

## Project 1 Report

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### 1 Basic

The the updated sample program and its output are shown in the figures.

```
# file: example.asm

.data
string1: .ascii "Student ID: 522031910547\n"
string2: .ascii "Name: Fanyue Zhu\n"
.text
main:

li $v0, 4
la $a0, string1
syscall

li $v0, 4
la $a0, string2
syscall

li $v0, 10
syscall
```

Figure 1: modified sample program

```
Student ID: 522031910547
Name: Fanyue Zhu

— program is finished running —
```

Figure 2: Output of modified sample program

## 2 Task: Branch

### 2.1 Coding

The assembly code is shown below.

```

1  #file: branch.asm
2  .data
3  A: .word 10
4  B: .word 15
5  C: .word 6
6  Z: .word 0
7  .text
8  main:
9  lw $t5, A
10 lw $t6, B
11 lw $t7, C
12 lw $t8, Z
13 bgt $t5, $t6, L10
14 blt $t7, 5, L10
15 j L110
16 L10:
17 li $t8, 1
18 j L20
19 L110:
20 beq $t5, $t6, L11
21 li $t8, 3
22 j L20
23 L11:
24 li $t8, 2
25 L20:
26 beq $t8, 1, L3
27 j L4
28 L3:
29 li $t8, -1
30 j L7
31 L4:
32 beq $t8, 2, L5
33 j L6
34 L5:
35 li $t8, -2
36 j L7
37 L6:
38 li $t8, 0
39 L7:
40 sw $t8, Z
41

```

Figure 3: Code of branch task

### 2.2 Result

The running result of all cases are shown as below.

| Expt      | Address                        | Code                    | Basic |
|-----------|--------------------------------|-------------------------|-------|
| 0x0400000 | 0x3e011001 lui \$1, 4097       | 11: lv \$t5, A          |       |
| 0x0400004 | 0x8c2d0000 lv \$13, 0(\$1)     |                         |       |
| 0x0400008 | 0x3e011001 lui \$1, 4097       | 12: lv \$t6, B          |       |
| 0x040000c | 0x8c2d0004 lv \$14, 4(\$1)     |                         |       |
| 0x0400010 | 0x3e011001 lui \$1, 4097       | 13: lv \$t7, C          |       |
| 0x0400014 | 0x8c2f0008 lv \$15, 8(\$1)     |                         |       |
| 0x0400018 | 0x3e011001 lui \$1, 4097       | 14: lv \$t8, 2          |       |
| 0x040001c | 0x8c30000c lv \$24, 12(\$1)    |                         |       |
| 0x0400020 | 0x01e082a1c lv \$1, \$14, \$13 | 15: hgt \$t5, \$t6, L10 |       |
| 0x0400024 | 0x14200003 hne \$1, \$0, 3     |                         |       |
| 0x0400028 | 0x29e10005 alu \$1, \$15, 5    | 16: hlt \$t7, 5, L10    |       |
| 0x040002c | 0x14200001 hne \$1, \$0, 1     |                         |       |
| 0x0400030 | 0x0810000f j 0x040003e         | 17: j L110              |       |
| 0x0400034 | 0x24180001 addiu \$24, \$0, 1  | 19: li \$t8, 1          |       |
| 0x0400038 | 0x08100013 j 0x040004e         | 20: j L20               |       |
| 0x040003c | 0x11e00002 beq \$13, \$14, 2   | 22: beq \$t5, \$t6, L11 |       |
| 0x0400040 | 0x24180003 addiu \$24, \$0, 3  | 23: li \$t8, 3          |       |
| 0x0400044 | 0x08100013 j 0x040004e         | 24: j L20               |       |
| 0x0400048 | 0x24180002 addiu \$24, \$0, 2  | 26: li \$t8, 2          |       |
| 0x040004c | 0x20010001 addi \$1, \$0, 1    | 28: beq \$t8, 1, L3     |       |
| 0x0400050 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400054 | 0x0810001b j 0x0400060         | 29: j L4                |       |
| 0x0400058 | 0x2418ffff addiu \$24, \$0, -1 | 31: li \$t8, -1         |       |
| 0x040005c | 0x0810001a j 0x0400078         | 32: j L7                |       |
| 0x0400060 | 0x20010002 addi \$1, \$0, 2    | 34: beq \$t8, 2, L5     |       |
| 0x0400064 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400068 | 0x0810001a j 0x0400074         | 35: j L6                |       |
| 0x040006c | 0x2418ffff addiu \$24, \$0, -2 | 37: li \$t8, -2         |       |
| 0x0400070 | 0x0810001a j 0x0400078         | 38: j L7                |       |
| 0x0400074 | 0x24180000 addiu \$24, \$0, 0  | 40: li \$t8, 0          |       |
| 0x0400078 | 0x3e011001 lui \$1, 4097       | 42: sv \$t8, 2          |       |

