MONSTARLAB

Practical mruby/c firmware development with CRuby

HASUMI Hitoshi @hasumikin

RubyKaigi 2019

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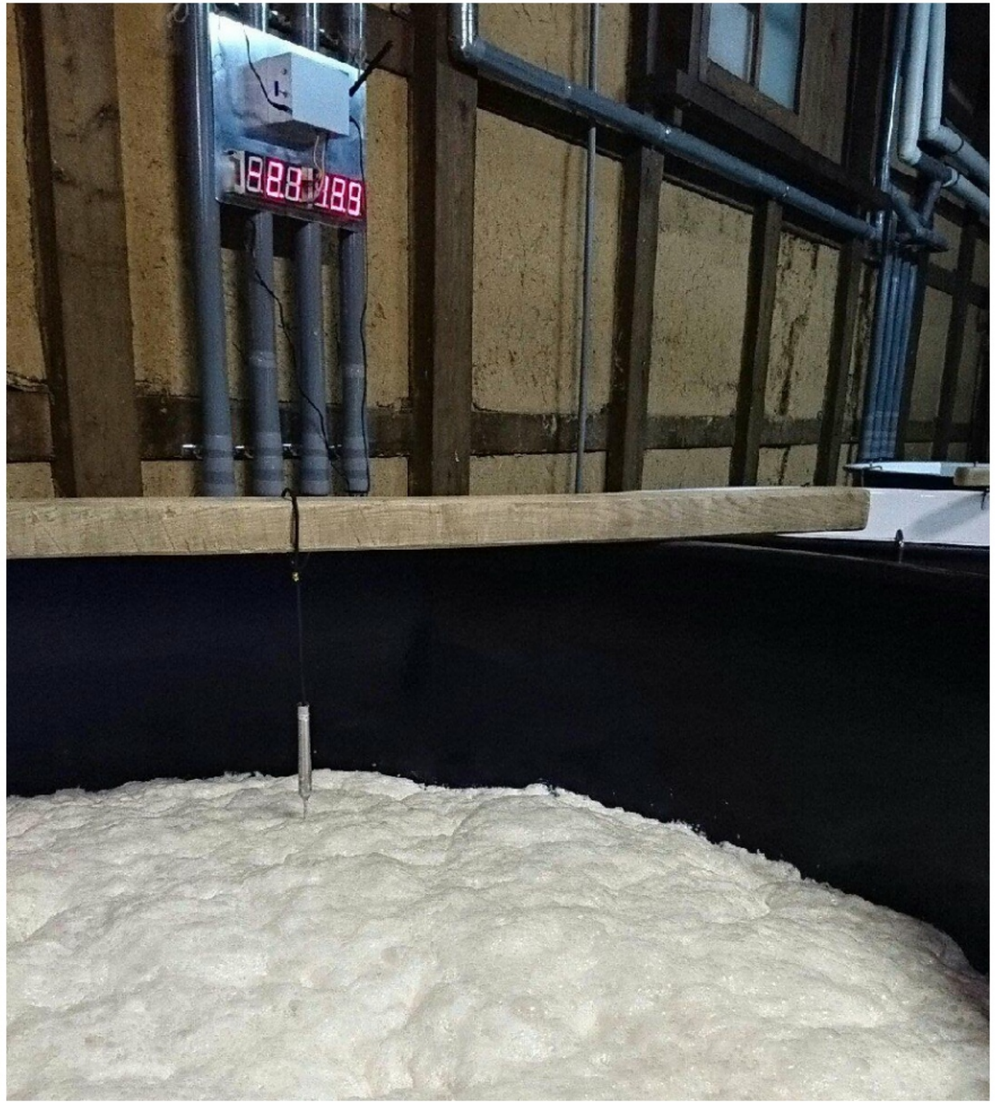
Fukuoka International Congress Center

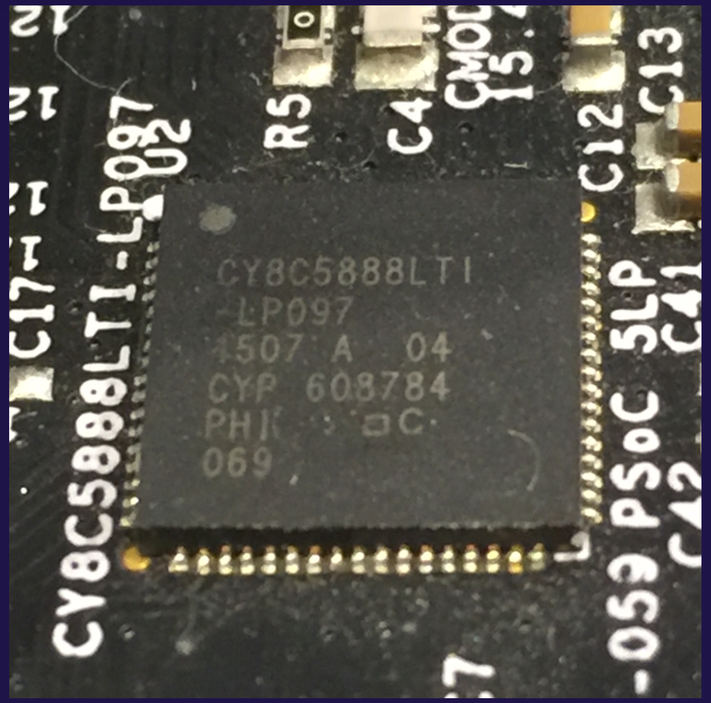
Sake IoT project



Sake IoT project

what is mruby/c?

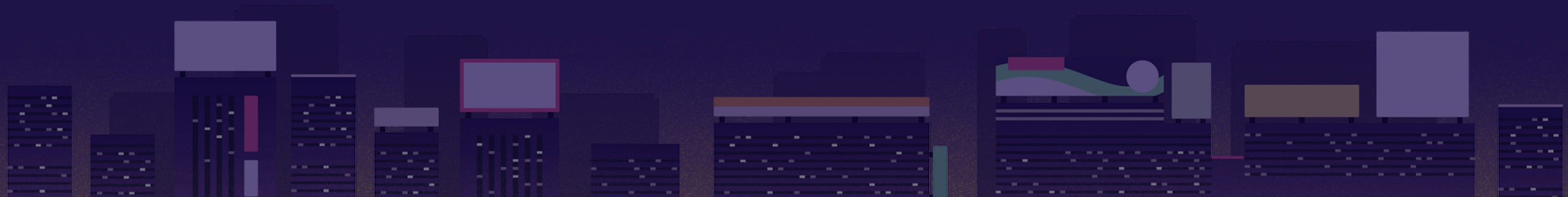
- github.com/mrubyc/mrubyc
- one of the mruby family
- `/c` symbolizes compact, concurrent and capability
- especially dedicated to one-chip microcontroller



mruby and mruby/c

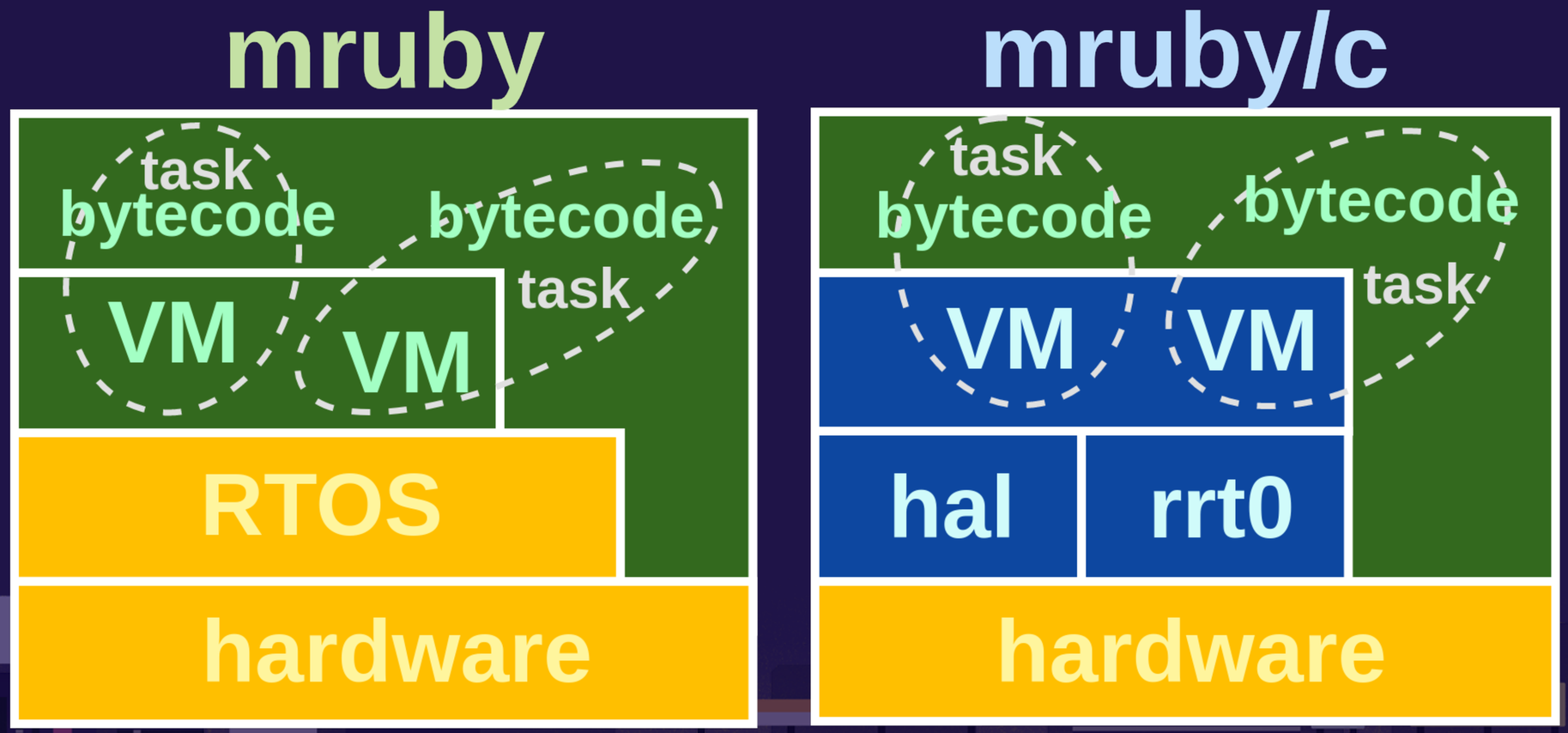
mruby	mruby/c
v1.0.0 in Jan 2014	v1.0 in Jan 2017
for general embedded software	for one-chip microcontroller
RAM < 400KB	RAM < 40KB

