1 Handwritten (35%)

2.8 (10%)

Translate the following RISC-V code to C. Assume that the variables f, g, h, i, and j are assigned to registers x5, x6, x7, x28, and x29, respectively. Assume that the base address of the arrays A and B are in registers x10 and x11, respectively.

```
addi x30, x10, 8
addi x31, x10, 0
sd x31, 0(x30)
ld x30, 0(x30)
add x5, x30, x31
```

2.9 (10%)

For each RISC-V instruction in Exercise 2.8, show the value of the opcode (op), source register (rs1), and destination register (rd) fields. For the I-type instructions, show the value of the immediate field, and for the R-type instructions, show the value of the second source register (rs2). For non U- and UJ-type instructions, show the funct3 field, and for R-type and S-type instructions, also show the funct7 field.

2.16 (15%)

Assume that we would like to expand the RISC-V register file to 128 registers and expand the instruction set to contain four times as many instructions.

2.16.1 (5%)

How would this affect the size of each of the bit fields in the R-type instructions?

2.16.2 (5%)

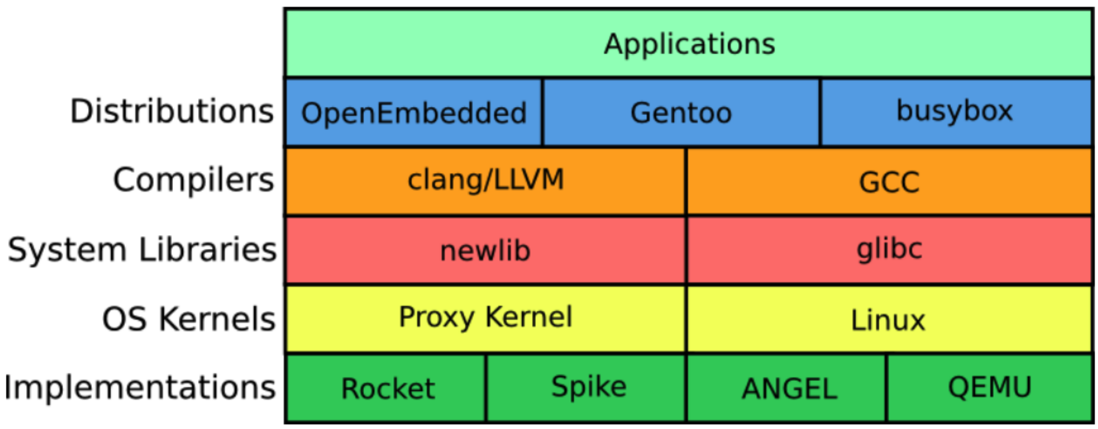
How would this affect the size of each of the bit fields in the I-type instructions?

2.16.3 (5%)

How could each of the two proposed changes decrease the size of a RISC-V assembly program? On the other hand, how could the proposed change increase the size of an RISC-V assembly program?

2 Programming (70%)

We will test the following problems on RISC-V software stack. The packages we use are spike, proxy kernel with newlib and gcc. And the riscv-isa we will use to test the program is RV64IMAFDC.



Before we start programming, we will use docker to set up our environment (Refer to the supplementary.pdf to see how to install docker and use it).

```
docker pull ntuca2020/hw2 // (4G)
docker run --name=test -it ntuca2020/hw2
cd /root
ls
```

The folder structure in the docker image looks like the following:

```
/root
    |-- Examples
    |   |-- Example1          // inline assembly test
    |   |-- Example2          // link with .s file test
    |   `-- Example3          // setup debug environment
    `-- Problems
        |-- fibonacci         // fibonacci number
        |   |-- Makefile
        |   |-- fibonacci.c
        |   `-- fibonacci.s
        |-- convert           // string to int
        |   |-- Makefile
        |   |-- convert.c
        |   `-- convert.s
        `-- matrix            // matrix multiplcation
            |-- Makefile
            |-- matrix.c
            `-- matrix.s
```

`make` and `make test` to try it out.
You only need to submit *.s file of each problem.

Fibonacci (20%)

Implement Fibonacci number in assembly. ($F_0 = 0, F_1 = 1$, output F_n, no overflow)

```
unsigned long long int fibonacci(int);
```

```
Input:                                        Output:
    70                                            190392490709135
```

Convert (20%)

- Convert an ASCII string containing a positive or negative integer decimal string to an integer. Input length is at most 15 bytes.
- '+' and '-' will appear optionally. And once they appear, they will only appear once in the first byte.
- If a non-digit character appears anywhere in the string, your program should stop and return -1.
- The return value will be printed out in 32bit-int format.

```
int convert(char *);
```

```
Input:                                        Output:
    +123                                          123
    +0000000123                                   123
    -123                                          -123
    -0000000321                                   -321
    2147483647                                    2147483647
    2147483648                                    -2147483648
    -2147483648                                   -2147483648
    -123123AAA                                    -1
    +123123AAA                                    -1
    123123AAA                                     -1
```

Matrix multiplication (15%)

Do matrix multiplication of size 128x128 with some additional operations.

```
for (int i = 0; i < SIZE; i++)
    for (int j = 0; j < SIZE; j++)
        for (int k = 0; k < SIZE; k++)
            C[i][j] = (C[i][j] + A[i][k] * B[k][j]) % 1024;
Elements in A and B are unsigned 16 bits numbers of range [0,1023]
```

We will score based on the cycle counts. You can use C as an initial attempt.

```
asm volatile ("rdcycle \%0" : "=r" (start));
// matrix multiplication
asm volatile ("rdcycle \%0" : "=r" (end));
```

Grading:

- Below 20,000,000 cycles (2%)
- Below 18,000,000 cycles (2%)
- Below 16,000,000 cycles (2%)
- Below 14,000,000 cycles (2%)
- Below 12,000,000 cycles (2%)
- Below 10,000,000 cycles (1%)
- Below 9,000,000 cycles (1%)
- Below 8,000,000 cycles (1%)
- Below 7,000,000 cycles (1%)
- Below 6,000,000 cycles (1%)

Report on matrix multiplication (15%)

- Briefly explain how you get below 6,000,000 cycles.
- Or you can answer the following questions:
  - How many cycles does it take by just doing the naive matrix multiplication?
  - How many load and store does it need (roughly) during the whole computation? (Considering the registers it use)
  - Is there any way to keep registers being used as much as possible before they're replaced? (Hint: blocking)
  - How many loop controls does it need (roughly) during the whole computation?

Submission

- All *.s file should be written assembly.
- Zip and upload your file to ceiba in the following format:

```
r09922028             <-- zip this folder
    |-- fibonacci.s
    |-- convert.s
    |-- matrix.s
    `-- report.pdf    // including handwritten part and report on matrix multiplication part
```

- Late submission within one-week: (Total score)*0.8
- Late submission within two-week: (Total score)*0.6
- Late submission over two-week: (Total score)*0
- If there's any question, please send email to r09922028@ntu.edu.tw.
- TA hour for this homework: