{EPITECH}
LEARN DIFFERENT*

ROBOT FACTORY

ELEMENTARY PROGRAMMING IN C

* apprendre autrement

ROBOT FACTORY

binary name: asm
language: C
compilation: via Makefile, including re, clean and fclean rules
Authorized functions: (f)open, (f)read, (f)write, (f)close, (l)stat, lseek, fseek, getline, malloc, realloc, free

- ✓ The totality of your source files, except all useless files (binary, temp files, objfiles,…), must be included in your delivery.
- ✓ All the bonus files (including a potential specific Makefile) should be in a directory named bonus.
- ✓ Error messages have to be written on the error output, and the program should then exit with the 84 error code (0 if there is no error).

You have brilliantly navigated the preparation of your lab, secured your most precious plans, and organized your workspace into a true fortress of efficiency. Now, the time has come to bring your ambitions to life. Before you lies the most exhilarating challenge yet: the Robot Factory.

In this new adventure, you'll step into the shoes of a true robotics engineer, but not just any engineer. Your mission is to transform theoretical plans, written in assembly language, into combat-ready machines. These robots will be your champions in the arena of the grand Corewar tournament.

Assembly language, with its precise instructions and low-level operations, is the ancient tongue of machines. You must master it to code the heart of your robots. But that's only the first step. Every line of code, every instruction, must be translated into bytecode - the universal language of our mechanical fighters. It's in this complex alchemy that the power and soul of your future champion reside.

Imagine your plans as ancient scrolls, holding the secrets of legendary warriors. Your task is to decipher these scrolls and transmute them into living force. This process requires a deep understanding of assembly and a mastery of transcription into bytecode, a skill that separates the true masters of robotics from the novices.

— Narrator —

The project

Objectives

The Corewar tournament is a game in which several programs called `Champions` will fight to stay the last one alive. Corewar is actually a computer simulation in which processors will share memory to run on.
The project is based on a virtual machine in which the champions will fight for memory by all possible means in order to win, the last champion being able to signal that he is alive wins the game. In other words, the last champion to execute the `live` instruction is declared winner.

In other words, the Robot Factory project will be your ability to transform robot plans, files written in **assembler**, into tournament-ready robots, files written in **bytecode**.

Search “corewars” and “redcode” on the Internet…

The different parts

The project is divided into two seperate parts, with only one to develop:

- ✓ **Champions** (given, you don’t have to write any)
  The champions are files written in an assembly language specific to our virtual machine. The file is filled with instructions that the champion must follow, it’s his line of conduct. It is in this file that the champion knows when he must attack, defend himself or announce that he is still alive. Examples of champions are given in the attachments.
- ✓ **The Assembler** (to develop)
  The purpose of this program, like a program that your own computer would try to run, is to transcribe the champions (the .s files) into a language that the Corewar tournament program can understand. It will therefore be necessary to understand the assembly language in order to translate it byte by byte.

op.c and op.h

To get to the end of the Corewar and for each of you to develop champions with similar instructions and architecture, two files are made available to you: `op.c` and `op.h`.
You will have to integrate them into your rendering directory.

All values written in **UPPERCASE** in this subject are variables obtainable in `op.c` or `op.h`.

The coding style will be checked on all the files that you deliver, including the currently non-compliant `op.c` and `op.h`.

Champions

Here's what a champion (an .s file) might look like:

```
Terminal
B-CPE-200> cat jon.s
        .name ‘‘Jon Snow’’
        .comment ‘‘Winter is coming’’

        sti r1, %:crow, %1
crow:   live %234
        ld %0, r3
        zjmp %:crow
```

The header

The header contains the informations that will be used to display champions informations during tournament.

- ✓ A name
  `.name "Jon Snow"`
- ✓ A description
  `.comment "winter is coming"`

There can be comments anywhere as long as the comment starts with a `'#'`.

The body

The body is a succession of lines which are for each of them a different instruction. In the example we have 4 distinct instructions like “sti r1, %:crow, %1”. These instructions are themselves decomposable into 3 sub-parts:

- ✓ There are so-called instruction codes (called opcode), which allow to define which instruction to
  execute.
  `"sti", "live", "ld", "zjmp"`

✓ And the parameters that go with them. Each instruction depends on parameters to be used.

```
"r1, %:crow, %1", "%234", "ld %0, r3", "%:crow"
```

✓ But there are also labels. followed by the **LABEL_CHAR** character (here, ':'). Labels can be any of the character strings that are composed of elements from the **LABEL_CHARS** string. It is a kind of function that allows to encompass several instructions. It serves as a coordinate point in the instructions of a champion.

```
"crow:"
```

The instructions

The champions have the possibility of executing one of our 16 instructions (detailed and established in the `op.c`). Below you will find a table explaining their parameters and operation.
Don't worry! You still don't understand everything written there but a lot of this information will actually come in handy during the tournament, not necessarily now!

