mruby machine

An Operating System for Microcontroller

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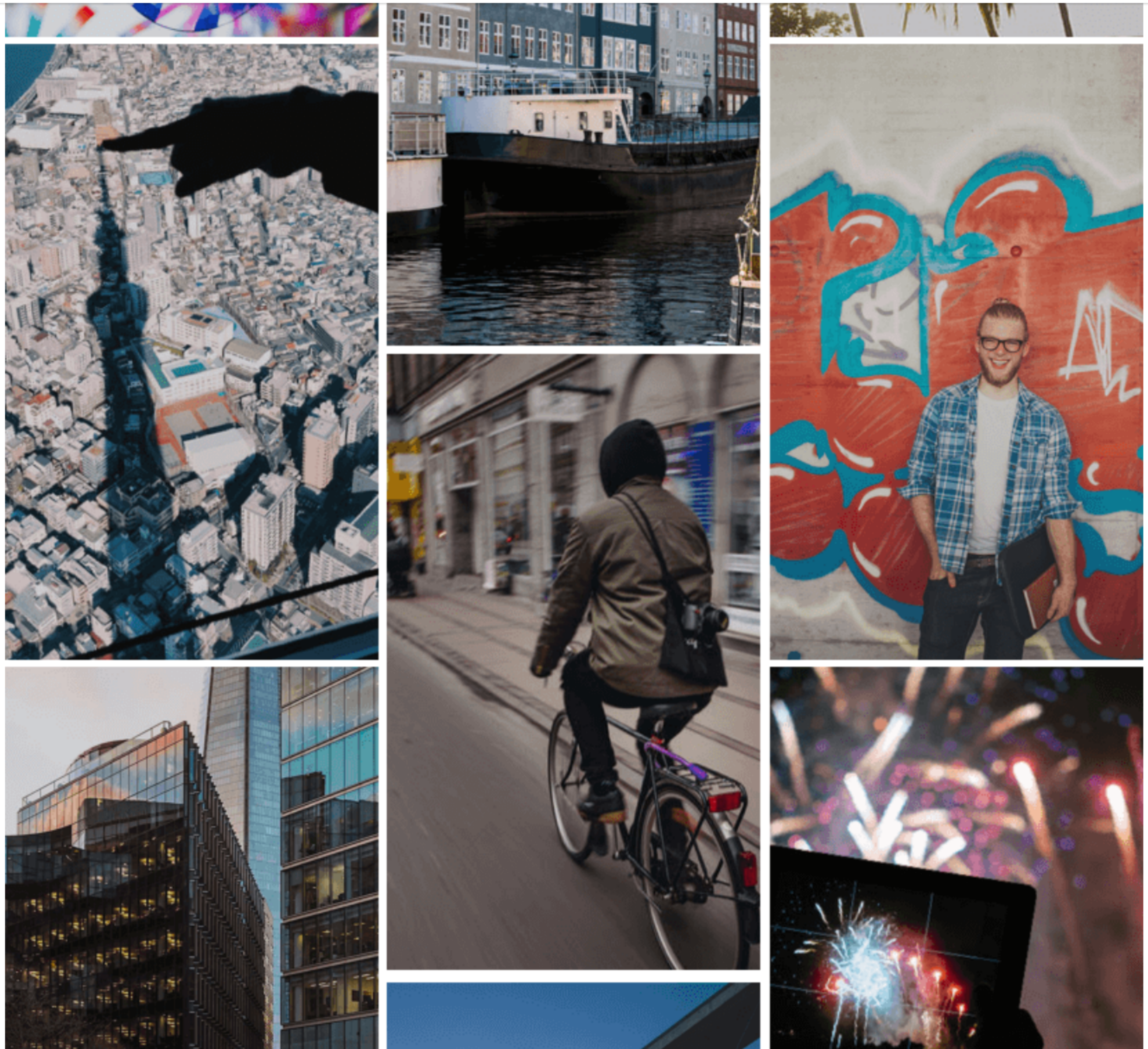


Chapter 1

Background

Motivation 😲 MicroPython

Generally, we keep minimal configuration of MicroPython under ***80K*** *of ARM Thumb2 code (which includes* ***compiler*** *and* ***interactive prompt****, ...). That means a Cortex-M microcontroller with* ***128KB*** *of* ***flash*** *can host a minimal version together with some hardware drivers.*