- sometimes mruby is still too big to run on microcontroller



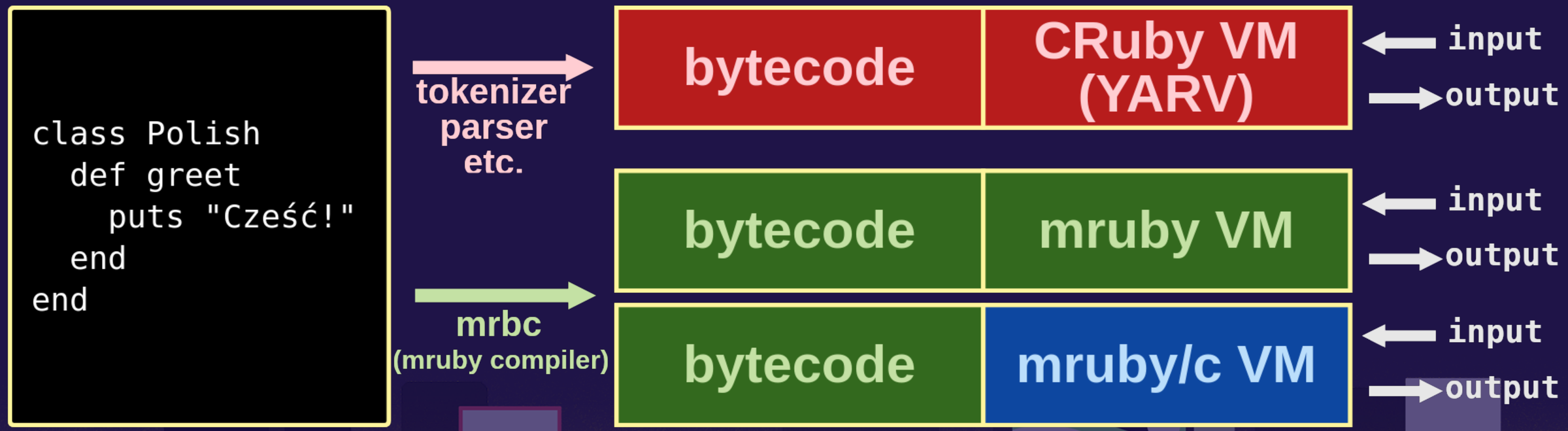
both mruby and mruby/c

- bytecodes are compiled by `mrbc`
  virtual machine (VM) executes the bytecode



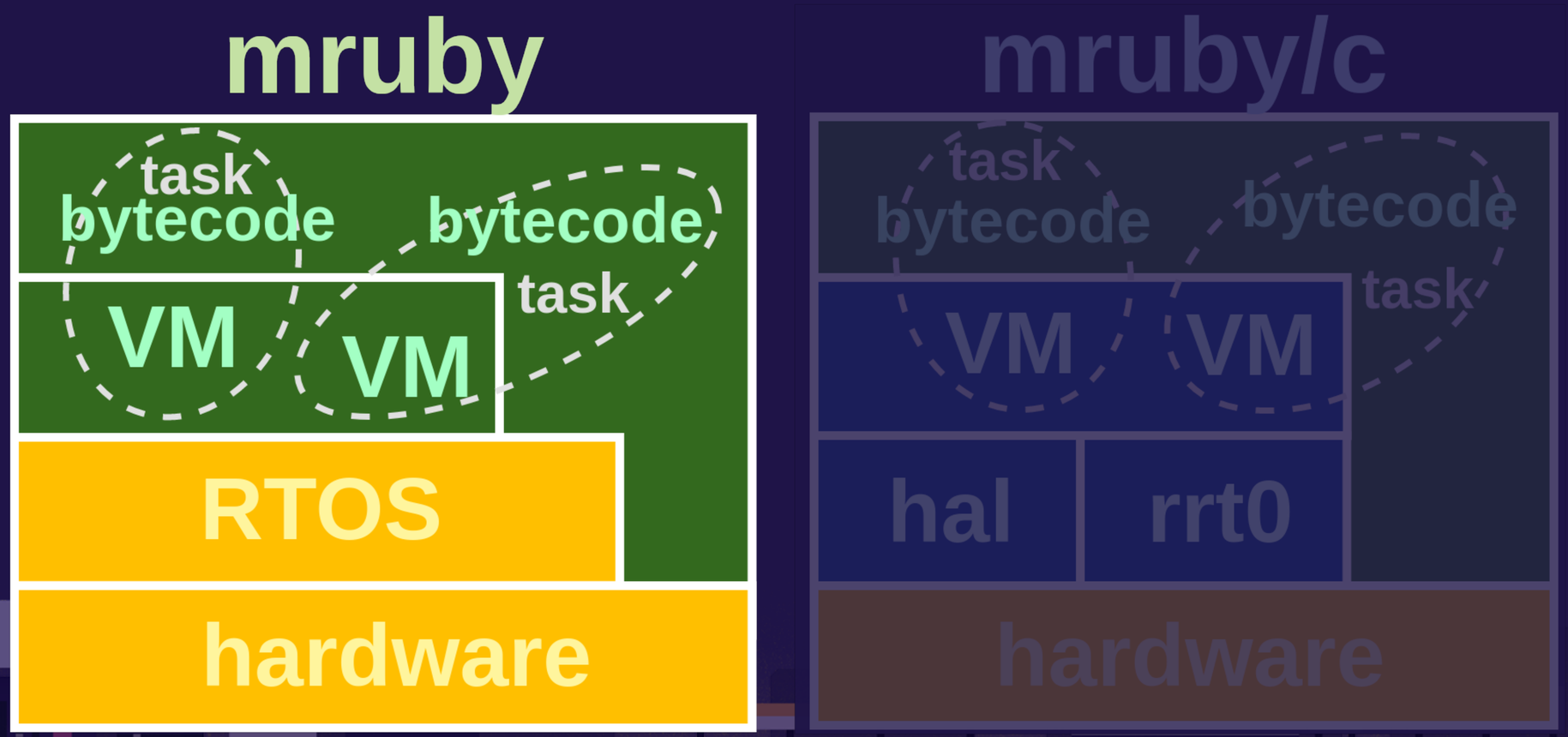
bytecode

- a kind of intermediate representation
- virtual machine dynamically interprets the bytecode and processes the program



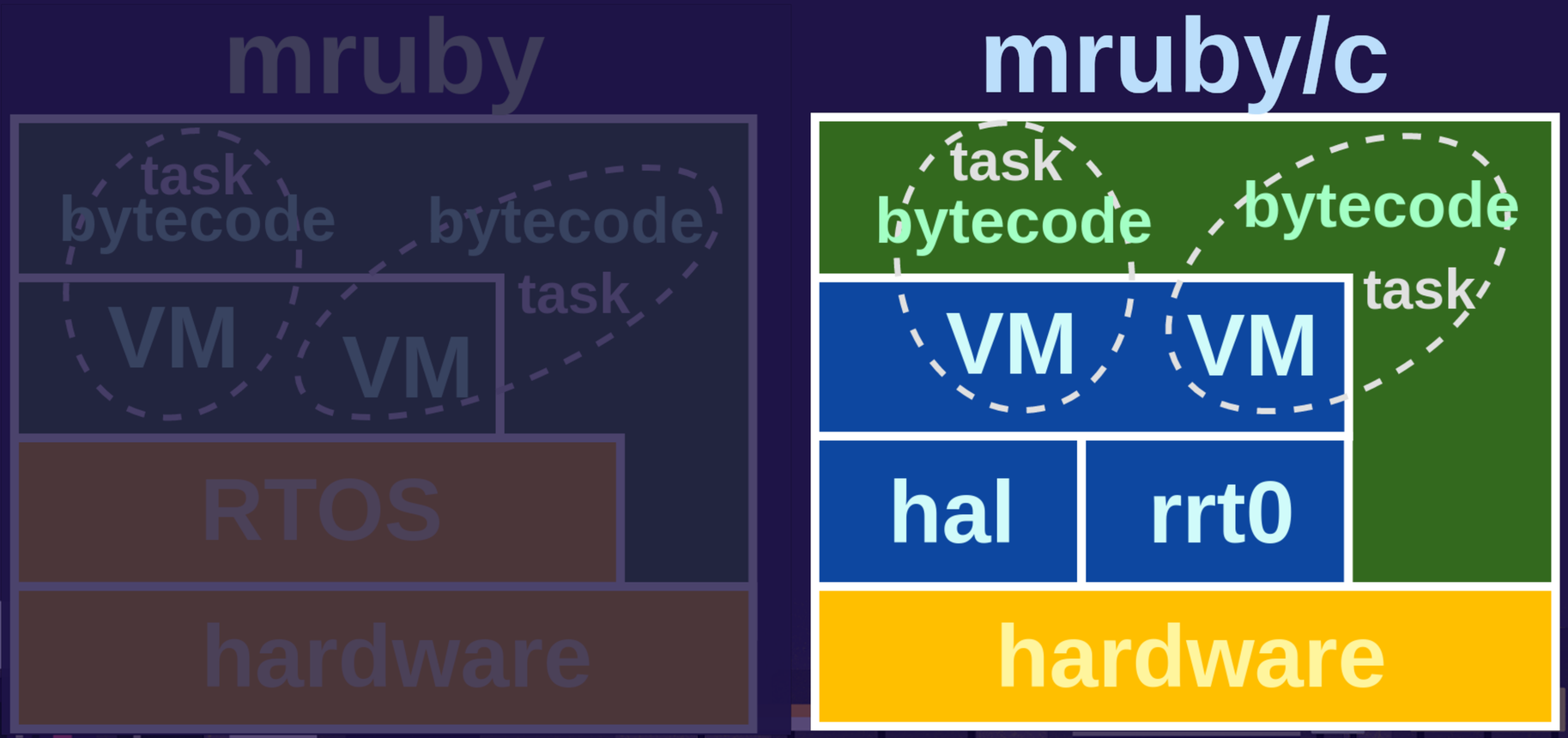
mruby on microcontroller

- RTOS (Real-Time OS) manages mruby VMs. RTOS has features like multi tasking, etc.



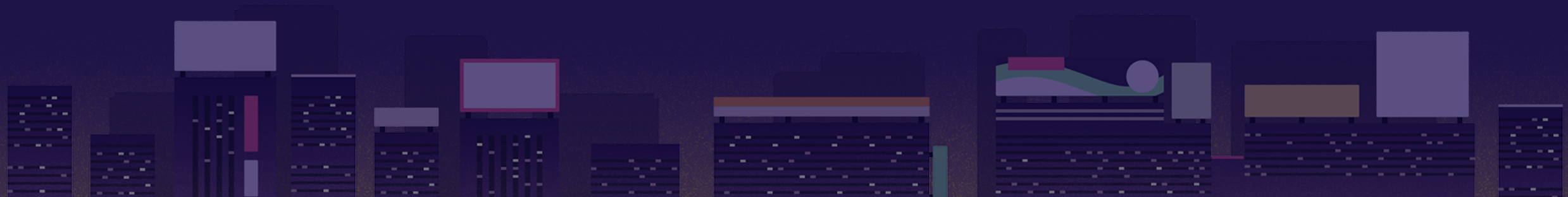
mruby/c on microcontroller

- mruby/c has its own mechanism to manage the runtime: **rrt0**

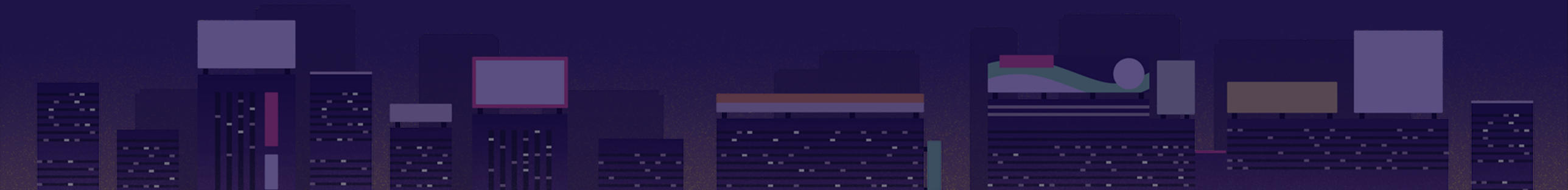


mruby/c - virtual machine (VM)

- much smaller than mruby's one
  - that's why mruby/c runs on smaller RAM
- accordingly, mruby/c has **less** functionality than mruby

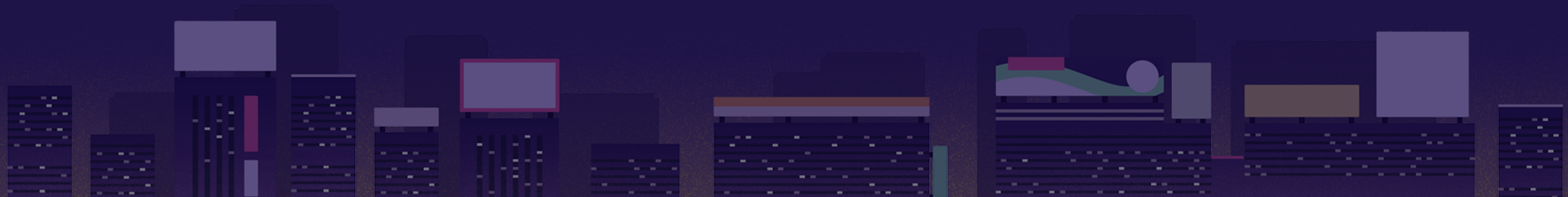


how less?



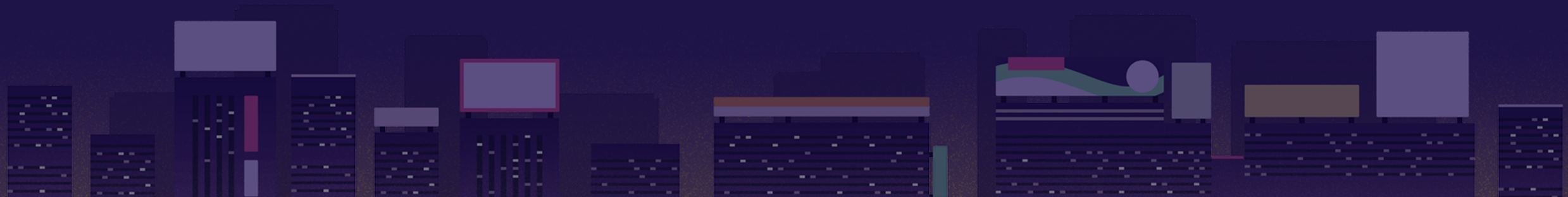
how **less**? - for example

- mruby/c doesn't have module, hence there is no Kernel module
- then you must wonder how can you `#puts`?
- in mruby/c, `#puts` is implemented in Object class



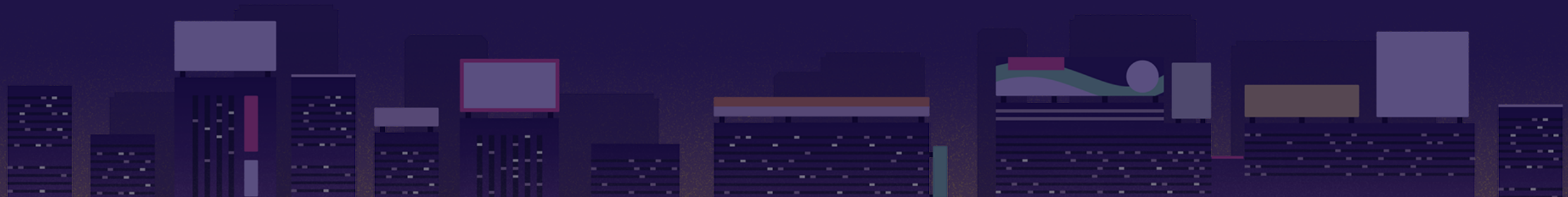
how **less**? - for example

- mruby/c doesn't have #send, #eval, nor #method_missing
- moreover, mruby/c neither have your favorite features like TracePoint nor Refinements ☹



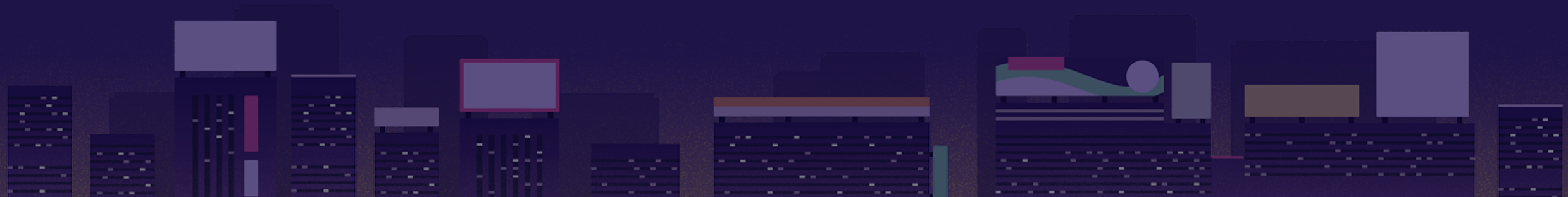
how **less**? - actually

- the full list of mruby/c's classes
  - Array, FalseClass, Fixnum, Float, Hash, Math, Mutex, NilClass, Numeric, Object, Proc, Range, String, Symbol, TrueClass, VM



