

- Serialize and de-serialize APIs
  - RubyVM::InstructionSequence#to_binary
  - RubyVM::InstructionSequnece.load_from_binary(binary)
- Loading API
  - RubyVM::InstructionSequence.load_iseq
    - Call this method at every loading time (if defined)
    - This method should return nil or loaded ISeq

Yomikomu.gem

Sample implementation of pre-compilation controller

When should we compile?

- Compile timing
    - Invoke a compiler explicitly
        - C/Java/… compilers
        - Invoke during gem installation is a good idea
    - Loading time (if not available, compile automatically)
        - Python (.pyc), Rubinius (.rbc)

Where to store?

- Make compiled binary files for each script?
- Store compiled binaries in one DB?

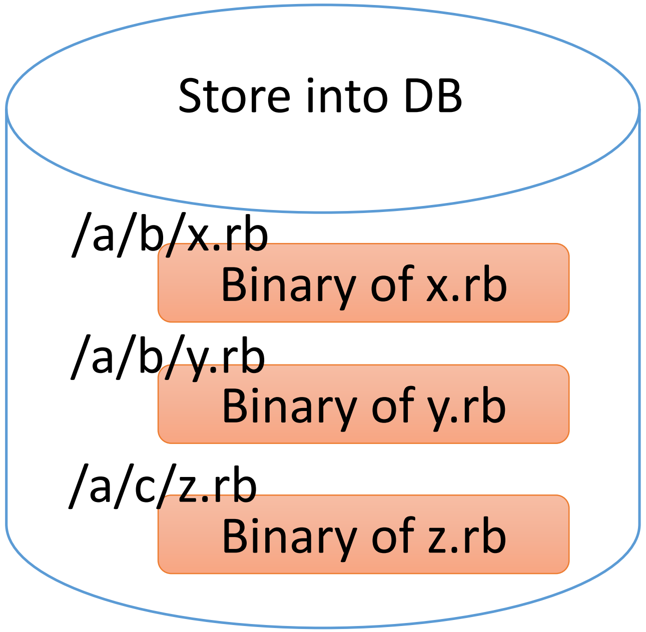
Store compiled binary in the same directory

```
/a/b/x.rb, x.rb.yarb
     y.rb, y.rb.yarb
   c/z.rb, z.rb.yarb
```

(Python and Rubinius do)

Store compiled binary in the specified directory

```
/a/b/x.rb, y.rb
   c/z.rb
/repos/a_b_x.rb.yarb
       a_b_y.rb.yarb
       a_c_z.rb.yarb
```



Store into DB

Where to store?

BTW, Matz doesn’t like storing binaries in same dir because he want to keep src dir clean.

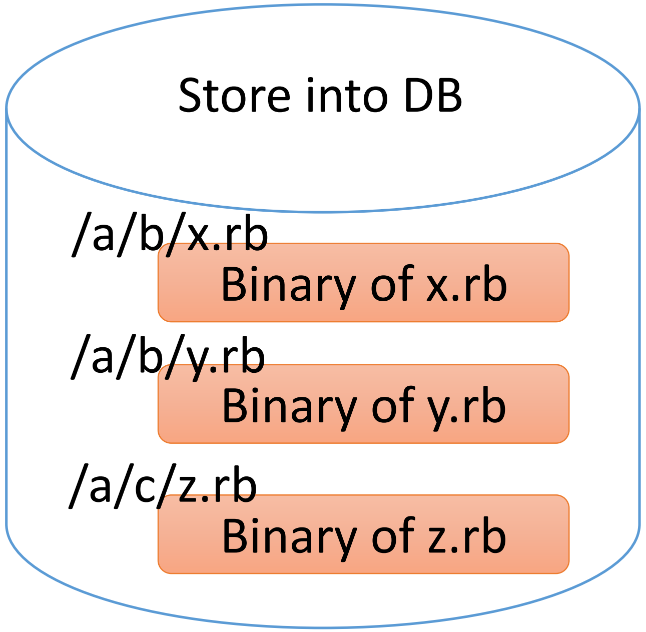
Store compiled binary in the same directory

```
/a/b/x.rb, x.rb.yarb
     y.rb, y.rb.yarb
   c/z.rb, z.rb.yarb
```

(Python and Rubinius do)

Store compiled binary in the specified directory

```
/a/b/x.rb, y.rb
   c/z.rb
/repos/a_b_x.rb.yarb
       a_b_y.rb.yarb
       a_c_z.rb.yarb
```