It is not up to you to write your own champions! That's could be a great bonus and help you to understand their behavior but champions are already provided in project side files

Mnemonic	Parameters / Effects
0x01 (live)	takes 1 parameter: 4 bytes that represent the player's number. It indicates that the player is alive.
0x02 (ld)	takes 2 parameters. It loads the value of the first parameter into the second parameter, which must be a register (not the PC). This operation modifies the carry. ld 34,r3 loads the REG_SIZE bytes starting at the address PC + 34 % IDX_MOD into r3.
0x03 (st)	takes 2 parameters. It stores the first parameter's value (which is a register) into the second (whether a register or a number). st r4,34 stores the content of r4 at the address PC + 34 % IDX_MOD. st r3,r8 copies the content of r3 into r8.
0x04 (add)	takes 3 registers as parameters. It adds the content of the first two and puts the sum into the third one (which must be a register). This operation modifies the carry. add r2,r3,r5 adds the content of r2 and r3 and puts the result into r5.
0x05 (sub)	similar to add, but performing a subtraction.
0x06 (and)	takes 3 parameters. It performs a binary AND between the first two parameters and stores the result into the third one (which must be a register). This operation modifies the carry. and r2, %0,r3 puts r2 & 0 into r3.
0x07 (or)	similar to and, but performing a binary OR.
0x08 (xor)	similar to and, but performing a binary XOR (exclusive OR).

Mnemonic	Parameters / Effects
0x09 (zjmp)	takes 1 parameter, which must be an index. It jumps to this index if the carry is worth 1. Otherwise, it does nothing but consumes the same time.
0x0a (ldi)	takes 3 parameters. The first two must be indexes or registers, the third one must be a register. This operation modifies the carry. ldi 3,%4,r1 reads IND_SIZ bytes from the address PC + 3 % IDX_MOD, adds 4 to this value. The sum is named S. REG_SIZE bytes are read from the address PC + S % IDX_MOD and copied into r1.
0x0b (sti)	takes 3 parameters. The first one must be a register. The other two can be indexes or registers. sti r2,%4,%5 copies the content of r2 into the address PC + (4+5)% IDX_MOD.
0x0c (fork)	takes 1 parameter, which must be an index. It creates a new program that inherits different states from the parent. This program is executed at the address PC + first parameter % IDX_MOD.
0x0d (lld)	similar to ld without the % IDX_MOD. This operation modifies the carry.
0x0e (lldi)	similar to ldi without the % IDX_MOD. This operation modifies the carry.
0x0f (lfork)	similar to fork without the % IDX_MOD.
0x10 (aff)	takes 1 parameter, which must be a register. It displays on the standard output the character whose ASCII code is the content of the register (in base 10). A 256 modulo is applied to this ASCII code. aff r3 displays '*' if r3 contains 42.

There are things you don't understand, aren't there? The PC, IDX_MOD, …, since these are the effects of instructions, they could be interesting elements for Corewar, but maybe not now. Still, you should keep it under your hat in the future, you never know.

The assembler

```
Terminal
B-CPE-200> ./asm -h
USAGE
./asm file_name[.s]
DESCRIPTION
file_name file in assembly language to be converted into file_name.cor, an executable in
the Virtual Machine.
```

Now that you know what a champion is made of, you will have to transcribe them into a language that the virtual machine can understand, i.e. into machine code.
To do this, you will have to translate line after line (instruction after instruction).

Parameters

As seen before, the structure of an instruction is thus: **<opcode> <parameters>**. It seems that the opcode is understood, it is the instruction to be executed, but what does the parameters that follow mean? An instruction can have from 0 to `MAX_ARGS_NUMBER` parameters, separated by commas. These parameters can be of 3 different types:

- ✓ Register
  Each champion will have to `REG_NUMBER` registers in which it can store integers (`r1` to `rREG_NUMBER`). Besides, the first register (`r1`) will contain the identifier of the champion in question.
- ✓ Direct
  The `DIRECT_CHAR` character, followed by a value or a label (preceded by `LABEL_CHAR`), which represents the direct value. For instance, %4 or %:label
- ✓ Indirect
  A value or a label (preceded by `LABEL_CHAR`), which represents the value that is found at the parameter's address (in relation to PC).

So now you understand `sti r1, %:crow, %1`? The instruction sti is executed with the direct value of :crow and 1.

For your interest, a register is a memory location internal to a processor, it is the fastest memory in a computer.

Example

Before continuing further, here is what the champions should look like once transcribed.

Using the command `"$ hexdump -C <file>"` will come to you as frantically as the revelio spell in Hogwarts Legacy

Terminal

```
B-CPE-200> ./asm jon.s && hexdump -C jon.cor
00000000 00 ea 83 f3 4a 6f 6e 20 53 6e 6f 77 00 00 00 00 |....Jon Snow....|
00000010 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |................|

00000080 00 00 00 00 00 00 00 00 00 00 00 16 57 69 6e 74 |............Wint|
00000090 65 72 20 69 73 20 63 6f 6d 69 6e 67 00 00 00 00 |er is coming....|
000000a0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |................|

00000890 0b 68 01 00 07 00 01 01 00 00 00 ea 02 90 00 00 |.h..............|
000008a0 00 00 03 09 ff f4 |......|
000008a6
```

Transcription

With hexdump, you have the ability to see each of the bytes transcribed by the assembly. For example you can see that the 4th byte `4a` is the hexadecimal value of the character `J`, the same `J` as in `Jon Snow`! This means two things:

- ✓ It is possible to take byte after byte a .cor file with its original .s file to understand how the transcription is made (to understand the particular cases it is very practical!)
- ✓ Before transcribing the instructions, the header (with name and comment) must be transcribed using the `header_t` structure provided in op.h.