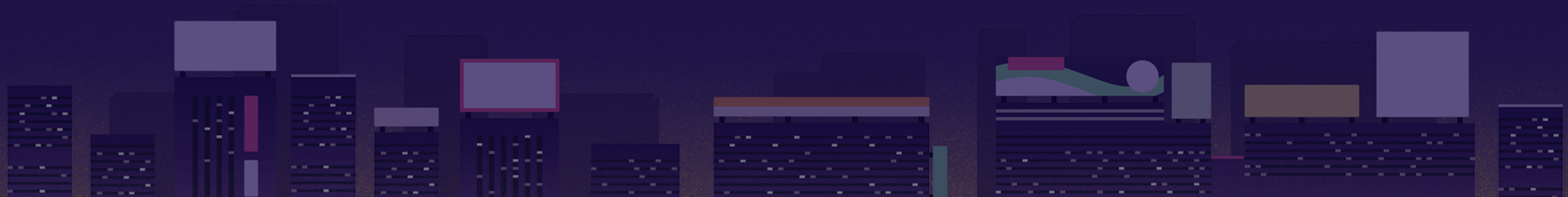
despite the fact,

- no problem in practical use of microcontroller
- as far as IoT go, mruby/c is enough Ruby as I expect
- we can fully develop firmwares with features of mruby/c



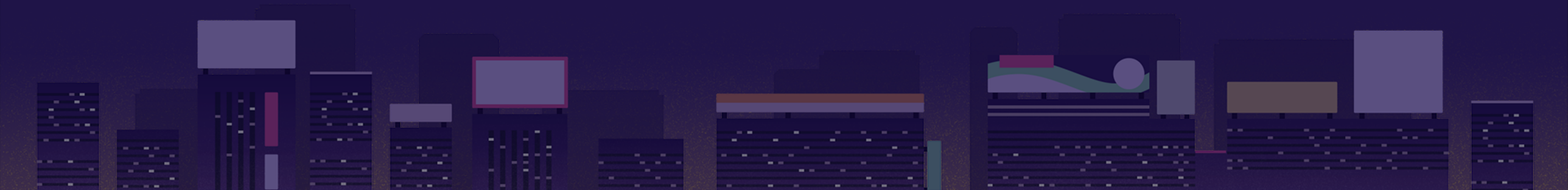
So

というわけで



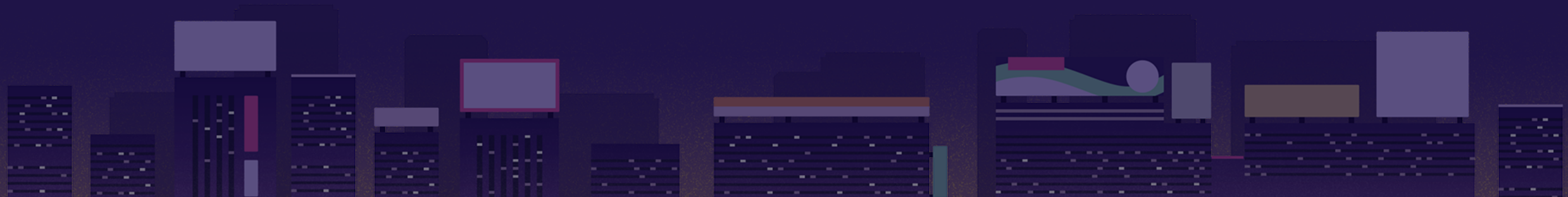
Today's agenda

きょうはこんな話をします



Little more Rubyish

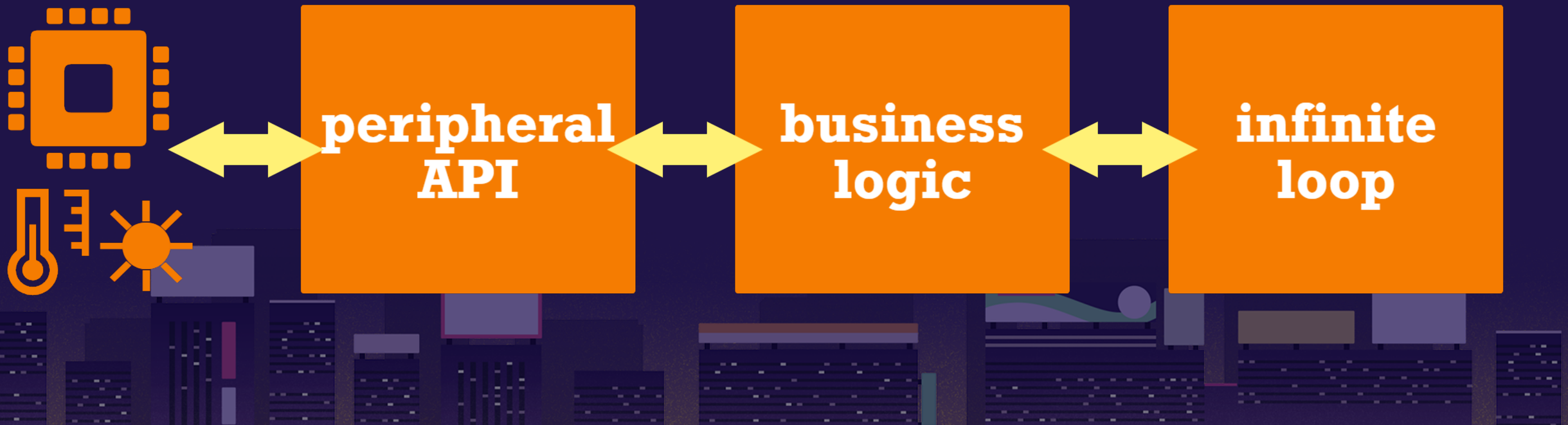
もうちょいRubyっぽくやろう




Matsue.rb

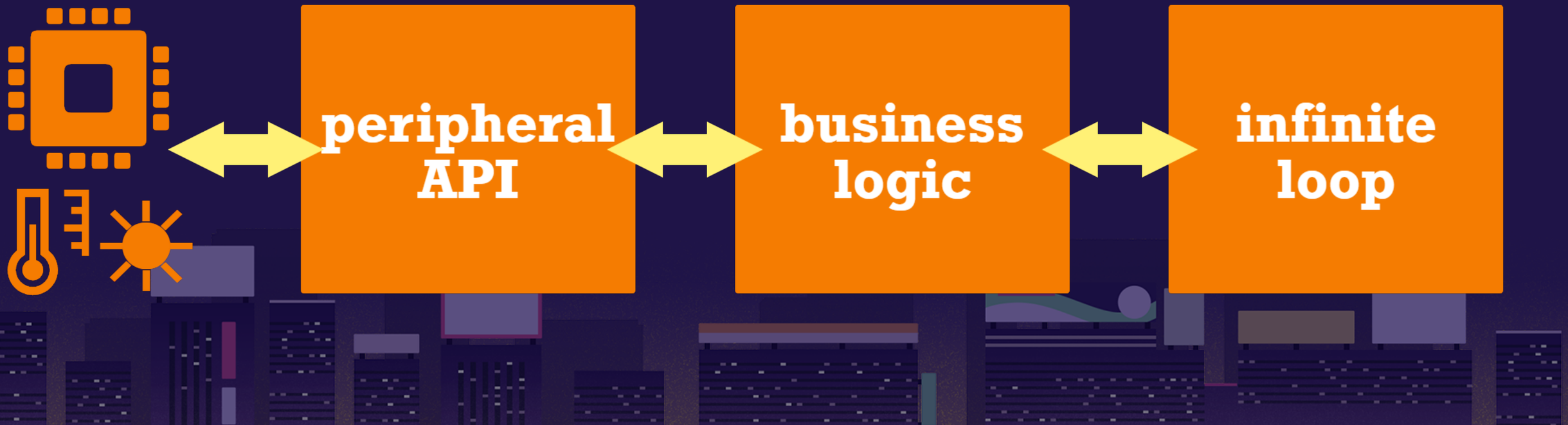
mruby/c firmware is made up of three parts

- 1) peripheral API wrapper (C)
- 2) business logic (mruby)
- 3) infinite loop (mruby)



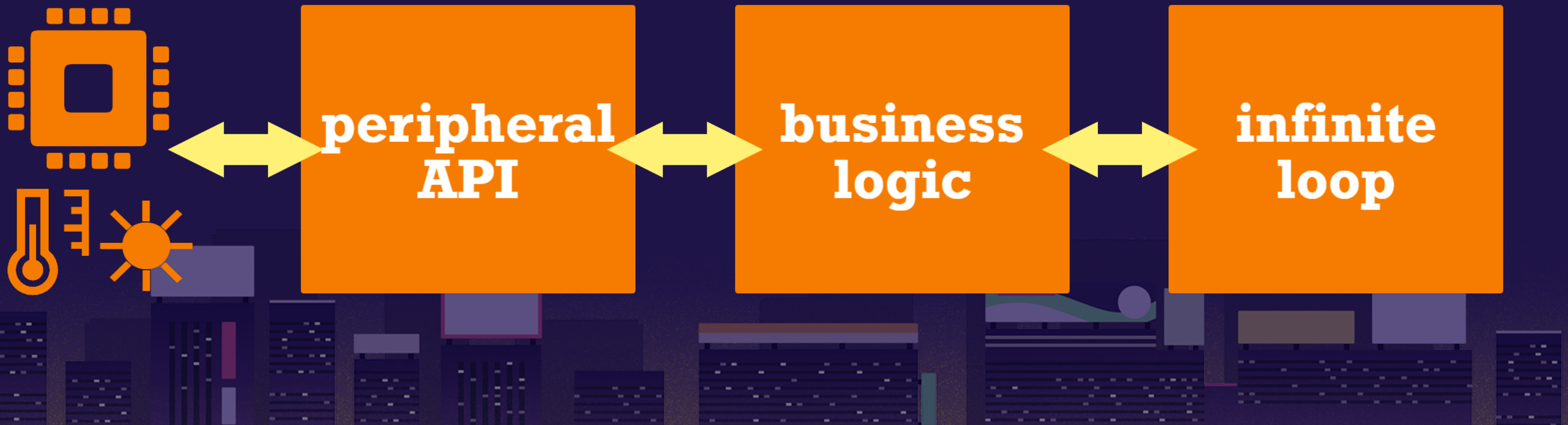
mruby/c firmware is made up of three parts

- 1) peripheral API wrapper (C)
- 2) business logic (mruby) - **model**
- 3) infinite loop (mruby) - **controller**



things make situation difficult

- peripheral API needs **real** hardware
- business logic needs peripheral APIs **really** work
- infinite loop needs **real** data from business logic



mruby/c firmware is made up of three parts

- 1) **peripheral API wrapper (C)**
- 2) business logic (mruby)
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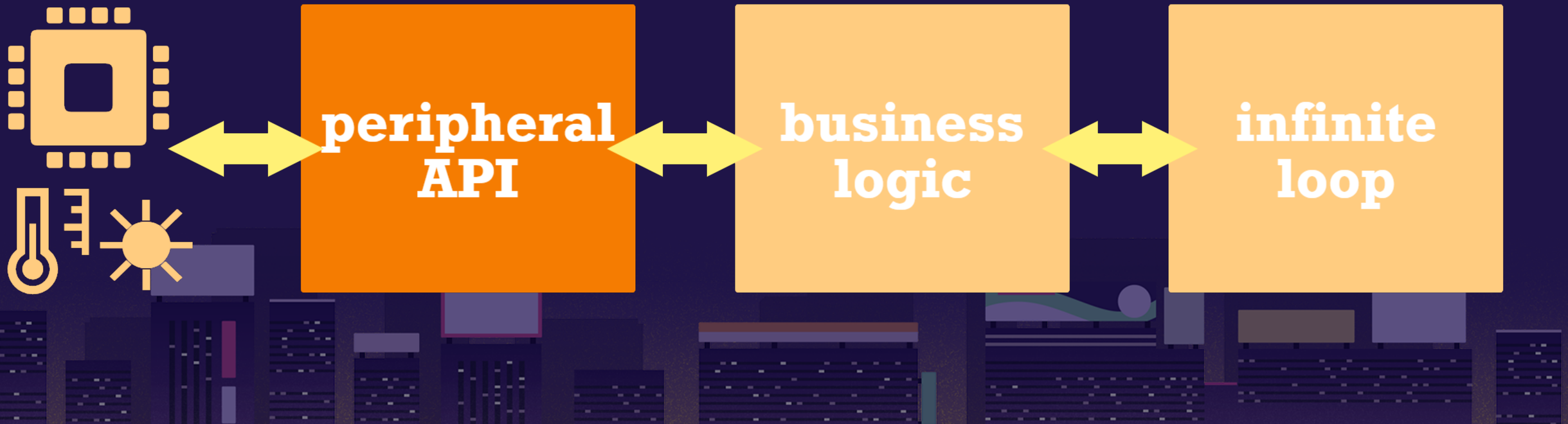


peripheral API wapper

- https://rubykaigi.org/2018

Hitoshi HASUMI

@hasumon

ammer of Monstar Lab at Shimane

JA

Firmware programming with mruby/c

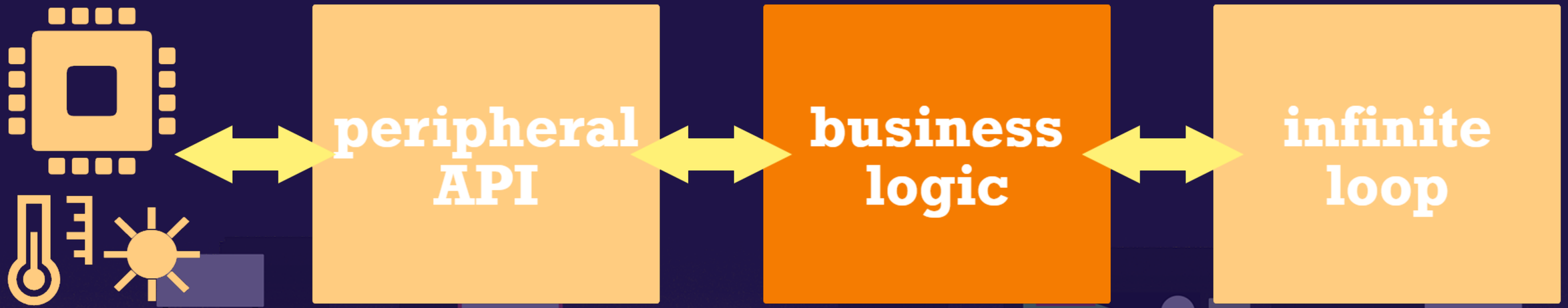
We have a new choice to write firmware for microcomputers(microcontrollers
to introduce mruby/c firmware programming. And besides, my actual IoT proje
will be described. Since mruby/c is still a young growing tool, you will know ther
can help it to become better.