| Address    | Value (+0) | Value (+4) | Value (+8) | Value (+c) |
|------------|------------|------------|------------|------------|
| 0x10010000 | 10         | 15         | 1          | -1         |

(a) Case1: A=10 B=15 C=1

| Expt      | Address                        | Code                    | Basic |
|-----------|--------------------------------|-------------------------|-------|
| 0x0400000 | 0x3e011001 lui \$1, 4097       | 11: lv \$t5, A          |       |
| 0x0400004 | 0x8c2d0000 lv \$13, 0(\$1)     |                         |       |
| 0x0400008 | 0x3e011001 lui \$1, 4097       | 12: lv \$t6, B          |       |
| 0x040000c | 0x8c2d0004 lv \$14, 4(\$1)     |                         |       |
| 0x0400010 | 0x3e011001 lui \$1, 4097       | 13: lv \$t7, C          |       |
| 0x0400014 | 0x8c2f0008 lv \$15, 8(\$1)     |                         |       |
| 0x0400018 | 0x3e011001 lui \$1, 4097       | 14: lv \$t8, 2          |       |
| 0x040001c | 0x8c30000c lv \$24, 12(\$1)    |                         |       |
| 0x0400020 | 0x01e082a1c lv \$1, \$14, \$13 | 15: hgt \$t5, \$t6, L10 |       |
| 0x0400024 | 0x14200003 hne \$1, \$0, 3     |                         |       |
| 0x0400028 | 0x29e10005 alu \$1, \$15, 5    | 16: hlt \$t7, 5, L10    |       |
| 0x040002c | 0x14200001 hne \$1, \$0, 1     |                         |       |
| 0x0400030 | 0x0810000f j 0x040003e         | 17: j L110              |       |
| 0x0400034 | 0x24180001 addiu \$24, \$0, 1  | 19: li \$t8, 1          |       |
| 0x0400038 | 0x08100013 j 0x040004e         | 20: j L20               |       |
| 0x040003c | 0x11e00002 beq \$13, \$14, 2   | 22: beq \$t5, \$t6, L11 |       |
| 0x0400040 | 0x24180003 addiu \$24, \$0, 3  | 23: li \$t8, 3          |       |
| 0x0400044 | 0x08100013 j 0x040004e         | 24: j L20               |       |
| 0x0400048 | 0x24180002 addiu \$24, \$0, 2  | 26: li \$t8, 2          |       |
| 0x040004c | 0x20010001 addi \$1, \$0, 1    | 28: beq \$t8, 1, L3     |       |
| 0x0400050 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400054 | 0x0810001b j 0x0400060         | 29: j L4                |       |
| 0x0400058 | 0x2418ffff addiu \$24, \$0, -1 | 31: li \$t8, -1         |       |
| 0x040005c | 0x0810001a j 0x0400078         | 32: j L7                |       |
| 0x0400060 | 0x20010002 addi \$1, \$0, 2    | 34: beq \$t8, 2, L5     |       |
| 0x0400064 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400068 | 0x0810001a j 0x0400074         | 35: j L6                |       |
| 0x040006c | 0x2418ffff addiu \$24, \$0, -2 | 37: li \$t8, -2         |       |
| 0x0400070 | 0x0810001a j 0x0400078         | 38: j L7                |       |
| 0x0400074 | 0x24180000 addiu \$24, \$0, 0  | 40: li \$t8, 0          |       |
| 0x0400078 | 0x3e011001 lui \$1, 4097       | 42: sv \$t8, 2          |       |