[cited from `https://github.com/micropython/micropython/wiki/FAQ']

Motivation 😐 MicroPython

*Regarding **RAM** usage, (...) **8KB** is minimal amount to run simple scripts. As Python is interpreted high-level language, the more memory you have, the more capable applications you can run. The reference MicroPython board, PyBoard, has **128KB** of RAM.*

[cited from `https://github.com/micropython/micropython/wiki/FAQ']

Motivation 😕 mruby and mruby/c

- Flashing mruby application into 128KB ROM and running it on 128KB RAM are difficult
- mruby/c runs on 64KB RAM but it doesn't have mruby compiler
  - You have to compile Ruby script into VM code before embedding

Motivation 😖

MicroPython:
"Overwhelming, we are!"

「圧倒的じゃないか、我が軍は」

Motivation 🤔

Would it be great if we have a smaller mruby compiler?

Target Microcontroller

- PSoC5LP: Reference board of mruby/c
  - Arm Cortex-M3 32bit processor
  - 64KB RAM
  - 256KB ROM
- It will be comparable to MicroPython if Ruby runs on PSoC5LP with compiler

Demo

Chapter 2

Terms and Tools

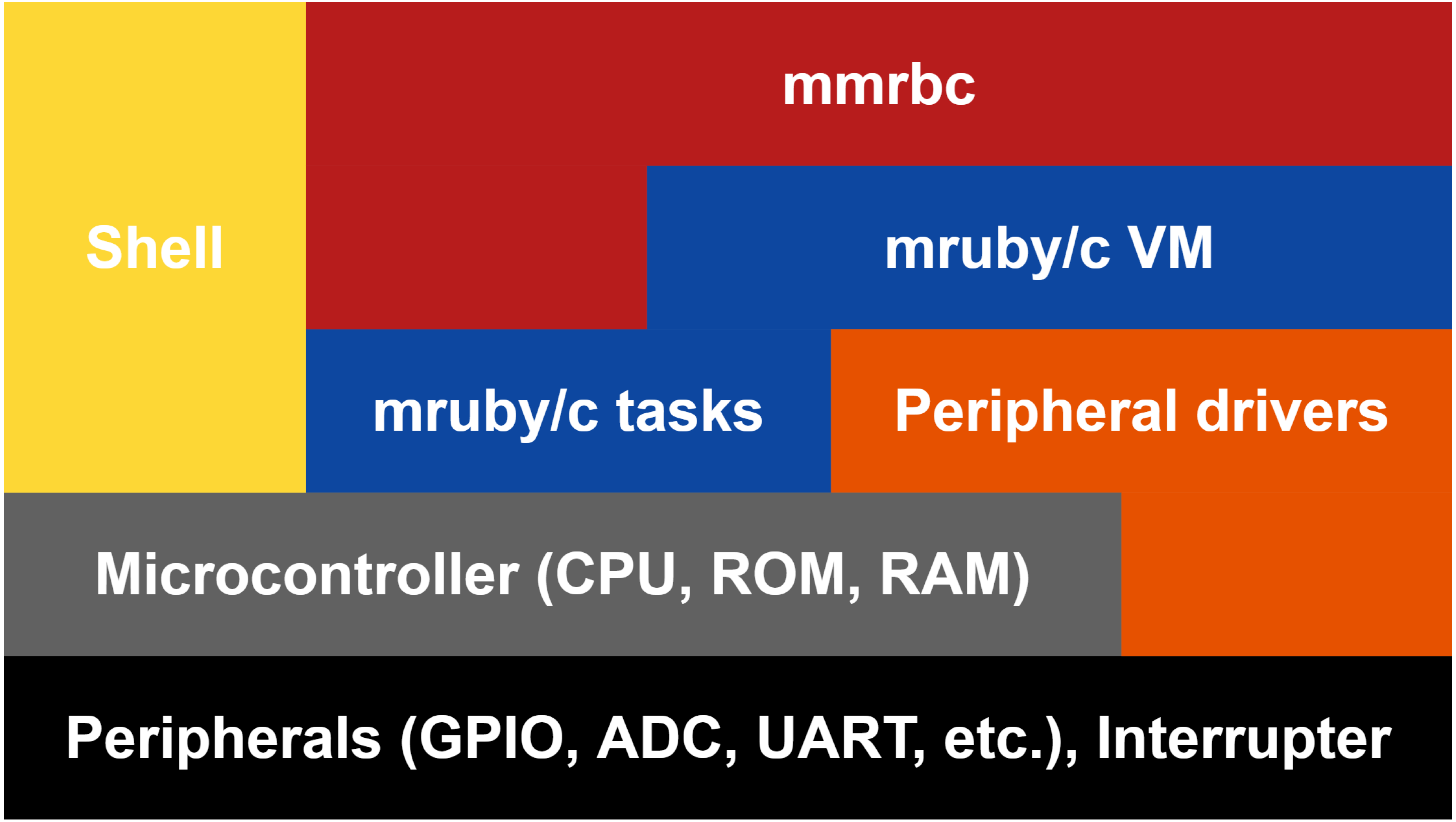
Terms

- mruby
  - A Ruby implementation for general embedded purpose
- mrbc
  - The original mruby compiler bundled with mruby
- mruby/c
  - Another implementation of mruby VM for one-chip microcontroller
  - It doesn't have compiler

Terms

- mmrbc (mini mruby compiler)
  - Another mruby compiler for one-chip microcontroller
- mmruby (mini mruby) = mmrbc + mruby/c
- mruby machine
  - A microcontroller embedded with integration of mmruby, CUI shell and peripheral drivers

mruby machine


mmrbc
Shell
mruby/c VM
mruby/c tasks
Peripheral drivers
Microcontroller (CPU, ROM, RAM)
Peripherals (GPIO, ADC, UART, etc.), Interrupter

Cross compilation tools for bare metal Arm

- arm-none-eabi-gcc, arm-none-eabi-ar, arm-none-eabi-ld, arm-none-eabi-strip, etc.
- What is "arm-none-eabi-" ?
  - arm: Arm architecture
  - none: Without OS (Bare metal)
  - eabi: Embedded Application Binary Interface