Store into DB

Sample implementation Yomikomu.gem

- “Yomikomu” = “読み込む” = “loading/reading”
- Implement many options

Usage of Yomikomu
3 steps

(1) **Set configuration** with environment variables

- Storage options and so on. See documents for details

(2) **Compile Ruby scripts** with **"kakidasu"** command

- "kakidasu" = "書き出す" = "write/output"
- $ kakidasu [script or directory]

(3) **put "require 'yomikomu'"** on your application

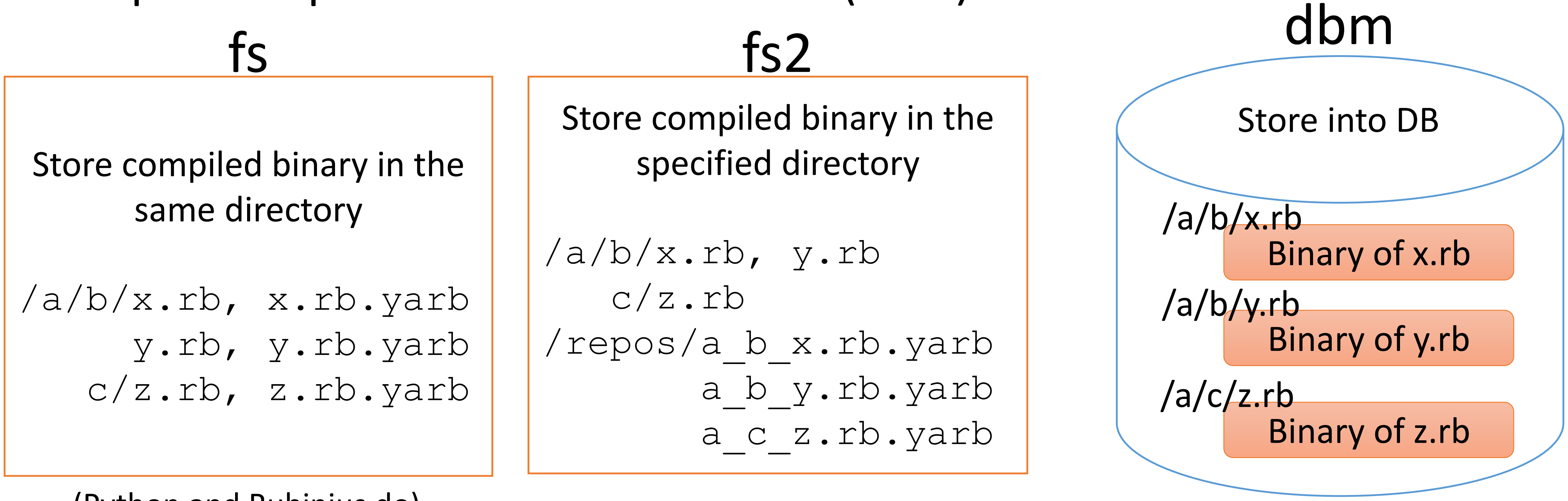
- Compiled binaries are loaded automatically

Configuration
Yomikomu supports several storages

- YOMIKOMU_STORAGE specifies how and where to store and load compiled binaries
  - fs (default)
  - fs2
  - fsgz
  - Fs2gz
  - dbm
  - flatfile

Configuration
Yomikomu supports 4 basic storages

- fs: put compiled binary files on same directory
- fs2: put compiled binary files on one directory
- dbm: put compiled binaries on one DB (dbm)



fs

Store compiled binary in the same directory

```
/a/b/x.rb, x.rb.yarb
     y.rb, y.rb.yarb
   c/z.rb, z.rb.yarb
```