| Address    | Value (+0) | Value (+4) | Value (+8) | Value (+c) |
|------------|------------|------------|------------|------------|
| 0x10010000 | 15         | 10         | 6          | -1         |

(b) Case2: A=15 B=10 C=6

| Expt      | Address                        | Code                    | Basic |
|-----------|--------------------------------|-------------------------|-------|
| 0x0400000 | 0x3e011001 lui \$1, 4097       | 11: lv \$t5, A          |       |
| 0x0400004 | 0x8c2d0000 lv \$13, 0(\$1)     |                         |       |
| 0x0400008 | 0x3e011001 lui \$1, 4097       | 12: lv \$t6, B          |       |
| 0x040000c | 0x8c2d0004 lv \$14, 4(\$1)     |                         |       |
| 0x0400010 | 0x3e011001 lui \$1, 4097       | 13: lv \$t7, C          |       |
| 0x0400014 | 0x8c2f0008 lv \$15, 8(\$1)     |                         |       |
| 0x0400018 | 0x3e011001 lui \$1, 4097       | 14: lv \$t8, 2          |       |
| 0x040001c | 0x8c30000c lv \$24, 12(\$1)    |                         |       |
| 0x0400020 | 0x01e082a1c lv \$1, \$14, \$13 | 15: hgt \$t5, \$t6, L10 |       |
| 0x0400024 | 0x14200003 hne \$1, \$0, 3     |                         |       |
| 0x0400028 | 0x29e10005 alu \$1, \$15, 5    | 16: hlt \$t7, 5, L10    |       |
| 0x040002c | 0x14200001 hne \$1, \$0, 1     |                         |       |
| 0x0400030 | 0x0810000f j 0x040003e         | 17: j L110              |       |
| 0x0400034 | 0x24180001 addiu \$24, \$0, 1  | 19: li \$t8, 1          |       |
| 0x0400038 | 0x08100013 j 0x040004e         | 20: j L20               |       |
| 0x040003c | 0x11e00002 beq \$13, \$14, 2   | 22: beq \$t5, \$t6, L11 |       |
| 0x0400040 | 0x24180003 addiu \$24, \$0, 3  | 23: li \$t8, 3          |       |
| 0x0400044 | 0x08100013 j 0x040004e         | 24: j L20               |       |
| 0x0400048 | 0x24180002 addiu \$24, \$0, 2  | 26: li \$t8, 2          |       |
| 0x040004c | 0x20010001 addi \$1, \$0, 1    | 28: beq \$t8, 1, L3     |       |
| 0x0400050 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400054 | 0x0810001b j 0x0400060         | 29: j L4                |       |
| 0x0400058 | 0x2418ffff addiu \$24, \$0, -1 | 31: li \$t8, -1         |       |
| 0x040005c | 0x0810001a j 0x0400078         | 32: j L7                |       |
| 0x0400060 | 0x20010002 addi \$1, \$0, 2    | 34: beq \$t8, 2, L5     |       |
| 0x0400064 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400068 | 0x0810001a j 0x0400074         | 35: j L6                |       |
| 0x040006c | 0x2418ffff addiu \$24, \$0, -2 | 37: li \$t8, -2         |       |
| 0x0400070 | 0x0810001a j 0x0400078         | 38: j L7                |       |
| 0x0400074 | 0x24180000 addiu \$24, \$0, 0  | 40: li \$t8, 0          |       |
| 0x0400078 | 0x3e011001 lui \$1, 4097       | 42: sv \$t8, 2          |       |

| Address    | Value (+0) | Value (+4) | Value (+8) | Value (+c) |
|------------|------------|------------|------------|------------|
| 0x10010000 | 15         | 15         | 6          | -2         |