Three tool-chains in my laptop (Intel 64)

1. (x86_64-linux-gnu-)gcc
   Usual compilation in daily development
2. arm-linux-gnueabi-gcc
   Binary runs on QEMU (machine emulator)
3. arm-none-eabi-gcc (--with-newlib)
   To make a final library archive (libmmrbc.a) for bare metal Arm

Docker image

(('tag:center'))

https://hub.docker.com/r/hasumikin/arm-none-eabi-tools

C Library

- glibc (GNU C Library)
- Newlib
  - Another C library especially for embedded system
  - Some implementation is missed. eg) regex.c
- Newlib-nano
  - Even smaller version of Newlib for Arm processor
- Yet other libraries
  - EGLIBC, Clibc, sglibc, etc.

Chapter 3

mmrbc

Repo

https://github.com/hasumikin/mmruby

Features of mmrbc

- Portable and Less dependent
  - Doesn't depend on mruby nor mruby/c
  - (To the contrary, mrbc depends on mruby itself)
  - Depends on only standard C library including Newlib(-nano)
  - Can be integrated with both mruby and mruby/c

Features of mmrbc

- Small (by linking to Newlib-nano)
  - Fits in less than 256KB ROM (including mruby/c VM and some application code)
  - Runs enough on less than 128KB RAM

Features of mmrbc

- **Lemon** as a parser generator instead of Yacc/Bison
  - Originally a parser generator of SQLite

Yacc/Bison

- LALR(1) parser generator, typical choice of parser generator
- Yacc (Barkley Yacc)
  - Non-reentrant
  - Parser-Calls-Lexer style (CRuby and mruby use it)
- Bison (Gnu Bison. Modernized version of Yacc)
  - Reentrant, Thread-Safe and Lexer-Calls-Parser style
  - (You can also select old Yacc style)

Lemon

- Reentrant
- Lexer-Calls-Parser style

Parser-Calls-Lexer style (Yacc)

```
yyparse(p);

/* in y.tab.c (generated by Yacc) */
int yyparse(parser_state *p) {
  yytoken = yylex(yylval, p);
  /* makes AST according as you defined */
  ...
  goto yyhogefuga;
  ...
}

/* yylex() is called by parser  */
int yylex(void *lval, parser_state *p) {
  # Find next token and return token type
  return tokenType;
}

GenerateVMCode(p->ast);
```

