Introduction to Computer Architecture
Project 1

RISC-V Binary Code

Hyungmin Cho
Department of Computer Science and Engineering
Sungkyunkwan University

Projects: Programming Assignments

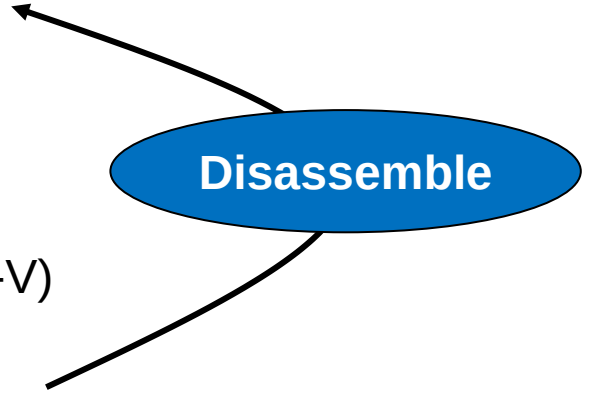
- Project 1: Interpret RISC-V binary code
- Project 2: Simulate a single-cycle CPU
- Project 3: ?

Project 1 Goal

- Your program reads a binary file containing RISC-V machine code and **prints the assembly representation of the code**

Assembly language program (RISC-V)

```
slli x6, x11, 3
add  x6, x10, x6
ld   x5, 0(x6)
ld   x7, 8(x6)
sd   x7, 0(x6)
sd   x5, 8(x6)
jalr x0, 0(x1)
```



Machine (object, binary) code (RISC-V)

```
00000000001101011001001100010011
00000000011001010000001100110011
00000000000000011001100101000011
00000000100000110011001110000011
00000000011100110011000000100011
00000000010100110011010000100011
00000000000000001000000001100111
```

Program Interface

- Executable file name
  - The name of the program should be "**`riscv-sim`**"
  - If using Python, name the main file "**`riscv-sim.py`**"

- Input
  - The input is a **binary file** containing RISC-V machine codes
  - The input file name is provided as the first command-line argument.
  - The file name length will not exceed 255 characters.

- Output
  - Print the disassembled instructions.
  - Each line should display one instruction in the following format:

```
inst <instruction number>: <32-bit binary code in hex format> <disassembled instruction>
```

Disassembled Instruction Format

- Use lowercase instruction names
  - `add, sub, sw, jal, …`
- Print registers using their register number
  - `x0, x1, x20`, …
  - Do not to use the register name (e.g., `sp`, `ra`, …)
- Follow these formatting rules:
  - Use a single space between the instruction name, registers, and immediate values.
  - Place a comma between registers (no comma at the end).
  - Do not use spaces for load / store / jalr offsets.
  - Examples of incorrect formatting:
    - `ADD x1 x2 x3` ← uppercase instruction name, no commas between registers.
    - `or x1 , x2,  x3,` ← incorrect comma placement, double space, comma at the end.
    - `lw x1, 20 (x3)` ← space between the offset value and parenthesis

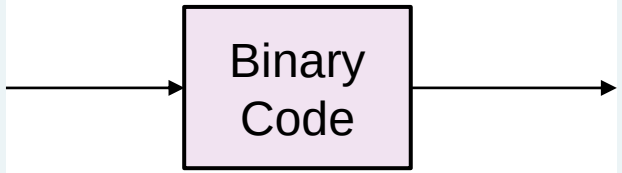
Immediate

- Represent immediate and address values as **signed decimal (base 10) integers**.
  - `lw x16, 20(x29)`
  - `addi x29, x29, -16`

- Print all immediate values in signed decimal format after sign-extending to 32 bits.
  - Note: This may cause confusion for the branch offsets and `lui` immediates..

Assembly code

```
HERE:
    addi x1, x2, 0x100
    beq x1, x3, HERE
    lui 0x1
```



What you need to print

```
addi x1, x2, 256
beq x1, x3, -4
lui 4096
```

Instructions to support

- `lui, auipc, jal, jalr, beq, bne, blt, bge, bltu, bgeu, lb, lh, lw, lbu, lhu, sb, sh, sw, addi, slti, sltiu, xori, ori, andi, slli, srli, srai, add, sub, sll, slt, sltu, xor, srl, sra, or, and`

- If an instruction cannot be interpreted, print "`unknown instruction`"

Execution Results

```
$ ./riscv-sim /home/swe3005/2023f/proj1/proj1_1.bin
inst 0: 00208033 add x0, x1, x2
inst 1: 41450fb3 sub x31, x10, x20
inst 2: 008319b3 sll x19, x6, x8
inst 3: 00a4d433 srl x8, x9, x10
inst 4: 40a4d433 sra x8, x9, x10
inst 5: 0010e0b3 or x1, x1, x1
$
```

- Print results to `stdout` using standard print functions (e.g., `print`, `printf`).
- DO NOT save the output to a text file.