(c) Case3: A=15 B=15 C=6

| Expt      | Address                        | Code                    | Basic |
|-----------|--------------------------------|-------------------------|-------|
| 0x0400000 | 0x3e011001 lui \$1, 4097       | 11: lv \$t5, A          |       |
| 0x0400004 | 0x8c2d0000 lv \$13, 0(\$1)     |                         |       |
| 0x0400008 | 0x3e011001 lui \$1, 4097       | 12: lv \$t6, B          |       |
| 0x040000c | 0x8c2d0004 lv \$14, 4(\$1)     |                         |       |
| 0x0400010 | 0x3e011001 lui \$1, 4097       | 13: lv \$t7, C          |       |
| 0x0400014 | 0x8c2f0008 lv \$15, 8(\$1)     |                         |       |
| 0x0400018 | 0x3e011001 lui \$1, 4097       | 14: lv \$t8, 2          |       |
| 0x040001c | 0x8c30000c lv \$24, 12(\$1)    |                         |       |
| 0x0400020 | 0x01e082a1c lv \$1, \$14, \$13 | 15: hgt \$t5, \$t6, L10 |       |
| 0x0400024 | 0x14200003 hne \$1, \$0, 3     |                         |       |
| 0x0400028 | 0x29e10005 alu \$1, \$15, 5    | 16: hlt \$t7, 5, L10    |       |
| 0x040002c | 0x14200001 hne \$1, \$0, 1     |                         |       |
| 0x0400030 | 0x0810000f j 0x040003e         | 17: j L110              |       |
| 0x0400034 | 0x24180001 addiu \$24, \$0, 1  | 19: li \$t8, 1          |       |
| 0x0400038 | 0x08100013 j 0x040004e         | 20: j L20               |       |
| 0x040003c | 0x11e00002 beq \$13, \$14, 2   | 22: beq \$t5, \$t6, L11 |       |
| 0x0400040 | 0x24180003 addiu \$24, \$0, 3  | 23: li \$t8, 3          |       |
| 0x0400044 | 0x08100013 j 0x040004e         | 24: j L20               |       |
| 0x0400048 | 0x24180002 addiu \$24, \$0, 2  | 26: li \$t8, 2          |       |
| 0x040004c | 0x20010001 addi \$1, \$0, 1    | 28: beq \$t8, 1, L3     |       |
| 0x0400050 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400054 | 0x0810001b j 0x0400060         | 29: j L4                |       |
| 0x0400058 | 0x2418ffff addiu \$24, \$0, -1 | 31: li \$t8, -1         |       |
| 0x040005c | 0x0810001a j 0x0400078         | 32: j L7                |       |
| 0x0400060 | 0x20010002 addi \$1, \$0, 2    | 34: beq \$t8, 2, L5     |       |
| 0x0400064 | 0x10380001 beq \$1, \$24, 1    |                         |       |
| 0x0400068 | 0x0810001a j 0x0400074         | 35: j L6                |       |
| 0x040006c | 0x2418ffff addiu \$24, \$0, -2 | 37: li \$t8, -2         |       |
| 0x0400070 | 0x0810001a j 0x0400078         | 38: j L7                |       |
| 0x0400074 | 0x24180000 addiu \$24, \$0, 0  | 40: li \$t8, 0          |       |
| 0x0400078 | 0x3e011001 lui \$1, 4097       | 42: sv \$t8, 2          |       |

| Address    | Value (+0) | Value (+4) | Value (+8) | Value (+c) |
|------------|------------|------------|------------|------------|
| 0x10010000 | 10         | 15         | 6          | 0          |

(d) Case4: A=10 B=15 C=6

Figure 4: Result of branch task

## 2.3 In-depth Investigation

As the figures shown below, in **slt \$t6 at \$t5**, PC, Instruction Memory, Registers(read port and write port), ALU and PC+4 adder are used. And in **bne \$zero at 3**, since this branch statement satisfies the jump condition, PC, Instruction Memory, Registers(read and write port), ALU, PC+4 adder and Branch adder are used.