Lexer-Calls-Parser style (Lemon)

```
/* in your own Lexer */
while (hasMoreToken(rubyScript)) {
  token = getToken(rubyScript);
  Parse(parser, tokenType, token);
}
Parse(parser, 0, "");

/* in parse.c (generated by Lemon) */
void Parse(void *yyp, int yymajor, ...) {
  /* makes AST according as you defined */
  ...
}

GenerateVMCode(p->ast);
```

Lemon

- LALR(1) parser generator as well
- Reentrant
- Lexer-Calls-Parser style
- Generated parser is, I'm still not sure though,
  - Faster than Yacc/Bison (according to its document)
  - Smaller code (according to someone)
- Grammar syntax of parse.y is different from Yacc/-Bison

Lemon

https://sqlite.org/src/doc/trunk/doc/lemon.html

Chapter 4:

How smaller than mrbc?

RAM consumption

- mruby's branch
  - `mruby3` as of August 14th

RAM consumption

- To make things simple, both mrbc and mmrbc are
  - built for x86_64 architecture
  - using `malloc()` and `free()` of glibc
    - (mmrbc usually uses `mrbc_alloc()` to manage heap area)
  - Linux file system to load Ruby script
    - (microcontroller doesn't have file system)
- As a result, we can simply compare with **valgrind**

RAM consumption

- Analysis command looks like:

```
valgrind \
  --tool=massif \
  --stacks=yes \
  path/to/(mrbc|mmrbc) path/to/script.rb
```

- Showing the result:

```
ms_print massif.out.xxxx | less
```

RAM consumption: Case 1

Ruby code:

```ruby
# hello_world.rb
puts "Hello World!"
```

Output:

```
Hello World!
```

RAM consumption: Case 1 / mrbc

```
--------------------------------------------------------------------------------
Command:            ../mruby/build/host/bin/mrbc ./hello_world.rb
Massif arguments:   --stacks=yes
ms_print arguments: massif.out.4087
--------------------------------------------------------------------------------
    KB
157.8^                                                                       #
     |                                                                       #
     |                                                                       #
     |                                                                       #
     |                                                                       #
     |                                                                      @#
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   0 +----------------------------------------------------------------------->Mi
     0                                                                   3.235
```

RAM consumption: Case 1 / mmrbc

```
--------------------------------------------------------------------------------
Command:            ../mmruby/build/host-production/bin/mmrbc ./hello_world.rb
Massif arguments:   --stacks=yes
ms_print arguments: massif.out.1652
--------------------------------------------------------------------------------
    KB
11.17^                                                                #
     |                                                               @#
     |                                                              @@#  ::
     |                                                              @@#:::::
     |                                            @     @  :@: : :: @@#:::::
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     |     ::::::::::::: :: : :::::::::@:::::@::: @: :::@:::@:::@:::@@#:::::@
   0 +----------------------------------------------------------------------->ki
     0                                                                   224.5
```

RAM consumption: Case 1 / mmrbc 👏 8888

```
--------------------------------------------------------------------------------
Command:            ../mmruby/build/host-production/bin/mmrbc ./hello_world.rb
Massif arguments:   --stacks=yes
ms_print arguments: massif.out.1652
--------------------------------------------------------------------------------
    KB
11.17^                                                                #
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   0 +----------------------------------------------------------------------->ki
     0                                                                   224.5
```

RAM consumption: Case 2

Ruby code:

```ruby
# idiotic_script.rb
ary = Array.new(3)
ary[0] = {a: 123e2}
ary[0][:key] = "string"
ary[1] = %w(abc ABC Hello)
ary[2] = 0x1f
ary[3] = !true
puts "my name is #{self.class}, result is #{ary[2] * ary[0][:a]}"
p ary
```

RAM consumption: Case 2

Output:

```
my name is Object, result is 381300
[{:a=>12300, :key=>"string"}, ["abc", "ABC", "Hello"], 31, false]
```