(Python and Rubinius do)

fs2

Store compiled binary in the specified directory

```
/a/b/x.rb, y.rb
   c/z.rb
/repos/a_b_x.rb.yarb
       a_b_y.rb.yarb
       a_c_z.rb.yarb
```

dbm

Store into DB

/a/b/x.rb

Binary of x.rb

/a/b/y.rb

Binary of y.rb

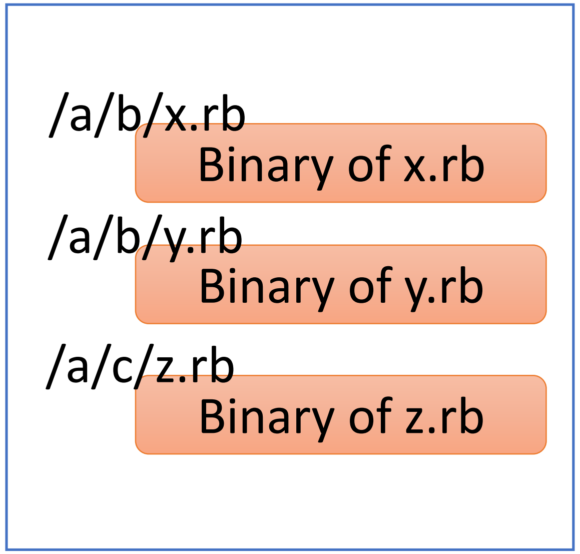
/a/c/z.rb

Binary of z.rb

Configuration
Yomikomu supports 4 basic storages

- flatfile: put compiled binaries into one file sequentially (and make index)
- ☺ we can locate binaries in loading order
- ☹ it does not support rewriting

flatfile



Configuration
Yomikomu supports compactions

- Store Gzip compressed compiled binary
  - fsgz, fs2gz, flatfilegz

Configuration
Yomikomu supports auto compilation

- YOMIKOMU_AUTO_COMPILE
  - If required script is not compiled, compile it and store to somewhere automatically
  - Similar to Python and Rubinius
  - You don’t need to use “kakidasu” command

Demonstration

(if I have time…)

Evaluation

Evaluation

- Measure loading time of same script 1,000 times
  - Use remove_const to cleanup each loading
  - Choose from lib/*.rb

Target script	Lines	Size (KB)
resolv.rb	2,855	73
csv.rb	2,346	83
fileutils.rb	1,761	48
forwardable.rb	290	8

Evaluation
Loading time (x1,000)

	Normal (sec)	Load (sec)	Lazy load (sec)
resolve.rb	13.19	3.92 (x3.36)	2.42 (x5.45)
csv.rb	7.88	4.19 (x1.88)	2.85 (x2.76)
fileutils.rb	8.55	4.64 (x1.84)	3.61 (x2.37)
forwardable.rb	0.48	0.18 (x2.67)	0.12 (x4.00)

☺ 5 times faster on resolv.rb seems good

☹ Nobody load resolv.rb 1,000 times

Evaluation
Compiled binary size

Target script	Lines	Script size (KB)	Binary size (KB)
resolv.rb	2,855	73	337 (x4.6)
csv.rb	2,346	83	170 (x2.0)
fileutils.rb	1,761	48	202 (x4.2)
forwardable.rb	290	8	14 (x1.7)

Evaluation
Rails launch time

- Loading time of Redmine 3.2.1 (rails app)
  - **$ bundle exec rails r “p:success”**
  - YOMIKOMU_STORAGE=fs

Execution time	Normal (sec)	Use Yomikomu (sec)	Use Yomikomu w/ lazy loading (sec)
w/o bundle	2.65	2.22 (x1.19)	2.03 (x1.31)
w/ bundle	2.94	2.45 (x1.20)	2.24 (x1.31)