Each instruction is coded through 3 elements:

- ✓ **the instruction code** (opcode)
- ✓ **the coding byte**, which is a value to describe the type of the parameters that follow (after all, once in machine code, how do you know what type the parameters are?) The byte coding will not be present for the `live`, `zjmp`, `fork` and `lfork` instructions.
- ✓ **the parameters**

But how to write them?

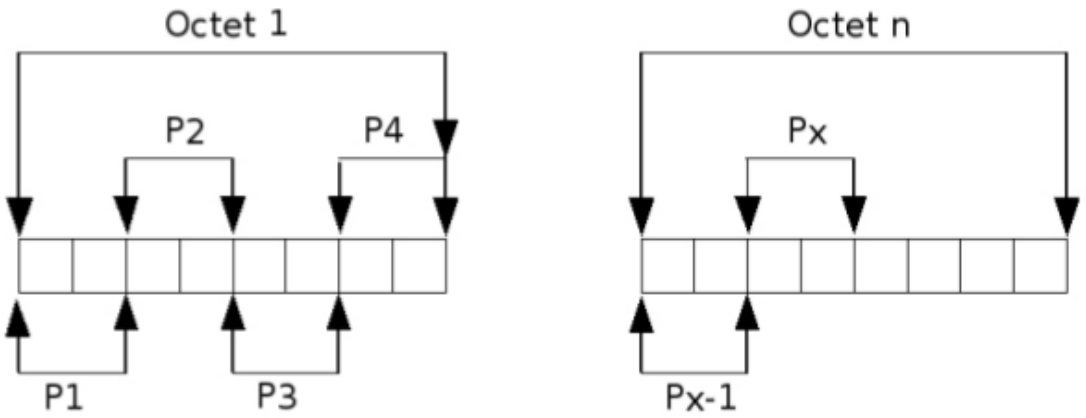
Instruction code

The instruction code can be found in `op_tab` in `op.h`. This instruction code is written on a single byte.
This will give `0x0b` for the `sti` instruction in our example.

Coding byte

The byte coding is calculated according to the following parameters. In a byte we will fill each of its 8 bits from the nature of the parameters. Bits 1 and 2 will be the type of parameter 1, bits 3 and 4 the type of parameter 2 etc.

- ✓ If the parameter is a register: 01
- ✓ If the parameter is a direct: 10
- ✓ If the parameter is an indirect: 11
- ✓ Otherwise: 00



The whole thing then forms a single byte ready to be written. This will give for example :
- The parameters `r2, 23, %34` will give: `01 11 10 00` and therefore worth: `0x78`
- The parameters `23, 45, %34` will give: `11 11 10 00` and therefore worth: `0xf8`
- The parameters `r1, r3, 34` will give: `01 01 11 00` and therefore will be worth: `0x5c`

Parameters

The parameters are transcribed one by one by writing their value directly on a number of bytes equivalent to their type.

- ✓ The value is written (in hexadecimal) on 1 byte for a register
- ✓ The value is written (in hexadecimal) on `DIR_SIZE` bytes for a direct
- ✓ The value is written (in hexadecimal) on `IND_SIZE` bytes for indirect

Using the examples from before:
- The parameters `r2, 23, %34` will give: `0x02`, `0x00 0x17` and `0x00 0x00 0x00 0x22`
- The parameters `23, 45, %34` will give: `0x00 0x17`, `0x00 0x2d` and `0x00 0x00 0x00 0x22`
- The parameters `r1, r3, 34` will give: `0x01, 0x03` and `0x00 0x22`

What happened when the parameter is a label like `%:crow`? You should let's compare .s and .cor file to see the result!

Those examples are only valid when none of the parameters are indexes

Did you say indexes ?

Instructions will sometime describe the parameters they take as `indexes`. This does not change the rules for the description of the parameters type but the size of the parameter itself might change.
Indexes size will always be `IND_SIZE` bytes, even when the parameter is a direct.
Read the Instructions section carefully to identify the function that have indexes as parameters.

The virtual machine for the tournament is BIG ENDIAN (like the Sun and unlike the i386). This changes the order of storage, and thus perhaps the way you should transcribe your information

Conclusion

For the rest, think about it and read op.h and op.c.
Your teaching assistants have also been through this, so don't be surprised if one of them looks at you wide-eyed when you ask them for help on certain bytes (spoiler: they'll know how to answer you, but might like to let you do a bit of thinking - that's the point of the project!).
Please verify that your programs are completely up to the coding style.

If you get this far, go back to page 2.

If you've arrived here again, go back to page 2 - it never hurts to reread the subject!

Here again? No but really, I assure you that rereading the subject one more time won't do you any harm.

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