Presentation Material

Firmware programming with mruby/c

mruby/c firmware is made up of three parts

- 1) peripheral API (C)
- 2) **business logic (mruby)**
- 3) infinite loop (mruby)



mruby/c firmware is made up of three parts

```
# infinite loop
foo = Foo.new
while true
  if foo.hoge == 1
    puts "SUCCESS!"
  end
  sleep 1
end
```

```
# business logic
class Foo
  def hoge
    fuga_val = fuga
    c_hoge(fuga_val)
  end
end
```

```
/* peripheral API wrapper */
static void c_hoge(mrb_vm *vm, mrb_value *v, int argc) {
  int result;
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mruby/c firmware is made up of three parts

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keeps waiting a value

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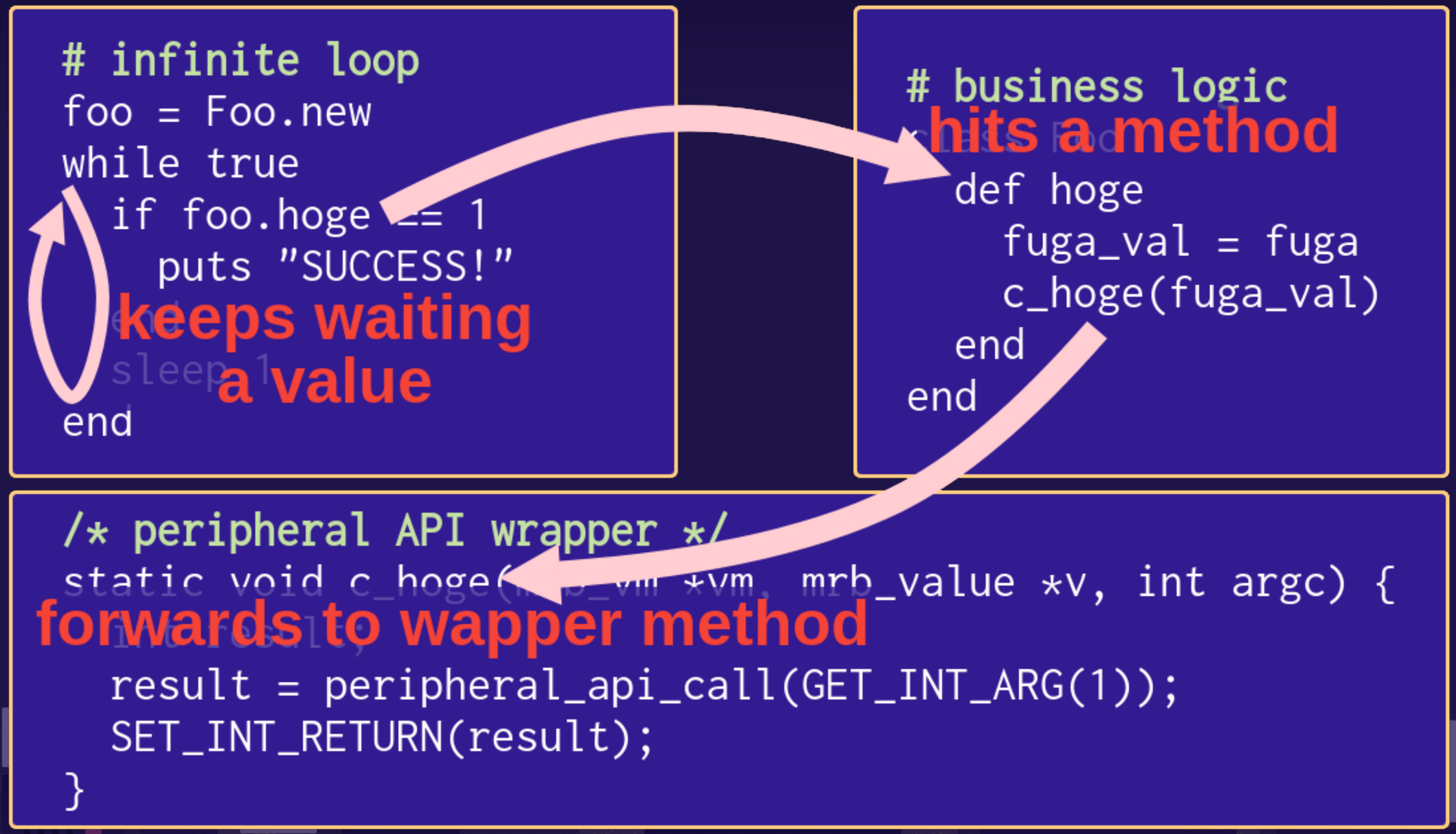

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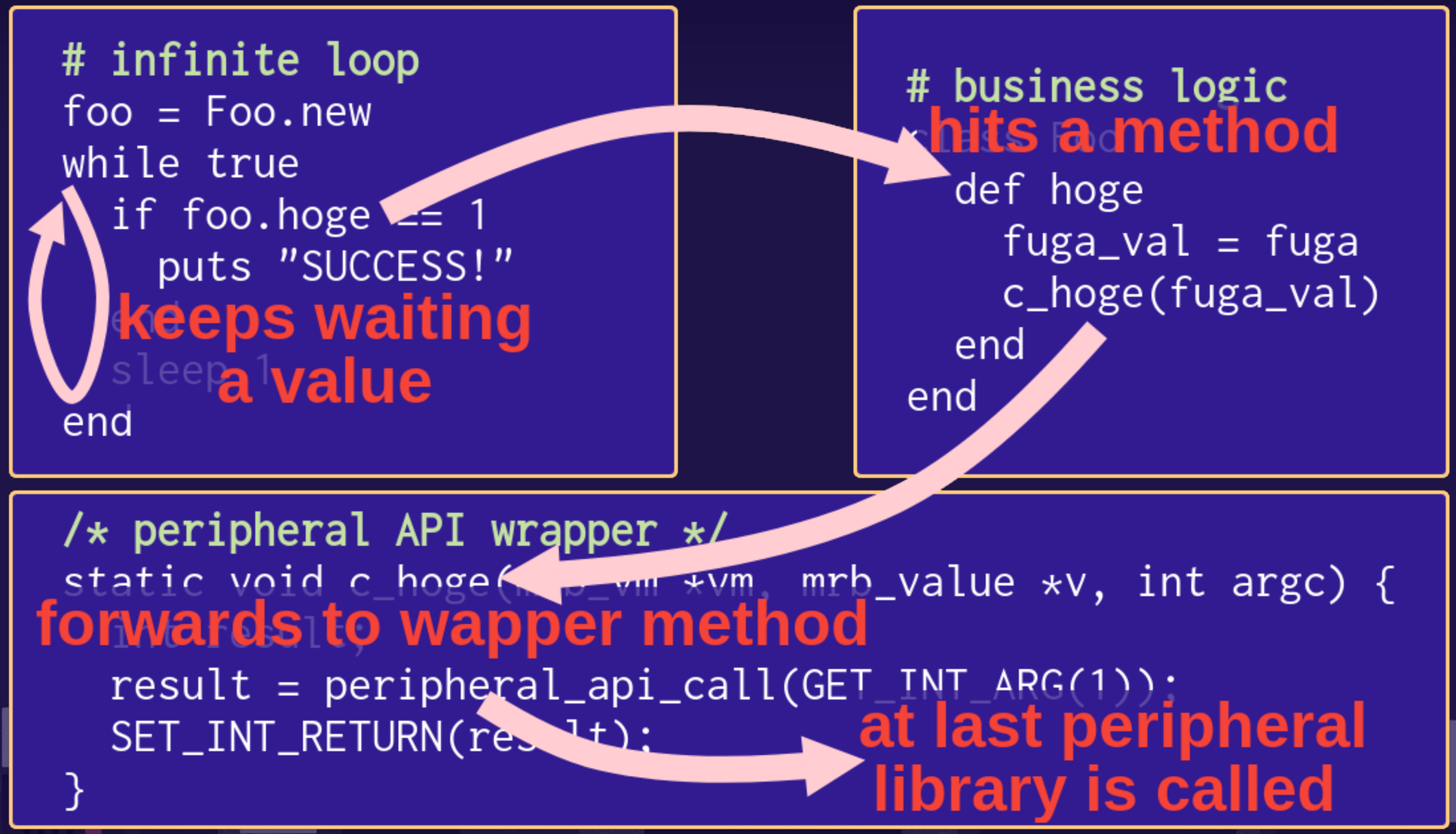


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by the way,

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fuga?

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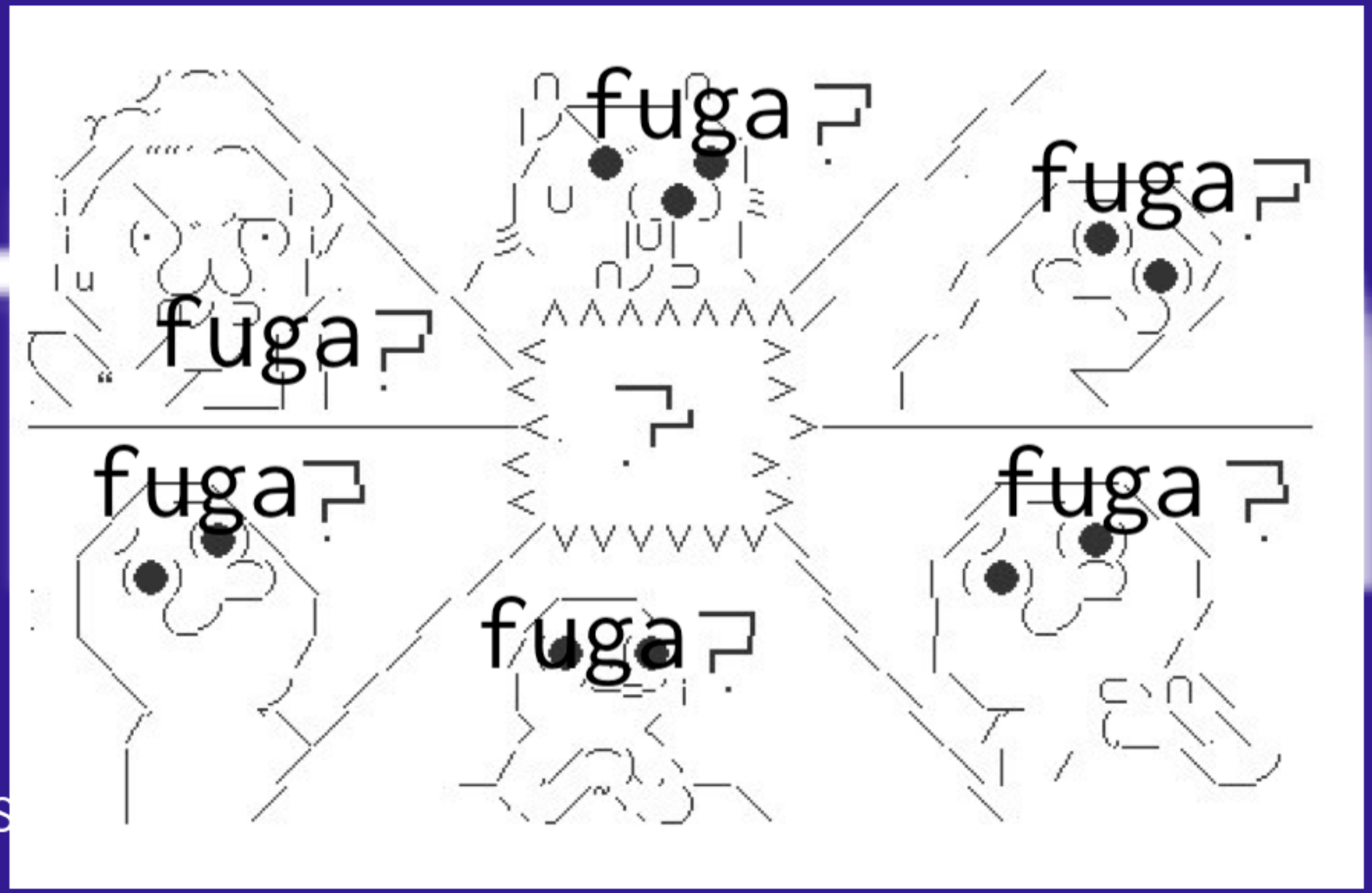
what is fuga?



will calling fuga raise error?