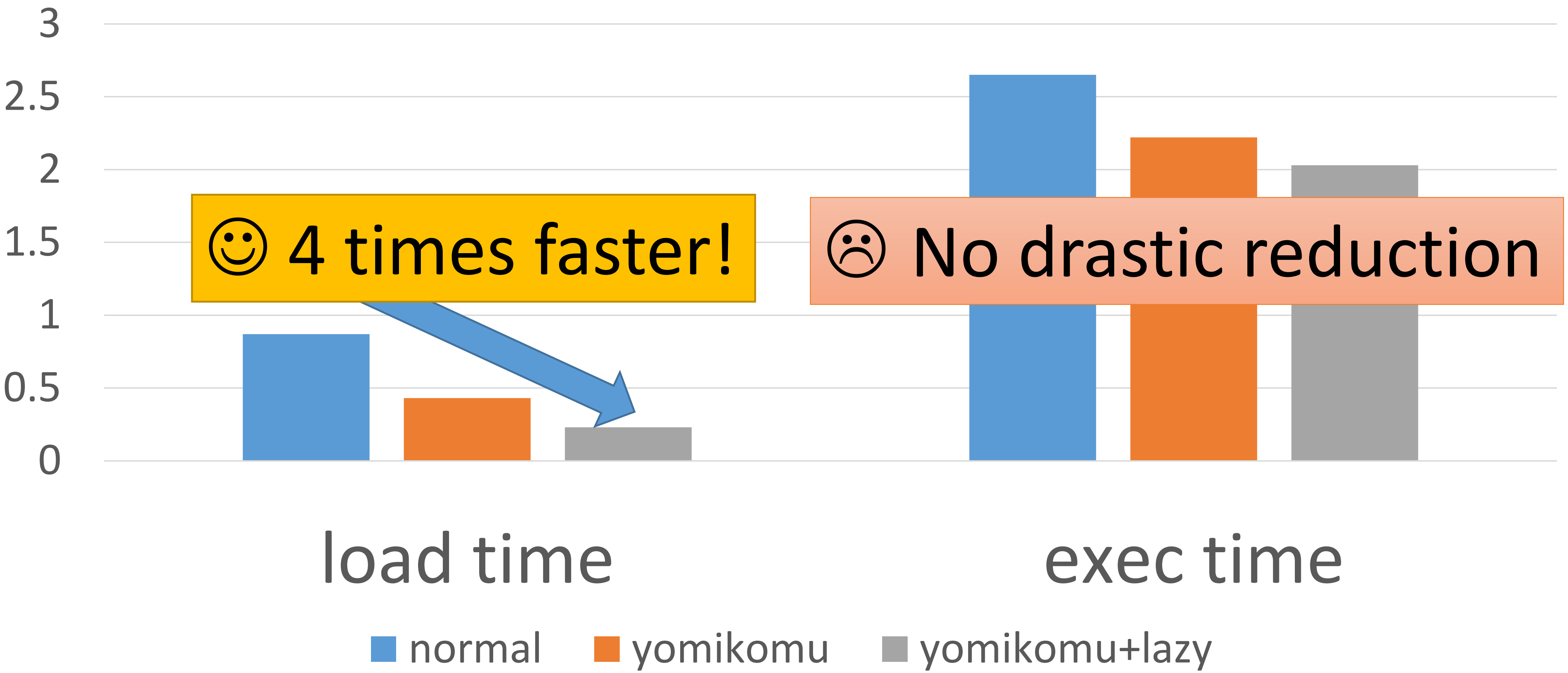
Evaluation
Compare only loading time

- Check the (load file + parse + compile) time and corresponding (load file + deserializing) time
  - YOMIKOMU_STORAGE=fs

Loading time	Normal: load file + parse + compile (sec)	Use Yomikomu: deserialize (sec)	Use Yomikomu w/ lazy loading (sec) (*)
w/o bundle	0.87 (33% of exec)	0.43 (x2.02)	0.23 (x3.78)

(*) Does not contain actual lazy loading time

Evaluation
Loading (parse & compile) overhead



☺ 4 times faster!

☹ No drastic reduction

Evaluation
Rails launch time w/ flatfile

- Loading time of Redmine 3.2.1 (rails app)
  - **$ bundle exec rails r “p:success”**
  - YOMIKOMU_STORAGE=flatfile

Execution time	Normal (sec)	Use Yomikomu (sec)	Use Yomikomu w/ lazy loading (sec)
w/o bundle	2.65	2.11 (x1.26)	2.05 (x1.29)
w/ bundle	2.94	2.46 (x1.20)	2.45 (x1.20)

Evaluation
Compare loading time w/ flatfile

- Check the (load file + parse + compile) time and corresponding (load file + deserializing) time
  - YOMIKOMU_STORAGE=flatfile

Loading time	Normal: parse + compile (sec)	Use Yomikomu: deserialize (sec)	Use Yomikomu w/ lazy loading (sec) (*)
w/o bundle	0.87	0.43 (x2.02)	0.22 (x3.95)

(*) Does not contain actual lazy loading time

Future work

- Reduce memory consumption by memory sharing with mmap (and so on)
- Reduce binary size with some techniques
  - Smart serialization technique
  - Compaction technique
- And more…

Today’s talk was about:

- New feature of Ruby 2.3

  “Pre-compilation primitives”
- Yomikomu gem: what is and how to use it.
- Evaluation results includes redmine boot time

Myth

“If we have an AOT compiler, the boot time issue will be solved”

Fact

“The world is not so easy”

Message

“Please enjoy making your own **Yomikomu** utility”

Thank you for your attention

Koichi Sasada

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