

Computer Architecture HW2

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2.8

```
addi x30, x10, 8 // x30 = A[1]'s addr
addi x31, x10, 0 // x31 = A[0]'s sddr
sd x31, 0(x30) // save A[0]'s addr in mem and extend to 64 bits
ld x30, 0(x30) // save A[0]'s addr to x30 and extend to 64 bits
add x5, x30, x31 // x5 = A[0]'s addr * 2
```

2.9

	Type	opcode, funct13, 7	rs1	rs2	rd	imm
addi x30, x10, 8	I-type	0x13, 0x0	10		30	8
addi x31, x10, 0	I-type	0x13, 0x0	10		31	0
sd x31, 0(x30)	S-type	0x23, 0x3	31	31		0
ld x30, 0(x30)	I-type	0x3, 0x3, -	30		30	0
add x5, x30, x31	R-type	0x33, 0x0, 0x0	30	31	5	

2.16

- expand the RISC-V register file to 128 registers:
register bit += 2
- expand the instruction set to contain four times as many instructions:
opcode len += 2

2.16.1

- opcode: 9 bits
- rd: 7 bits
- rs1: 7 bits
- rs2: 7 bits

2.16.2

- opcode: 9 bits
- rd: 7 bits
- rs: 7 bits

Report on matrix multiplication

Q: How many cycles does it take by just doing the naive matrix multiplication?

A:

12010245 cycles

Q: How many load and store does it need (roughly) during the whole computation?

A:

- **Naive**

array C[i][j]在外面兩層迴圈load進來之後，裡面的迴圈可以一直把C[i][j]放在register，總共用了 128×128 個(load + store), array B[k][j]因為每次都要跑最裡面的迴圈，無法放在register裡面，要用 $128 \times 128 \times 128$ 次(load)，array A[i][k]也因為每次都要跑最裡面的迴圈，無法放在register裡面，要用 $128 \times 128 \times 128$ 次(load)，總共約需要 $128 \times 128 \times 258 = 2^{22}$ 次 load + store

- **Blocking**

假設一個block的大小為 4×4 ，而用在array A上的register數為4個，array B上的register為 $4 \times 4 = 16$ 個，array C上的則為1個，則每次在計算一個block時，A需要load 16次，B也需要load 16次，C load+store是32次，總共為64次，而每個block交互相乘，會需要 $32 \times 32 \times 32$ 次iteration，所以總共為 $32 \times 32 \times 32 \times 64 = 2^{21}$ 次 load + store。

Q: Is there any way to keep registers being used as much as possible before they're replaced

A:

使用blocking的方法可以讓每一塊block中的記憶體位置在被load出來之後最大化他的使用次數後再被register丟棄，有效的減少load跟store造成的overhead。另外，也可以把loop展開，減少loop control的指令

Q: How many loop controls does it need (roughly) during the whole computation

A:

- **Naive**

由內而外的迴圈所需的loop controls為 $128 \times 128 \times 128 \times 2 + 128 \times 128 \times 2 + 128 \times 2 = 2^{22} + 2^{16} + 2^8$ 約等於 2^{22} 次

- **Blocking**

假設一個block的大小為 4×4 ，由於有5個loop，由外而內的迴圈所需的loop controls為 $32 \times 2 + 32 \times 32 \times 2 + 32 \times 32 \times 128 \times 2 + 32 \times 32 \times 128 \times 4 \times 2 + 32 \times 32 \times 128 \times 4 \times 4 \times 2$ 約等於 2^{22} 次