```
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keeps waiting a value

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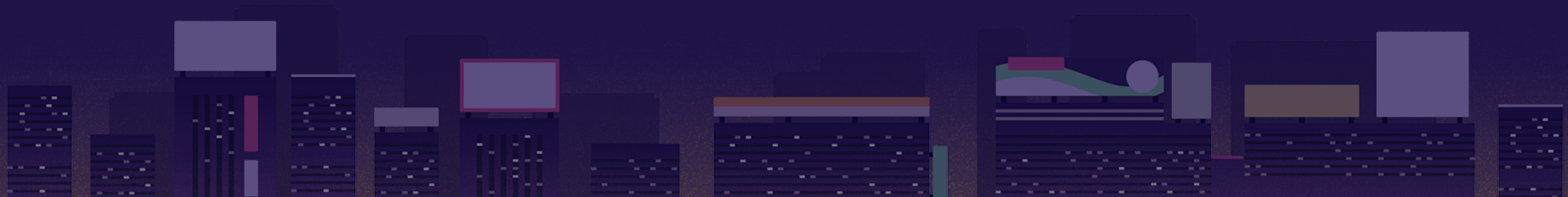
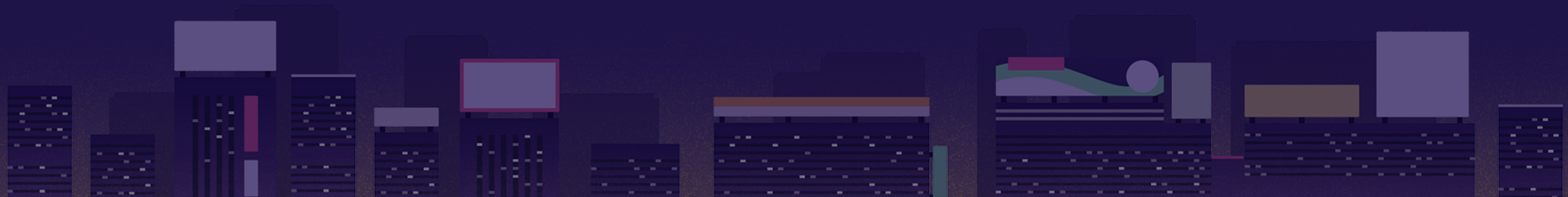
```

methods still not implemented

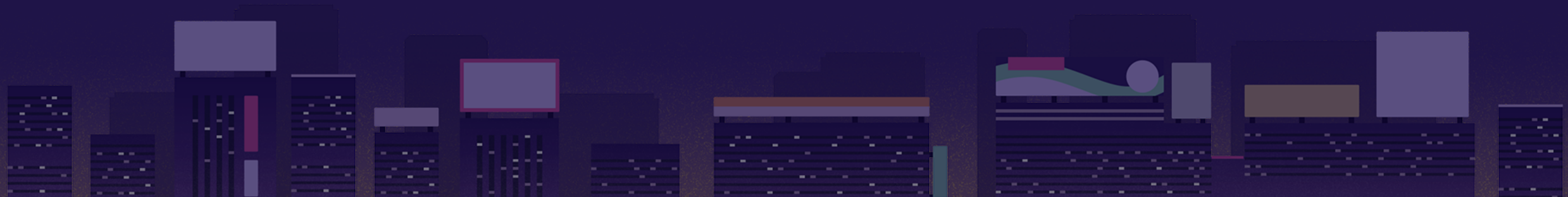
- we often should write business logic without hitting peripherals
  - it will cost a lot in some case
  - it is possible the design of peripheral details might not be finished yet
- what you expect in this situation?



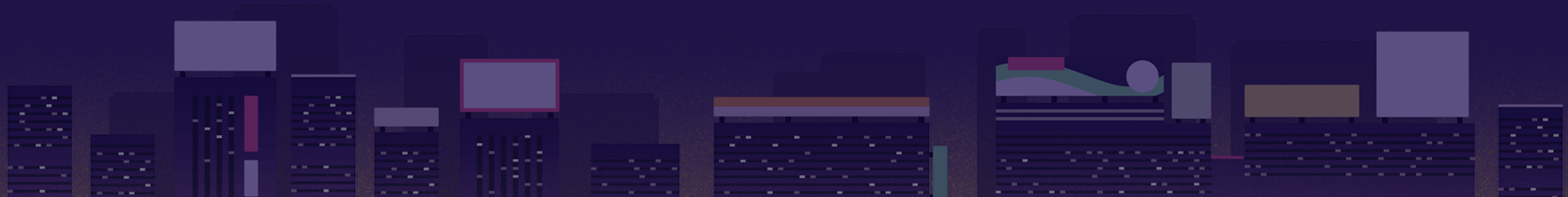
Stub



Mock

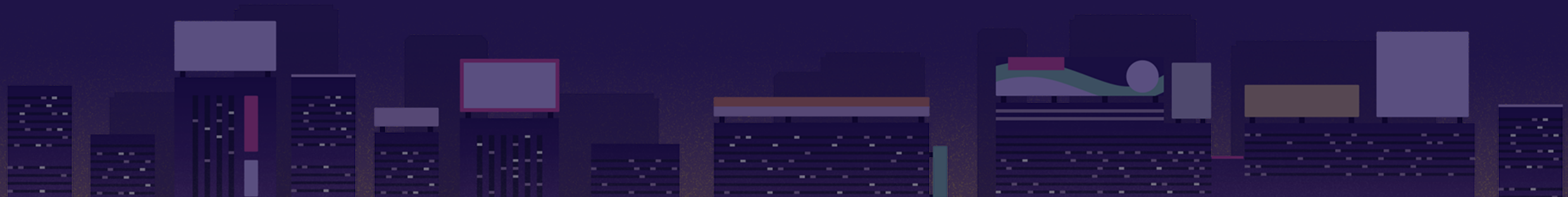


Test Driven Development for Embedded Ruby



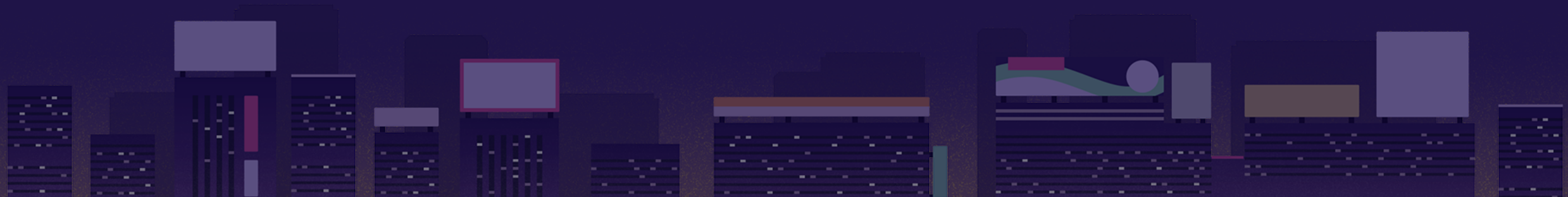
(DEMO)

github.com/hasumikin/mrubyc-test

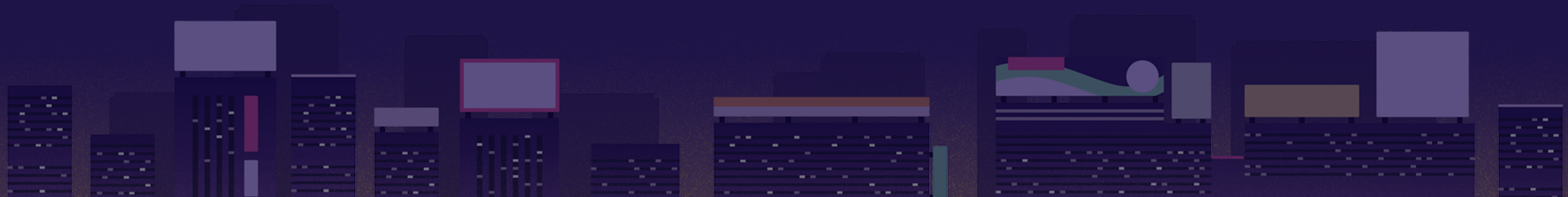


when I started to use mruby/c

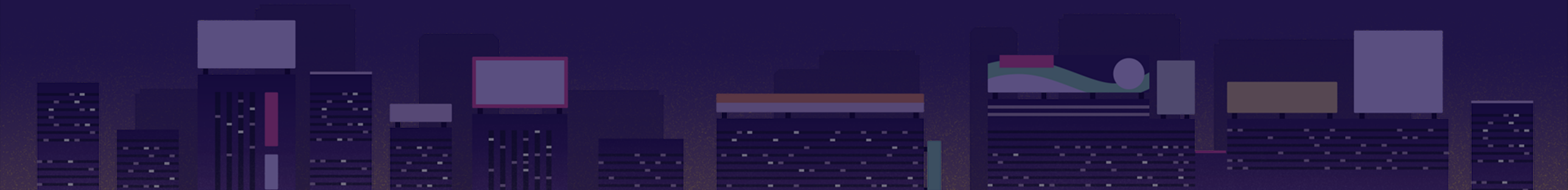
- there is no **testing tool**
- even mruby/c itself sometimes regressed 😨
- I had difficulties of writing my application



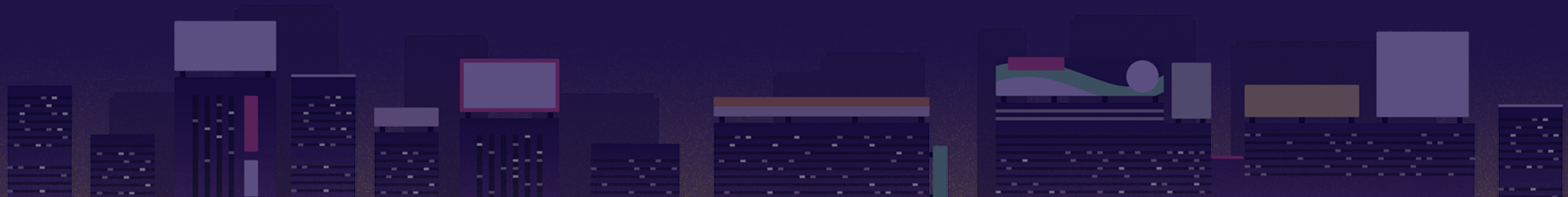
so, why did I use mruby/c?



DESTINO - 運命

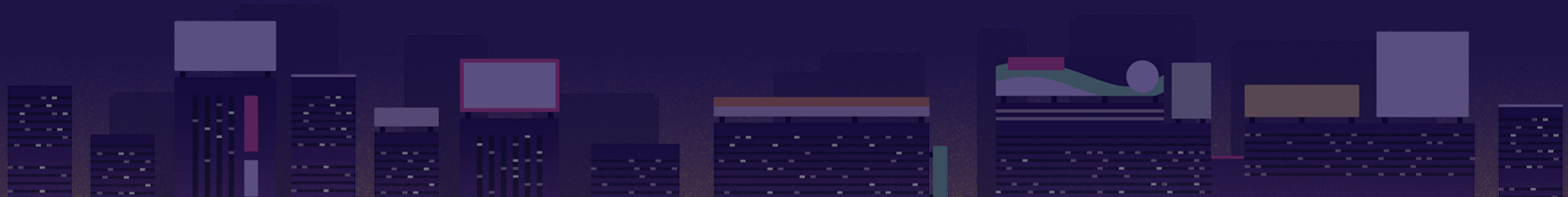


Anyway, I started to create mrubyc-test.gem



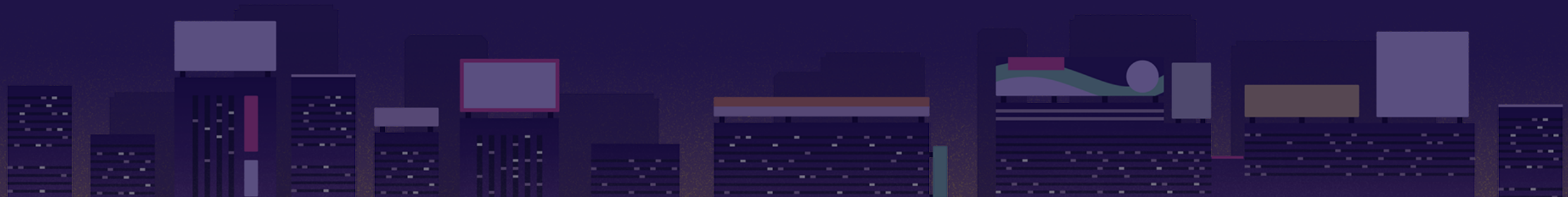
mrubyc-test.gem

- it's the first testing tool for mruby/c ever
- I wanted to go Rubyish in order to make it
- but mruby/c doesn't have enough features to make testing tool as you saw just before



mrubyc-test.gem - designed as

- a **RubyGem**, implemented in CRuby instead of mruby
- Test::Unit-like API
- supports stub and mock
  - now you can test your business logic without implementing peripheral functions like **#fuga**



mrubyc-test.gem - stub

```ruby
# app code
class Sample
  attr_accessor :result
  def do_something(arg)
    @result = arg + still_not_defined_method
  end
end

# test code
class SampleTest < MrubycTestCase
  def stub_case
    sample_obj = Sample.new
    stub(sample_obj).still_not_defined_method { ", it must be Ruby" }
    sample_obj.do_something("If it behaves like Ruby")
    assert_equal "If it behaves like Ruby, it must be Ruby", sample_obj.result
  end
end
```

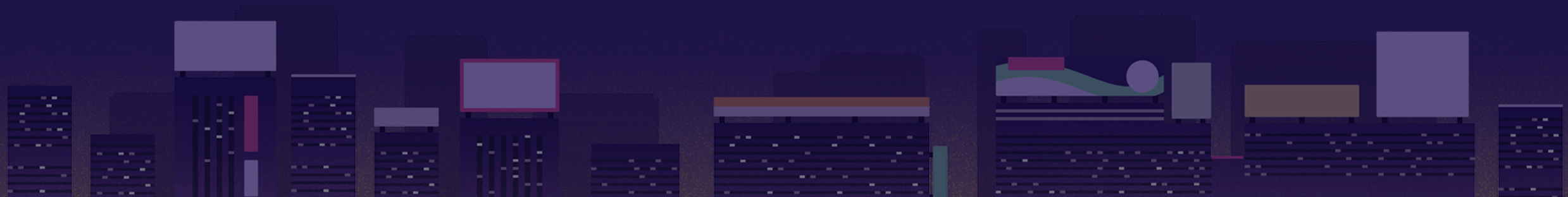
mrubyc-test.gem - mock

```
# app code
class Sample
  def do_other_thing
    to_be_hit()
  end
end

# test code
class SampleTest < MrubycTestCase
  def mock_case
    sample_obj = Sample.new
    mock(sample_obj).to_be_hit
    sample_obj.do_other_thing
  end
end
```

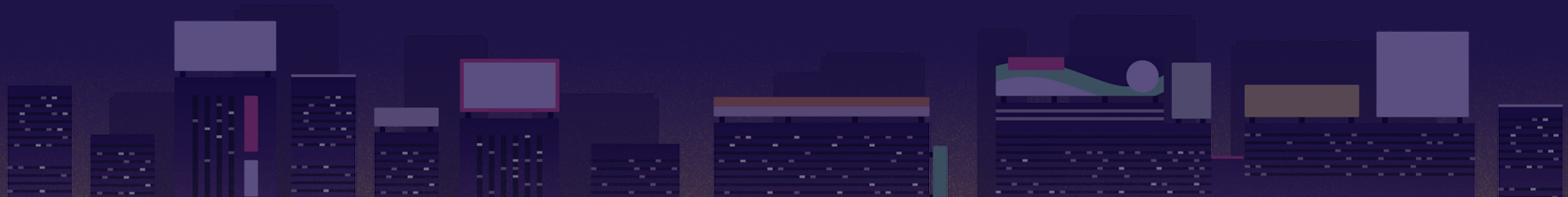
it was my personal tool

github.com/hasumikin/mrubyc-test



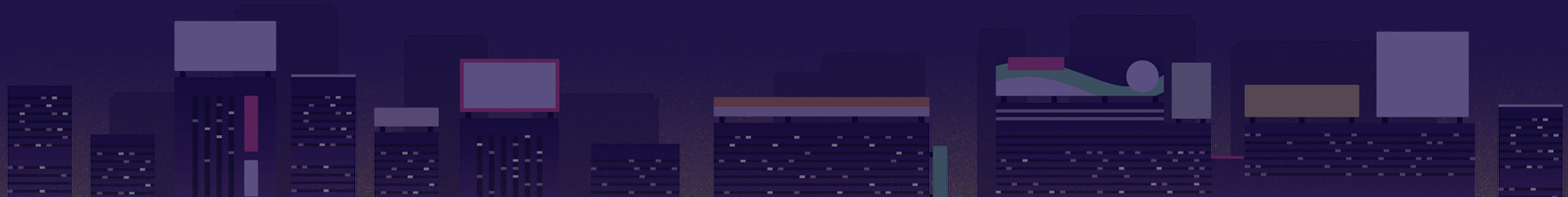
but already abandoned because

~~github.com/hasumikin/mrubyc-test~~



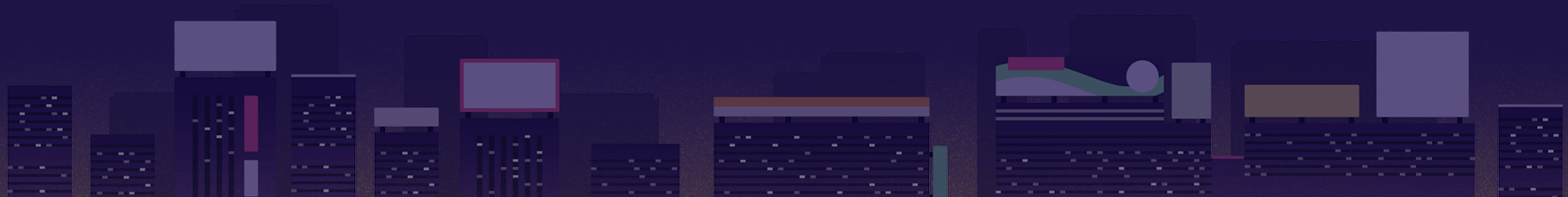
now it's official 🎉

github.com/**mrubyc**/mrubyc-test



mrubyc-test.gem

- adopted as the testing tool for mruby/c itself
  - so now you can safely send pull request to mruby/c
  - you can write mruby/c application with confidence



mrubyc-test.gem - internal

- the gist is creating **test.rb** by `test code generator` implemented in CRuby

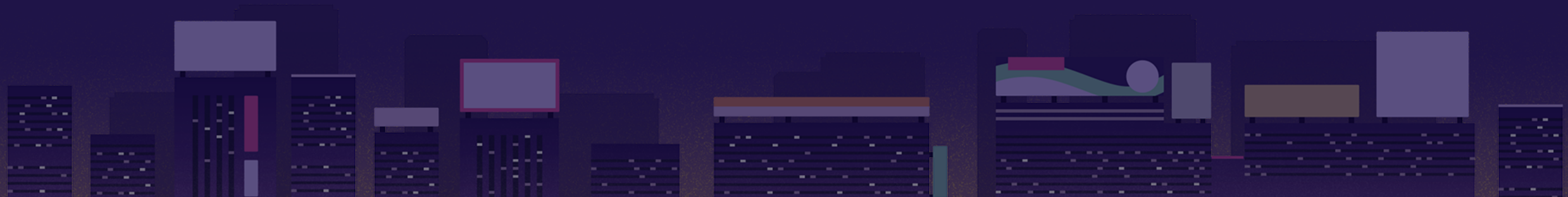
```
class Sample
  def hoge
    "fuga"
  end
end
```

```
class SampleTest < MrubycTestCase
  def some_case
    obj = Sample.new
    assert_equal obj.hoge, "fuga"
  end
end
```

```
SampleTest#some_case
  assertion : assert_equal
  result    : fuga
Finished
1 examples, 0 failures
```

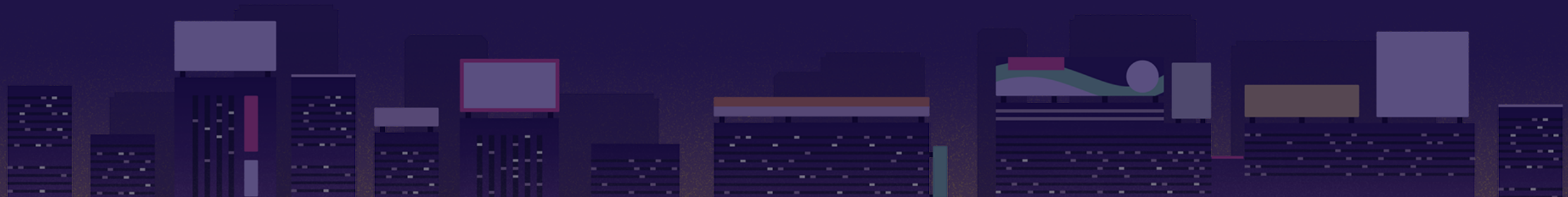
mrubyc-test.gem - how to make the test.rb

- gathers information of test cases by #method_added
  - I learned this technique from Test::Unit
- generates stub methods and mock methods
- makes all-in-one script: **test.rb**
  - all the indispensable mechanism of assertion, stub, mock, app code and test code get together



mrubyc-test.gem - Module#method_added

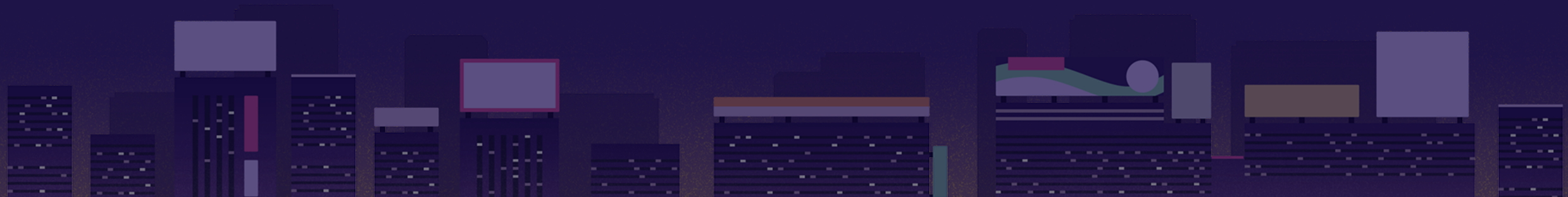
```
class MrubycTestCase
  def self.method_added(name)
    return false if %i(method_missing setup teardown).include?(name)
    location = caller_locations(1, 1)[0]
    path = location.absolute_path || location.path
    line = location.lineno
    @@added_methods << {
      method_name: name.to_s,
      path:        File.expand_path(path),
      line:        line
    }
```



mrubyc-test.gem

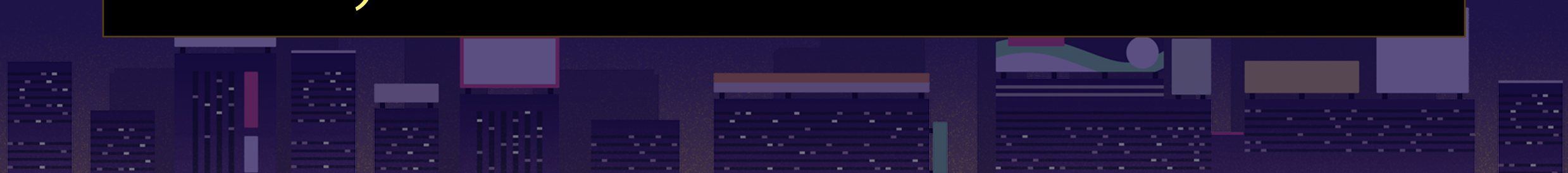
```
class SampleTest < MrubycTestCase
  desc "stub test sample"
  def stub_case # hooks #method_added
    sample_obj = Sample.new
    stub(sample_obj).still_not_defined_method {
      ", it must be Ruby"
    }
```

- test code inherits MrubycTestCase to be analyzed



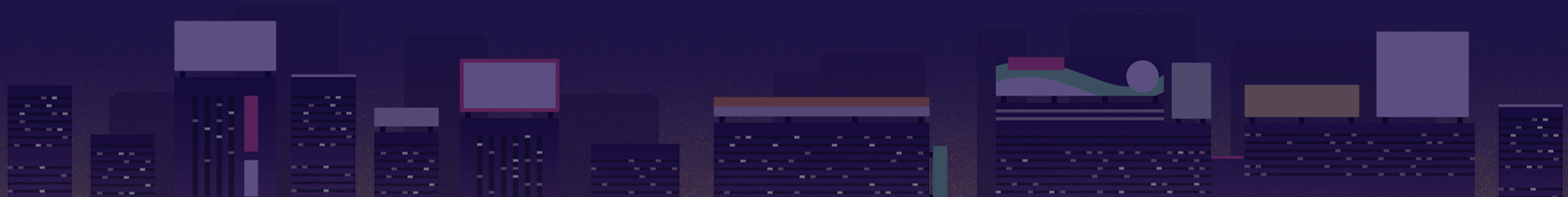
mrubyc-test.gem - BasicObject#method_missing

```
class MrubycTestCase
  def method_missing(method_name, *args)
    case method_name
    when :stub, :mock
      location = caller_locations(1, 1)[0]
      Mrubyc::Test::Generator::Đouble.new(
        method_name, args[0], location
      )
```



mrubyc-test.gem - generated stub method