Test Input Files

- Obtain test input files from the department servers (`swui.skku.edu`, `swye.skku.edu`, `swji.skku.edu`)
  - `~swe3005/2023f/proj1/proj1_1.bin`
  - `~swe3005/2023f/proj1/proj1_2.bin`
  - …
  - `~swe3005/2023f/proj1/proj1_7.bin`
- To check the contents of the binary file, use the '**xxd**' program

```
$ xxd /home/swe3005/2023f/proj1/proj1_1.bin
00000000: 3380 2000 b30f 4541 b319 8300 33d4 a400
00000010: 33d4 a440 b3e0 1000
```

Test Result

- You may compare your program's output with the reference implementation.

```
$ /home/swe3005/2023f/proj1/riscv-sim /home/swe3005/2023f/proj1/ proj1_1.bin
inst 0: 00208033 add x0, x1, x2
inst 1: 41450fb3 sub x31, x10, x20
inst 2: 008319b3 sll x19, x6, x8
inst 3: 00a4d433 srl x8, x9, x10
inst 4: 40a4d433 sra x8, x9, x10
inst 5: 0010e0b3 or x1, x1, x1
```

Test Result

- Your output should EXACTLY MATCH with the reference output.
  - Any difference (e.g., extra character) is considered incorrect.

- Check your output correctness using the `diff` command.

```
$ ./riscv-sim /home/swe3005/2023f/proj1/proj1_1.bin > my_output.txt
$ /home/swe3005/2023f/proj1/riscv-sim /home/swe3005/2023f/proj1/proj1_1.bin > ref_output.txt
$ diff my_output.txt ref_output.txt
$
```

← This will save your output to my_output.txt

← Nothing will be printed if two files match.
Otherwise, it will show the differences.

Project Rule – IMPORTANT!

- You may use C, C++, or Python.
  - If you want to use a different programming language, inform the TAs in advance.

- Your submission must be compliable and executable on the department Linux server.
  - Test your program on the server if you developed it on your own PC.

- Provide a `Makefile` to compile your code
  - The compiled executable should be named **`riscv-sim`**
  - If the build fails, your project score is **zero**.
  - No `Makefile` is needed for Python

Makefile Example

- C

Makefile

```
CC=gcc
CCFLAGS=

#add C source files here
SRCS=main.c

TARGET=riscv-sim

OBJS := $(patsubst %.c,%.o,$(SRCS))

all: $(TARGET)

%.o:%.c
	$(CC) $(CCFLAGS) $< -c -o $@

$(TARGET): $(OBJS)
	$(CC) $(CCFLAGS) $^ -o $@

.PHONY=clean

clean:
	rm -f $(OBJS) $(TARGET)
```

- C++

Makefile

```
CXX=g++
CXXFLAGS=

#add C++ source files here
SRCS=main.cc

TARGET=riscv-sim

OBJS := $(patsubst %.cc,%.o,$(SRCS))

all: $(TARGET)

%.o:%.cc
	$(CXX) $(CXXFLAGS) $< -c -o $@

$(TARGET): $(OBJS)
	$(CXX) $(CXXFLAGS) $^ -o $@

.PHONY=clean

clean:
	rm -f $(OBJS) $(TARGET)
```

Script Example

- Python (if your python file is mips-sim.py)

`riscv-sim` ← Don't forget to give the execute permission: `chmod +x riscv-sim`

```
python3 riscv-sim.py "$@"
```

- Also, be aware of the python version on the server
  - python: python 2.7.17
  - python3: python 3.6.9

Project Environment

- We will use the department's In-Ui-Ye-Ji cluster
  - `swui.skku.edu`
  - `swye.skku.edu`
  - `swji.skku.edu`
  - ssh port: 1398

- First time users :
  - ID: your student ID (e.g., 2020123456)
  - Use the default password (unless you already changed your password…)
    - "pw"+Student_ID (last 8 digits)
    - e.g., The initial password for 2020123456 is `pw20123456`
  - MUST change your password after the first login (Use **`yppasswd`** command)

Submission

- Clear the build directory before submission.
  - Do not leave any executable or object files in your submission
  - `make clean`

- Use the `submit` program
  - `~swe3005/bin/submit project_id path_to_submit`
  - If you want to submit the ‘project_1’ directory…
    - **`~swe3005/bin/submit proj1 project_1`**

```
Submitted Files for proj1:
File Name                                    File Size       Time
--------------------------------------------------------------------------------
proj1-2021123456-Sep.05.17.22.388048074        268490                  Thu Sep  5 17:22:49 2021
```

- Verify the submission
  - **`~swe3005/bin/check-submission proj1`**

Multiple Submissions

- You may submit multiple times before the deadline.

- You will be scored using the **last** submission.

Project 1 Due Date

- 2023 Oct. 13th, Friday, 23:59:59

- **No late submission**

Project 0

- A dummy project to test the submission process.
- Not mandatory. It will not affect your grade.
- However, it is highly recommended to try the submission process
- Familiarize yourself with the submission system. Incorrect submissions from proj1 onwards will not be scored.

Project 0 – What to submit

- Submit your source code (+Makefile) that prints the following two lines of text to `stdout` (i.e., console).

```
inst 0: 00220020 add x0, x1, x2
inst 1: 8d420020 lw x2, 32(x10)
```

- No input file.

- Use project id “proj0”
  - **`~swe3005/bin/submit proj0 your_project_0_directory`**

Project 0 Due Date

- 2023 Oct. 6th, Friday, 23:59:59

Homework Discussions

- If you have questions about the programming assignment…
- Recommended way of discussion:
  - Use the i-Campus discussion section
  - Visit the office hour
- Avoid sending direct messages to the TAs unless the question requires privacy.