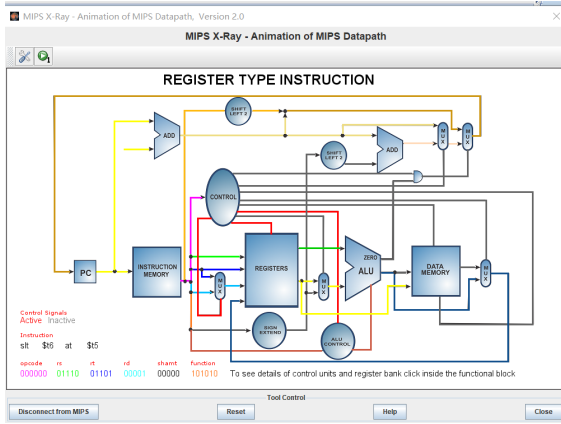
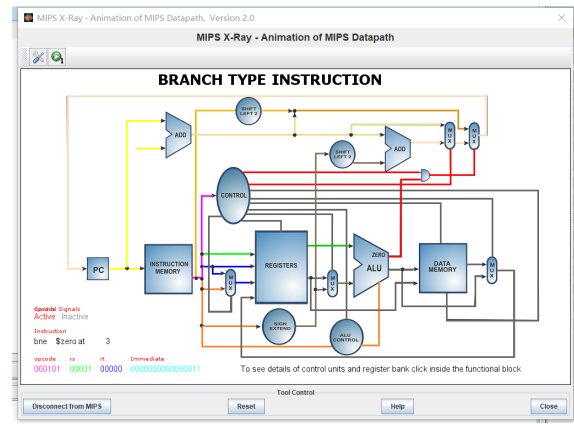
(a) **slt \$t6 at \$t5**(b) **bne \$zero at 3**

Figure 5: MIP X-Ray

### 3 Task: Loop

#### 3.1 Coding

The assembly code is shown as below.

```
1  #file:loop.asm
2  .data
3  Z:.word 99
4  i:.word 0
5  .text
6  main:
7  lw $t1, Z
8  lw $t2, i
9  Loop1:
10 add $t2, $t2, 1
11 blt $t2, $t1, Loop1
12
13 bgt $t2, 0, Loop2
14 Loop2:
15 add $t1, $t2, $t1
16 add $t2, $t2, -1
17 bgt $t2, 0, Loop2
18
19 sw $t1, Z
20 sw $t2, i
21
```

Figure 6: Code of loop task

### 3.2 Result

The running result of both cases are shown as below.