```ruby
# part of test.rb
class Sample
  def still_not_defined_method
    ", it must be Ruby"
  end
end
```

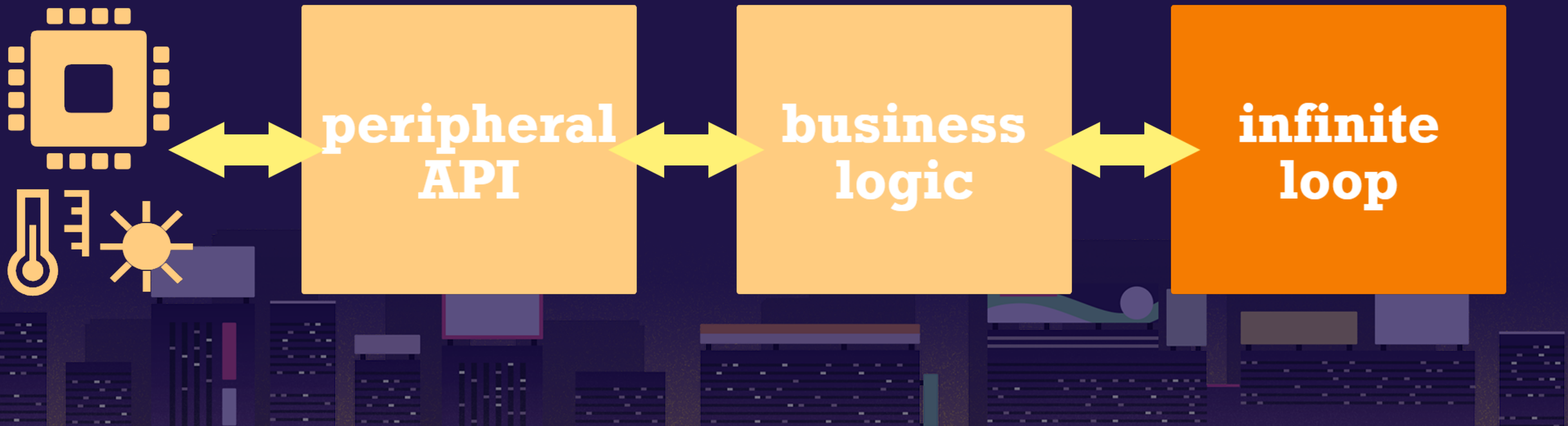


mrubyc-test.gem - template of stub

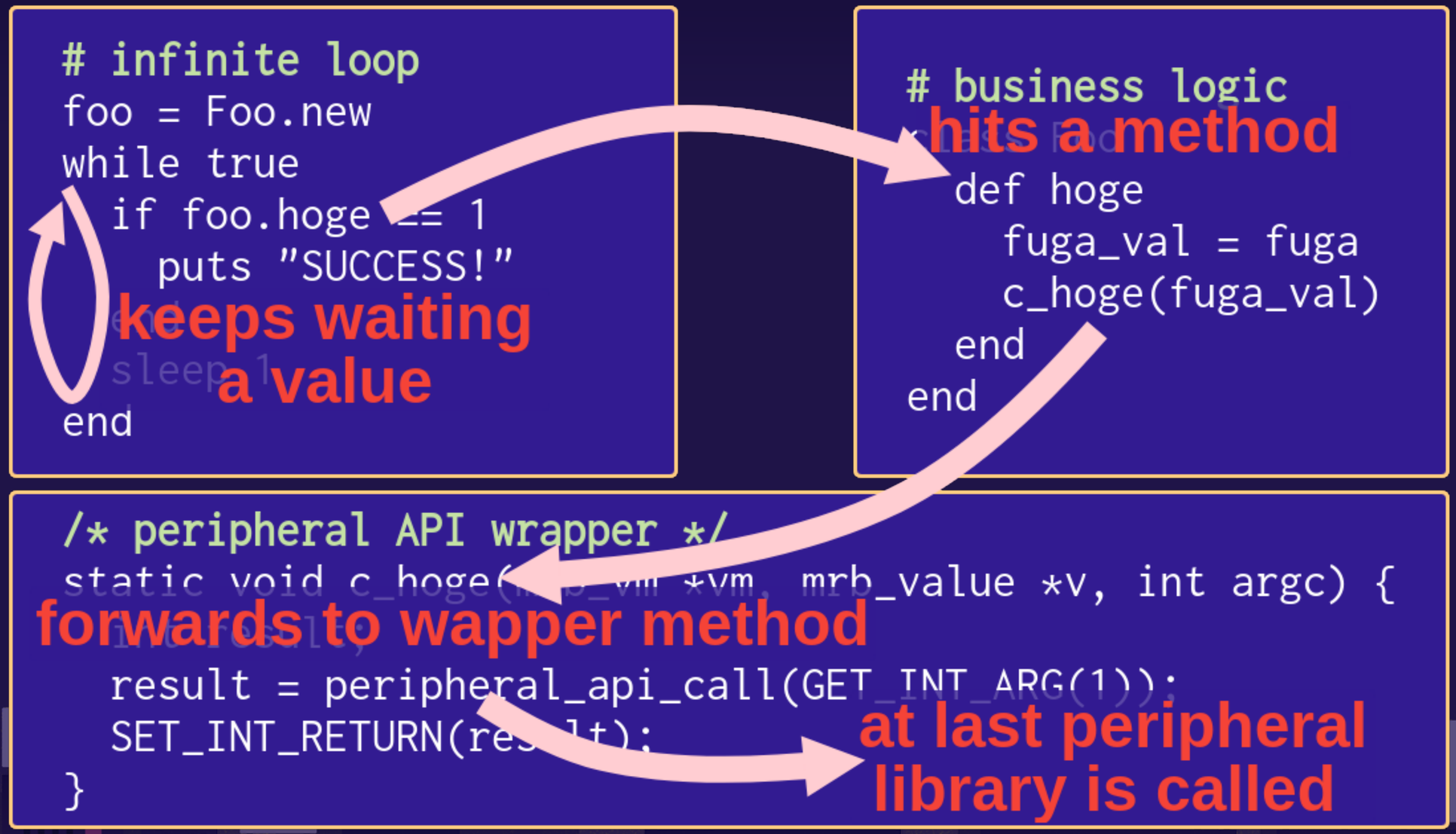
```
<% test_cases.each do |test_case| -%>
  <% test_case[:stubs].each do |stub| -%>
    class <%= stub[:class_name] %>
      attr_accessor <%= stub[:instance_variables] %>
      def <%= stub[:method_name] %>
        <% if stub[:return_value].is_a?(String) -%>
          "<%= stub[:return_value] %>"
        <% else -%>
          <%= stub[:return_value] %>
        <% end -%>
      end
    end
  <% end -%>
```

mruby/c firmware is made up of three parts

- 1) peripheral API (C)
- 2) business logic (mruby)
- 3) **infinite loop (mruby)**



mruby/c firmware is made up of three parts



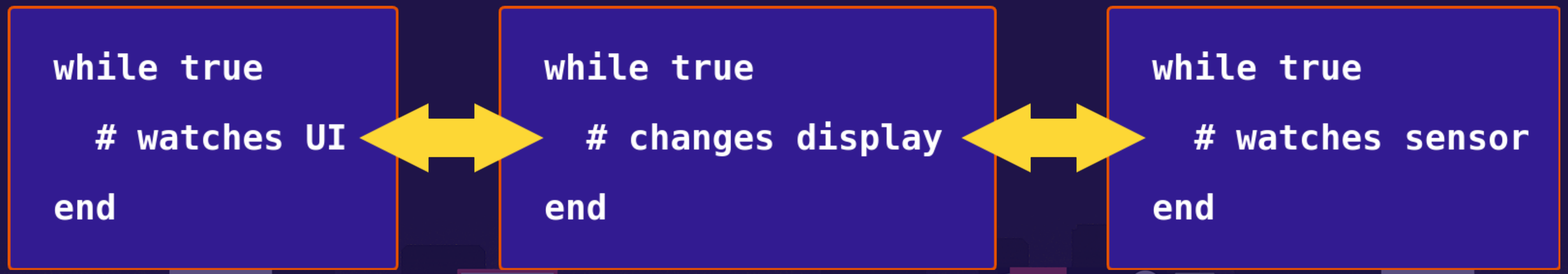

```
# infinite loop
foo = Foo.new
while true
  if foo.hoge == 1
    puts "SUCCESS!"
  end
  sleep 1
end
```

```
# business logic
class Foo
  def hoge
    fuga_val = fuga
    c_hoge(fuga_val)
  end
end
```

```
/* peripheral API wrapper */
static void c_hoge(mrb_vm *vm, mrb_value *v, int argc) {
  int result;
  result = peripheral_api_call(GET_INT_ARG(1));
  SET_INT_RETURN(result);
}
```

we have multiple infinite loops

- firmware programming is essentially thread programming which consists of multiple infinite loops
- they keep watch on status like user input, changing sensor value and BLE/WiFi message, then display some information to indicate internal status



the loops of mruby/c are

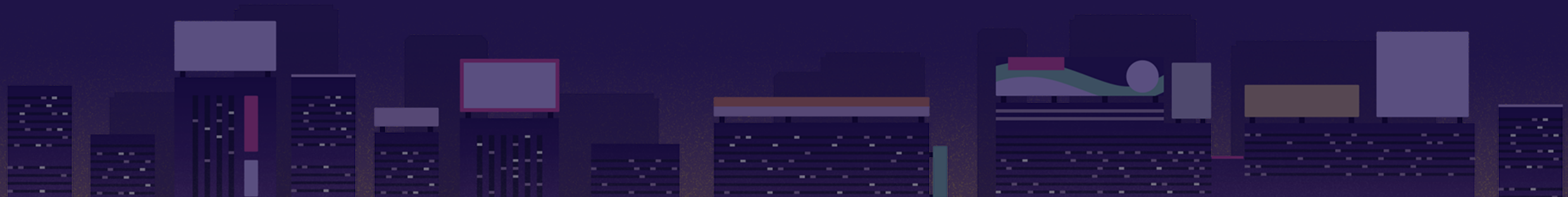
- user space threads managed by mruby/c's runtime

```c
/* main.c */
#define MEMORY_SIZE (1024 * 40) /* 40KB */
static uint8_t mrubyc_vm_pool[MEMORY_SIZE];
int main(void) {
  mrbc_init(mrubyc_vm_pool, MEMORY_SIZE);
  mrbc_create_task(watch_user_interace, 0);
  mrbc_create_task(change_display, 0);
  mrbc_create_task(watch_sensor_value, 0);
  mrbc_run();
}
```

threads of CRuby

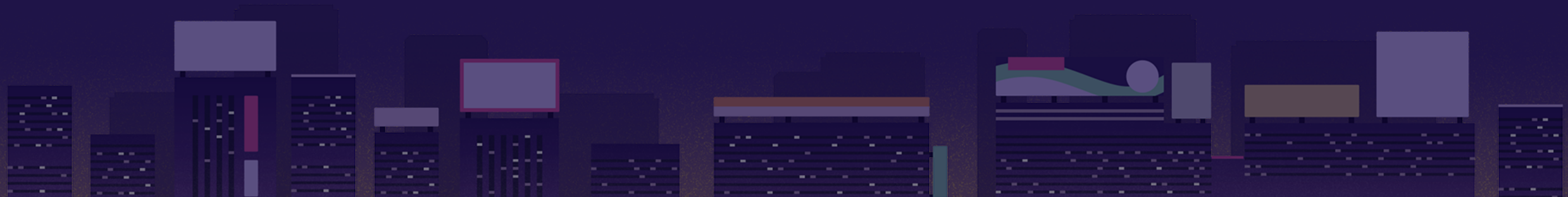
- correspond to native threads (with GVL)

```
def start_loops
  threads = []
  threads << Thread.new { watch_user_interface }
  threads << Thread.new { change_display }
  threads << Thread.new { watch_sensor_value }
  threads.each(&:join)
end
```



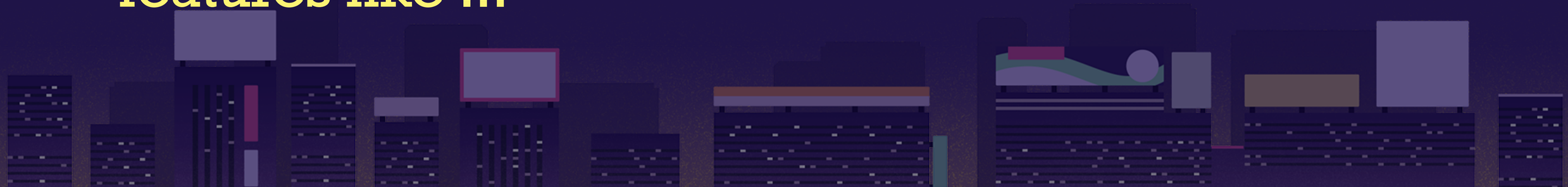
(DEMO)

github.com/hasumikin/mrubyc-debugger

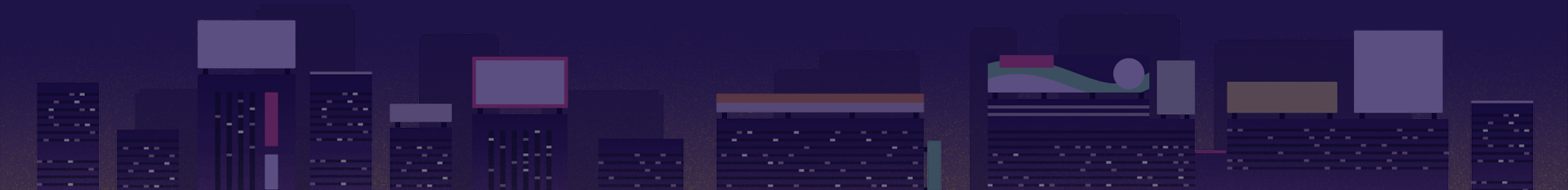


mrubyc-debugger.gem

- mrubyc-debugger runs mruby/c loop script as a CRuby thread
- it simultaneously shows which lines are being executed
- besides, it have to take over the debug print of the script
- in order to do that, we can use your favorite CRuby features like ...



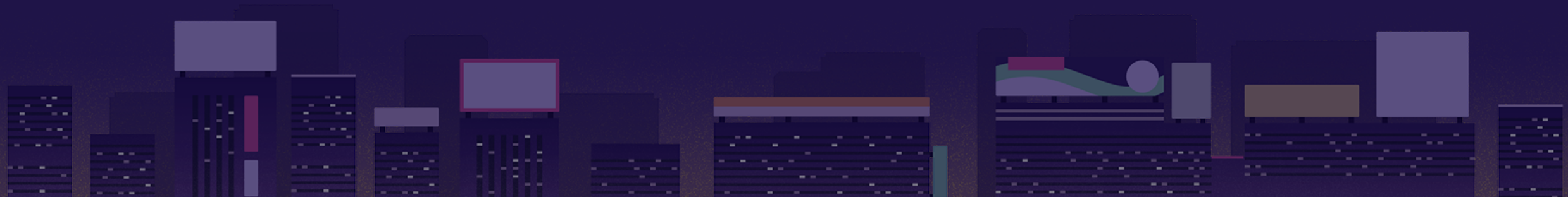
TracePoint



mrubyc-debugger.gem - TracePoint