RAM consumption: Case 2 / mrbc

```
--------------------------------------------------------------------------------
Command:            ../mruby/build/host/bin/mrbc ./idiotic_script.rb
Massif arguments:   --stacks=yes
ms_print arguments: massif.out.4133
--------------------------------------------------------------------------------
    KB
162.9^                                                                     ##
     |                                                                     #
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     |                                                                    @#
     |                                                                    @#
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     |     :: :::: ::::: :: :: ::: :@ :::: @ :: ::@:: ::: :::@ :: :::@  @:@# :
   0 +----------------------------------------------------------------------->Mi
     0                                                                   3.470
```

RAM consumption: Case 2 / mmrbc

```
--------------------------------------------------------------------------------
Command:            ../mmruby/build/host-production/bin/mmrbc idiotic_script.rb
Massif arguments:   --stacks=yes
ms_print arguments: massif.out.13414
--------------------------------------------------------------------------------
    KB
53.20^                                                                 #
     |                                                                 #
     |                                                                @#  :::
     |                                                                @#  : :
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     |      : :: @ :: :::::: ::@ @ :@: @:: @@ :@::@: @ :@:: @:: :@@: @@#::: ::
   0 +----------------------------------------------------------------------->Mi
     0                                                                    1.616
```

RAM consumption: Summary

Ruby script	mrbc	mmrbc
hello_world.rb	157.8KB	11.17KB
idiotic_script.rb	162.9KB	53.20KB

Note: These results are larger than possible results on 32bit architecture because of pointer size

Idiotic script

```ruby
# idiotic_script.rb
ary = Array.new(3)
ary[0] = {a: 123e2}
ary[0][:key] = "string"
ary[1] = %w(abc ABC Hello)
ary[2] = 0x1f
ary[3] = !true
puts "my name is #{self.class}, result is #{ary[2] * ary[0][:a]}"
p ary

=>
my name is Object, result is 381300
[{:a=>12300, :key=>"string"}, ["abc", "ABC", "Hello"], 31, false]
```

Syntax that mmrbc can compile

Syntax ✅ implemented

- lvar, $gvar, @ivar, CONSTANT
- assignment, fcall, method chain
- Literals: Array, Hash, String, Fixnum, Float, etc.
- Keywords: true, false, nil, return, self, etc.
- +, -, *, /, %, **, +=, -=, *=, /=, %=, &=, |=, ^=, **=, <<=, >>=
- !, ~, +, -, not, &, |, ^, <<, >>
- Syntax sugar: `%w(a b c)`
- Interpolation: `"The answer is #{get_result(@attr)}!"`

Syntax 🛠 under construction

- if then elif else end, unless
- case when else then
- while, until, break, next, redo, retry, for in
- [0,1].each do |var| end
- def method_name(arg); end
- class MyClass < ParentClass; end
- rescue, ensure
- ..., etc.

Roadmap

https://github.com/hasumikin/mmruby/issues/6

Code size (to estimate ROM consumption)

```
% ls -l
(...)
.rwxrwxrwx 609k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.a
.rwxrwxrwx 903k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.elf
.rwxrwxrwx 650k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.hex
.rwxrwxrwx 425k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.map

% size mruby_machine_PSoC5LP.elf
   text    data     bss     dec     hex filename
 136080     320   63009  199409   30af1 mruby_machine_PSoC5LP.elf
```

Code size (to estimate ROM consumption)

```
% ls -l
(...)
.rwxrwxrwx 609k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.a
.rwxrwxrwx 903k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.elf
.rwxrwxrwx 650k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.hex
.rwxrwxrwx 425k hasumi 17 Aug  7:03 mruby_machine_PSoC5LP.map

% size mruby_machine_PSoC5LP.elf
   text	   data	    bss	    dec	    hex	filename
 136080	    320	  63009	 199409	  30af1	mruby_machine_PSoC5LP.elf
```

136_080 + 320 = 136_400 ≒ **133.2KB** 👍

Summary

- mmrbc is a mini mruby compiler
  - VM code runs on both mruby VM and mruby/c VM
  - Still incomplete regarding syntax and memory efficiency
- mruby machine
  = mmrbc + mruby/c + shell + dirivers
  - Runs on PSoC5LP { RAM: 64KB, ROM: 256KB }

Thank you!