| Text Segment             |            |                                |                           |
|--------------------------|------------|--------------------------------|---------------------------|
| Bkpt                     | Address    | Code                           | Basic                     |
| <input type="checkbox"/> | 0x00400000 | 0x3e011001 lui \$1, 4097       | 7: lw \$t1, Z             |
| <input type="checkbox"/> | 0x00400004 | 0x8c290000 lw \$9, 0(\$1)      |                           |
| <input type="checkbox"/> | 0x00400008 | 0x3e011001 lui \$1, 4097       | 8: lw \$t2, i             |
| <input type="checkbox"/> | 0x0040000c | 0x8c2a0004 lw \$10, 4(\$1)     |                           |
| <input type="checkbox"/> | 0x00400010 | 0x214a0001 addi \$10, \$10, 1  | 10: add \$t2, \$t2, 1     |
| <input type="checkbox"/> | 0x00400014 | 0x0149082a slt \$1, \$10, \$9  | 11: blt \$t2, \$t1, Loop1 |
| <input type="checkbox"/> | 0x00400018 | 0x1420ffff bne \$1, \$0, -3    |                           |
| <input type="checkbox"/> | 0x0040001c | 0x20010000 addi \$1, \$0, 0    | 13: bgt \$t2, 0, Loop2    |
| <input type="checkbox"/> | 0x00400020 | 0x002a082a slt \$1, \$1, \$10  |                           |
| <input type="checkbox"/> | 0x00400024 | 0x14200000 bne \$1, \$0, 0     |                           |
| <input type="checkbox"/> | 0x00400028 | 0x01494820 add \$9, \$10, \$9  | 15: add \$t1, \$t2, \$t1  |
| <input type="checkbox"/> | 0x0040002c | 0x214a0001 addi \$10, \$10, -1 | 16: add \$t2, \$t2, -1    |
| <input type="checkbox"/> | 0x00400030 | 0x20010000 addi \$1, \$0, 0    | 17: bgt \$t2, 0, Loop2    |
| <input type="checkbox"/> | 0x00400034 | 0x002a082a slt \$1, \$1, \$10  |                           |
| <input type="checkbox"/> | 0x00400038 | 0x1420ffff bne \$1, \$0, -5    |                           |
| <input type="checkbox"/> | 0x0040003c | 0x3e011001 lui \$1, 4097       | 19: sw \$t1, Z            |
| <input type="checkbox"/> | 0x00400040 | 0x8c290000 sw \$9, 0(\$1)      |                           |
| <input type="checkbox"/> | 0x00400044 | 0x3e011001 lui \$1, 4097       | 20: sw \$t2, i            |
| <input type="checkbox"/> | 0x00400048 | 0x8c2a0004 sw \$10, 4(\$1)     |                           |

| Data Segment |            |            |            |
|--------------|------------|------------|------------|
| Address      | Value (+0) | Value (+4) | Value (+8) |
| 0x10010000   | 5150       | 0          | 0          |

(a) Case1: Z=100 i=0

| Text Segment             |            |                                |                           |
|--------------------------|------------|--------------------------------|---------------------------|
| Bkpt                     | Address    | Code                           | Basic                     |
| <input type="checkbox"/> | 0x00400000 | 0x3e011001 lui \$1, 4097       | 7: lw \$t1, Z             |
| <input type="checkbox"/> | 0x00400004 | 0x8c290000 lw \$9, 0(\$1)      |                           |
| <input type="checkbox"/> | 0x00400008 | 0x3e011001 lui \$1, 4097       | 8: lw \$t2, i             |
| <input type="checkbox"/> | 0x0040000c | 0x8c2a0004 lw \$10, 4(\$1)     |                           |
| <input type="checkbox"/> | 0x00400010 | 0x214a0001 addi \$10, \$10, 1  | 10: add \$t2, \$t2, 1     |
| <input type="checkbox"/> | 0x00400014 | 0x0149082a slt \$1, \$10, \$9  | 11: blt \$t2, \$t1, Loop1 |
| <input type="checkbox"/> | 0x00400018 | 0x1420ffff bne \$1, \$0, -3    |                           |
| <input type="checkbox"/> | 0x0040001c | 0x20010000 addi \$1, \$0, 0    | 13: bgt \$t2, 0, Loop2    |
| <input type="checkbox"/> | 0x00400020 | 0x002a082a slt \$1, \$1, \$10  |                           |
| <input type="checkbox"/> | 0x00400024 | 0x14200000 bne \$1, \$0, 0     |                           |
| <input type="checkbox"/> | 0x00400028 | 0x01494820 add \$9, \$10, \$9  | 15: add \$t1, \$t2, \$t1  |
| <input type="checkbox"/> | 0x0040002c | 0x214a0001 addi \$10, \$10, -1 | 16: add \$t2, \$t2, -1    |
| <input type="checkbox"/> | 0x00400030 | 0x20010000 addi \$1, \$0, 0    | 17: bgt \$t2, 0, Loop2    |
| <input type="checkbox"/> | 0x00400034 | 0x002a082a slt \$1, \$1, \$10  |                           |
| <input type="checkbox"/> | 0x00400038 | 0x1420ffff bne \$1, \$0, -5    |                           |
| <input type="checkbox"/> | 0x0040003c | 0x3e011001 lui \$1, 4097       | 19: sw \$t1, Z            |
| <input type="checkbox"/> | 0x00400040 | 0x8c290000 sw \$9, 0(\$1)      |                           |
| <input type="checkbox"/> | 0x00400044 | 0x3e011001 lui \$1, 4097       | 20: sw \$t2, i            |
| <input type="checkbox"/> | 0x00400048 | 0x8c2a0004 sw \$10, 4(\$1)     |                           |