```
tasks = Dir.glob(File.join(Dir.pwd, "mrubyc_loops_dir", "*.rb"))
TracePoint.new(:c_call, :call, :line) do |tp|
  number = nil
  caller_locations(1, 1).each do |caller_location|
    tasks.each_with_index do |task, i|
      number = i if caller_location.to_s.include?(File.basename(task))
    end
    if number
      @@mutex.lock
      event = {
        method_id:       tp.method_id,
        lineno:          tp.lineno,
        caller_location: caller_location,
        binding:         tp.binding }
      $event_queues[number].push event
      @@mutex.unlock
```

Refinements

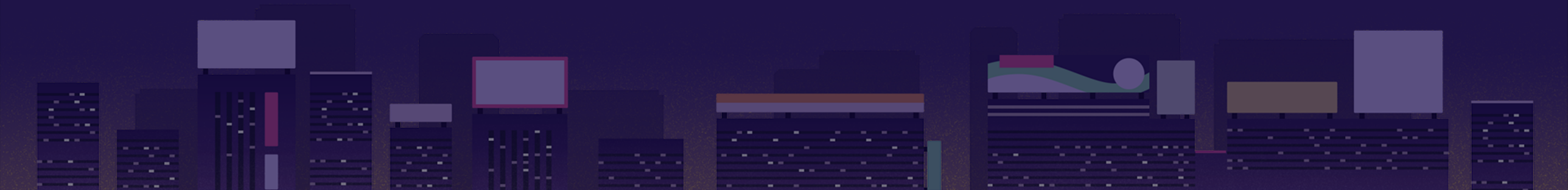


mrubyc-debugger.gem - Refinements

```
module DebugQueue
  refine Kernel do
    def puts(text)
      $debug_queues[Thread.current[:index]] << {
        level: :debug,
        body: text }
```

- assuming mruby/c loops use `#puts` for print debug on serial console,
- mrubyc-debugger takes it over to print on Curses window

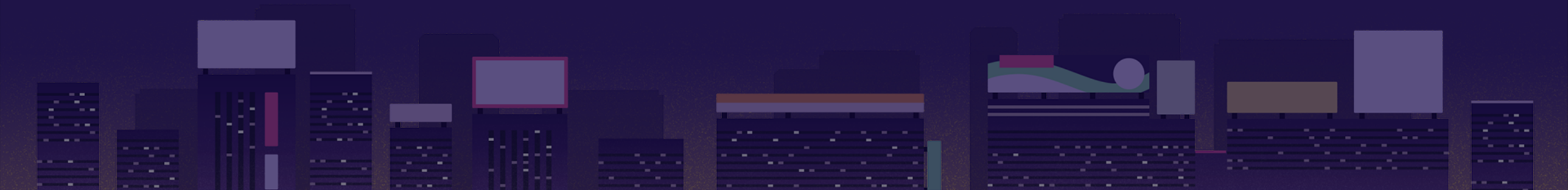
Curses



mrubyc-debugger.gem - Curses

```
include Curses
debug = $debug_queues[i].pop # took over by Refinements
wins[i][:out].addstr " #{debug[:level]} " + debug[:body]
event = $event_queues[i].pop # event info by TracePoint
(1..(wins[i][:src].maxy - 2)).each do |y|
  wins[i][:src].setpos(y, 1)
  if !@srcs[i][y]
    wins[i][:src].addstr ' ' * wins[i][:src].maxx
  else
    # hilighten current line
    wins[i][:src].attron(A_REVERSE) if y == event[:lineno]
  end
end
vars = {}
event[:tp_binding].local_variables.each do |var|
  vars[var] = event[:tp_binding].local_variable_get(var).inspect
end
```

Binding

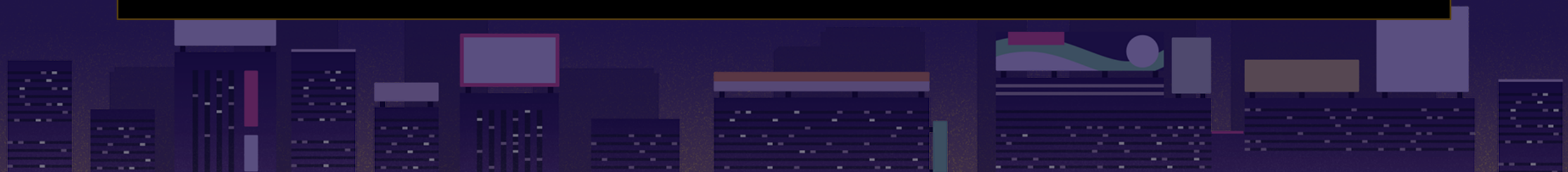


mrubyc-debugger.gem - Binding

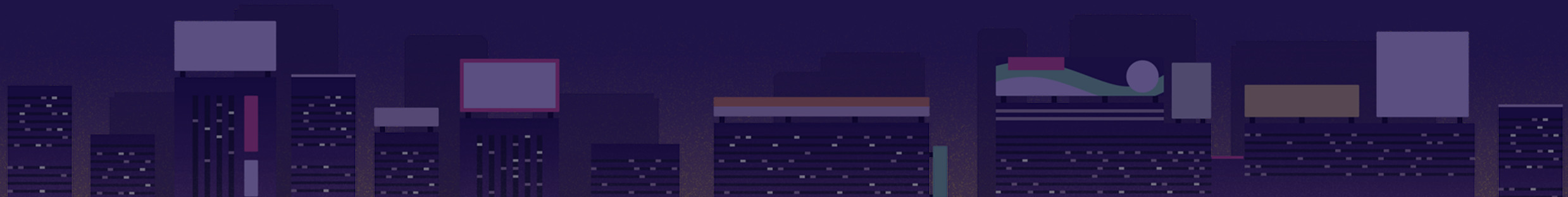
```
binding.local_variables
# => [:var_a, :var_b, ...]

binding.local_variable_get(:var_a)
# => "foo"

binding.local_variable_set(:var_a, "bar")
binding.local_variable_get(:var_a)
# => "bar"
```



summary



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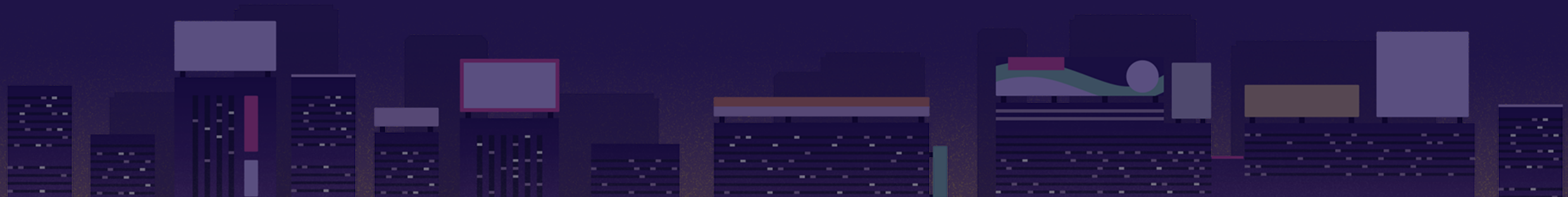
- mrubyc-test is the first testing tool for mruby/c. it means mruby/c started to have its ecosystem



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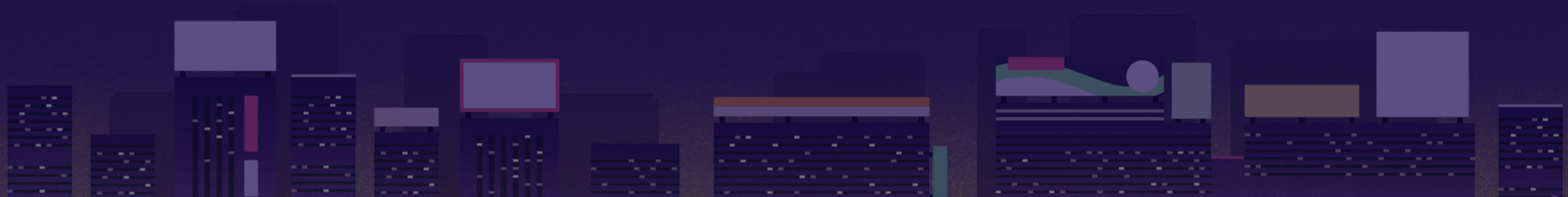

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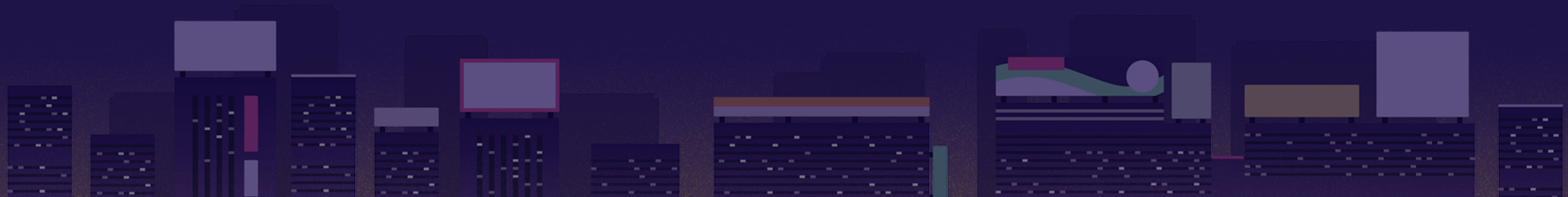

summary

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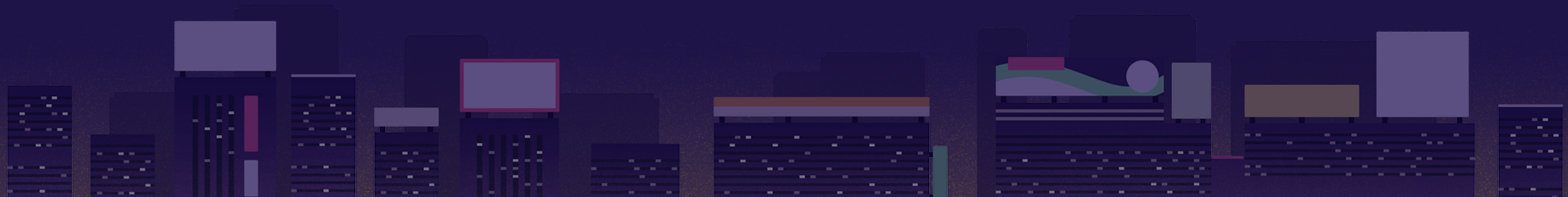
- mrubyc-debugger is a visualization tool of concurrent mruby/c loop tasks powered by CRuby's Thread
  no matter what Matz regrets



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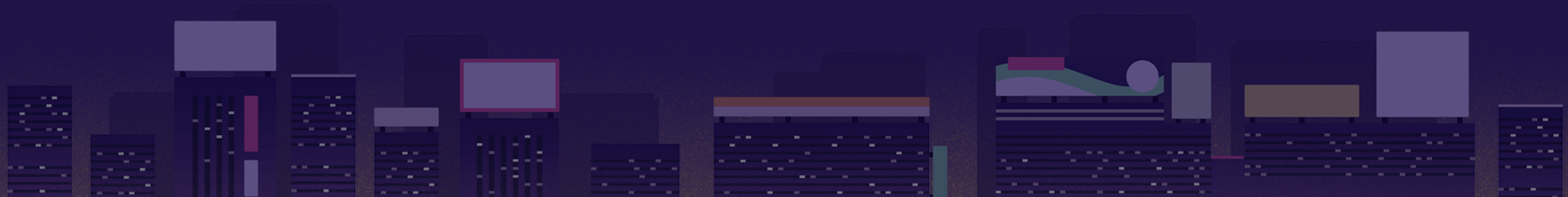

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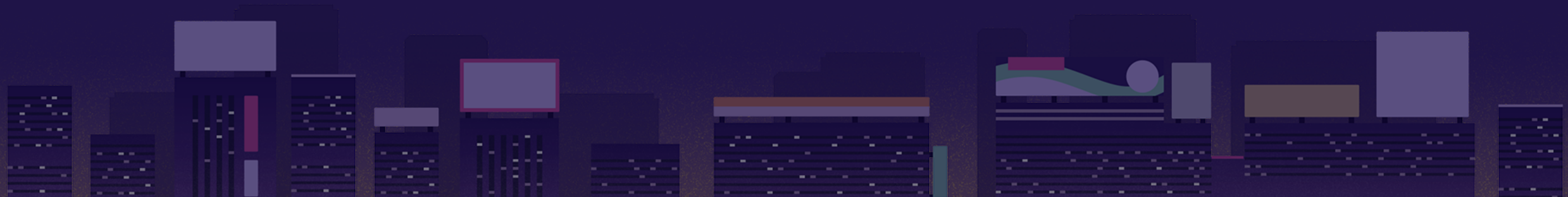
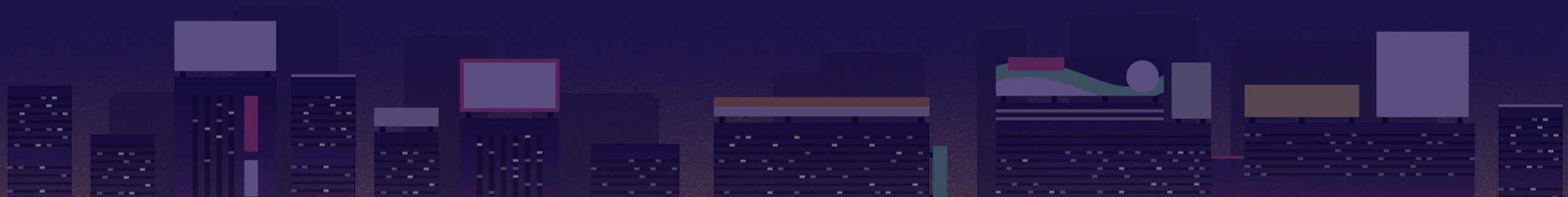


summary

- at a glance, developing with mruby/c seems to be very restricted due to lack of dynamic features
- however, it will be more effective by using the power of CRuby and our own tools
- above all, Rubyish-terminal-based development is fun!



me

- HASUMI Hitoshi
  @hasumikin
- Monstar Lab, inc.
  Shimane office
- Sake 🍶
  Soba 🍜
  Coffee ☕

Thank you!