| Data Segment |            |            |            |
|--------------|------------|------------|------------|
| Address      | Value (+0) | Value (+4) | Value (+8) |
| 0x10010000   | 5049       | 0          | 0          |

(b) Case2: Z=99 i=0

Figure 7: Result of branch task

### 3.3 Optimization

Simplify the number of calculations by unrolling the loop into groups of 16 and recording  $16*i$  with a new variable  $t$  for each group. Finally, the last group that is less than 16 is solved by traversing it. This reduces the number of calculations for each case to less than 400.

The numbers of instructions required for program execution are shown as below.

| Data Segment |            |            |            |
|--------------|------------|------------|------------|
| Address      | Value (+0) | Value (+4) | Value (+8) |
| 0x10010000   | 100        | 0          | 0          |
| 0x10010004   | 0          | 0          | 0          |
| 0x10010008   | 0          | 0          | 0          |
| 0x1001000c   | 0          | 0          | 0          |
| 0x10010010   | 0          | 0          | 0          |
| 0x10010014   | 0          | 0          | 0          |
| 0x10010018   | 0          | 0          | 0          |
| 0x1001001c   | 0          | 0          | 0          |
| 0x10010020   | 0          | 0          | 0          |
| 0x10010024   | 0          | 0          | 0          |
| 0x10010028   | 0          | 0          | 0          |
| 0x1001002c   | 0          | 0          | 0          |
| 0x10010030   | 0          | 0          | 0          |
| 0x10010034   | 0          | 0          | 0          |
| 0x10010038   | 0          | 0          | 0          |
| 0x1001003c   | 0          | 0          | 0          |
| 0x10010040   | 0          | 0          | 0          |
| 0x10010044   | 0          | 0          | 0          |

(a) Case1: Z=100 i=0

| Data Segment |            |            |            |
|--------------|------------|------------|------------|
| Address      | Value (+0) | Value (+4) | Value (+8) |
| 0x10010000   | 99         | 0          | 0          |
| 0x10010004   | 0          | 0          | 0          |
| 0x10010008   | 0          | 0          | 0          |
| 0x1001000c   | 0          | 0          | 0          |
| 0x10010010   | 0          | 0          | 0          |
| 0x10010014   | 0          | 0          | 0          |
| 0x10010018   | 0          | 0          | 0          |
| 0x1001001c   | 0          | 0          | 0          |
| 0x10010020   | 0          | 0          | 0          |
| 0x10010024   | 0          | 0          | 0          |
| 0x10010028   | 0          | 0          | 0          |
| 0x1001002c   | 0          | 0          | 0          |
| 0x10010030   | 0          | 0          | 0          |
| 0x10010034   | 0          | 0          | 0          |
| 0x10010038   | 0          | 0          | 0          |
| 0x1001003c   | 0          | 0          | 0          |
| 0x10010040   | 0          | 0          | 0          |

(b) Case2: Z=99 i=0

Figure 8: Optimization for the number of instructions