MIPS Assembler 简介

1、所支持的指令：

```
R
add      rd, rs, rt   10 0000 0x20
addu     rd, rs, rt   10 0001 0x21
and      rd, rs, rt   10 0100 0x24
break                 00 1101 0x0D
div          rs, rt   01 1010 0x1A
divu         rs, rt   01 1011 0x1B
jalr     rd, rs       00 1001 0x09
jr           rs       00 1000 0x08
mfhi     rd           01 0000 0x10
mflo     rd           01 0010 0x12
mthi         rs       01 0001 0x11
mtlo         rs       01 0011 0x13
mult         rs, rt   01 1000 0x18
multu        rs, rt   01 1001 0x19
nor      rd, rs, rt   10 0111 0x27
or       rd, rs, rt   10 0101 0x25
sll      rd, rt, sa   00 0000 0x00
sllv     rd, rt, rs   00 0100 0x04
slt      rd, rs, rt   10 1010 0x2A
sltu     rd, rs, rt   10 1011 0x2B
sra      rd, rt, sa   00 0011 0x03
srav     rd, rt, rs   00 0111 0x07
srl      rd, rt, sa   00 0010 0x02
srlv     rd, rt, rs   00 0110 0x06
sub      rd, rs, rt   10 0010 0x22
subu     rd, rs, rt   10 0011 0x23
syscall               00 1100 0x0C
xor      rd, rs, rt   10 0110 0x26

I
addi     rt, rs, immediate   00 1000 0x08
addiu    rt, rs, immediate   00 1001 0x09
andi     rt, rs, immediate   00 1100 0x0C
beq      rs, rt, label       00 0100 0x04
bgez     rs, label           00 0001 0x01   rt = 00001
bgtz     rs, label           00 0111 0x07   rt = 00000
blez     rs, label           00 0110 0x06   rt = 00000
bltz     rs, label           00 0001 0x01   rt = 00000
```

```
bne     rs, rt, label         00 0101 0x05
lb      rt, immediate(rs)     10 0000 0x20
lbu     rt, immediate(rs)     10 0100 0x24
lh      rt, immediate(rs)     10 0001 0x21
lhu     rt, immediate(rs)     10 0101 0x25
lui     rt, immediate         00 1111 0x0F
lw      rt, immediate(rs)     10 0011 0x23
lwc1    rt, immediate(rs)     11 0001 0x31
ori     rt, rs, immediate     00 1101 0x0D
sb      rt, immediate(rs)     10 1000 0x28
slti    rt, rs, immediate     00 1010 0x0A
sltiu   rt, rs, immediate     00 1011 0x0B
sh      rt, immediate(rs)     10 1001 0x29
sw      rt, immediate(rs)     10 1011 0x2B
swc1    rt, immediate(rs)     11 1001 0x39
xori    rt, rs, immediate     00 1110 0x0E


J
j   label   000010  coded address of label 0x02
jal label   000011  coded address of label 0x03
```

其中，syscall 的更进一步实现尚不支持，但是支持将这一指令翻译为机器码。

除此之外，本汇编器支持标号，有较完备的错误提示系统。

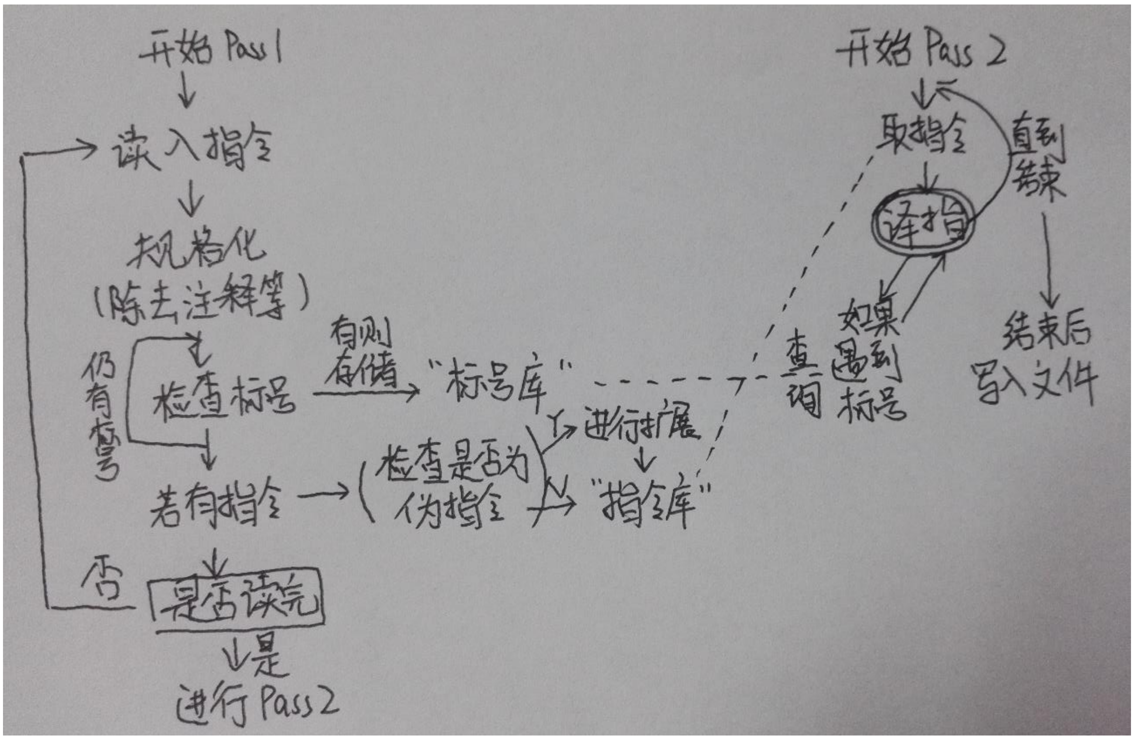
目前除部分指令外尚不支持的功能有：表达式以及伪指令，不过在本程序的源代码中为伪指令的实现以及表达式的支持预留了接口，且可以方便的增加指令，扩展程序支持的指令集。

要使本程序支持伪指令，只需写 translate.c 文件中的 `AsmCode getRealInstrLine(int32 psedoSerNum, uint32 lineNum)` 函数并将 basic.h 文件中的宏定义 `PSEDO_MODE` 定义为 1 即可；要使本程序支持表达式，只需对 translate.c 文件中的 `AsmCode clearInBracSpace(AsmCode line)` 函数进行加强，使得在‘($’子串前留出空格，并重写 assmebler.c 文件中的 `int32 getImme(char* labelOrImme, AsmRecorder* asmRecorderPtr)` 函数，随后对 `void genMachineCode(AsmRecorder* asmRecorderPtr)` 函数的静态变量 delimiters 进

行修改即可；要增加指令，只需在 translate.h 文件的宏定义中增加相应的项并修改对应的宏定义 XX_NUM（实际上不修改并不会引发错误），随后在 assmebler.c 文件中的 `void genMachineCode(AsmRecorder* asmRecorderPtr)` 函数中增添相应的项即可，若增加的是伪指令，则应去修改 translate.c 文件中的 `AsmCode getRealInstrLine(int32 psedoSerNum, uint32 lineNum)` 函数。

2、程序框图：

因为需要处理标号，本程序采取两遍扫描，第一遍记录标号并读取指令，第二遍翻译指令为机器码，当指令中存在标号的时候则去查询标号并进行相应的计算，具体流程如下（以正常流程为例）：



其中指令到机器码的翻译是编译的关键一步，以下为伪代码叙述（以目前所支持的指令为例，依然不考虑出错情况）：

```
void genMachineCode(AsmRecorder* asmRecorderPtr)
{
```

```
#define GET_REGISTER(rx) \
        registerName = strtok(NULL, delimiters); \
        rx = getRegisterSerNum(registerName);
#define CHECKEND
#define GET_LABELORINNE \
        labelOrImme = strtok(NULL, delimiters); \
        immeOrOffset = getImmeOrOffset(labelOrImme, asmRecorderPtr);
#define GET_IMME \
        labelOrImme = strtok(NULL, delimiters); \
        immeOrOffset = getImme(labelOrImme, asmRecorderPtr);

    static char* delimiters = " \t,()";
    char* instr = asmRecorderPtr->instruction;
    Mnemonic mnemonic = strtok(instr, delimiters);
    int32 mnemonicSerNum = getMnemonicSerNum(mnemonic);
    char *registerName;
    if (mnemonicSerNum < R_NUM)
    {
        uint32 rd, rs, rt;
        int32 schamt;
        rd = rs = rt = schamt = 0x0;
        asmRecorderPtr->code = getFuncOrOpcode(mnemonicSerNum);
        switch (asmRecorderPtr->code)
        {
        case 0x20:
        case 0x21:
        case 0x24:
        case 0x27:
        case 0x25:
        case 0x2A:
        case 0x2B:
        case 0x22:
        case 0x23:
        case 0x26: // dst
            GET_REGISTER(rd)
            GET_REGISTER(rs)
            GET_REGISTER(rt)
            CHECKEND
            break;
        case 0x00:
        case 0x03:
        case 0x02: // dta
            GET_REGISTER(rd)
            GET_REGISTER(rt)
```

```
            char* schamtStr = strtok(NULL, delimiters);
            schamt = getImme(schamtStr, asmRecorderPtr);
            schamt &= 0x1F;
            CHECKEND
            break;
        case 0x04:
        case 0x07:
        case 0x06: // dts
            GET_REGISTER(rd)
            GET_REGISTER(rt)
            GET_REGISTER(rs)
            CHECKEND
            break;
        case 0x09: // ds
            GET_REGISTER(rd)
            GET_REGISTER(rs)
            CHECKEND
            break;
        case 0x1A:
        case 0x1B:
        case 0x18:
        case 0x19: // st
            GET_REGISTER(rs)
            GET_REGISTER(rt)
            CHECKEND
            break;
        case 0x08:
        case 0x11:
        case 0x13: // s
            GET_REGISTER(rs)
            CHECKEND
            break;
        case 0x10:
        case 0x12: // d
            GET_REGISTER(rd)
            CHECKEND
            break;
        case 0x0D:
        case 0x0C: // 0
            CHECKEND
            break;
        }
        asmRecorderPtr->code |= (rs << 21);
        asmRecorderPtr->code |= (rt << 16);
```

```
        asmRecorderPtr->code |= (rd << 11);
        asmRecorderPtr->code |= (schamt << 6);
        return;
    }
    else
    {
        uint32 rt, rs;
        char* labelOrImme;
        int32 immeOrOffset;
        rt = rs = immeOrOffset = 0x0;
        asmRecorderPtr->code = getFuncOrOpcode(mnemonicSerNum) <<
26;
        switch (asmRecorderPtr->code)
        {
        case 0x02 << 26:
        case 0x03 << 26: // J
            GET_LABELORINNE
            CHECKEND
            immeOrOffset &= 0x3FFFFFF;
            asmRecorderPtr->code |= immeOrOffset;
            return;
        case 0x08 << 26:
        case 0x09 << 26:
        case 0x0C << 26:
        case 0x0D << 26:
        case 0x0A << 26:
        case 0x0B << 26:
        case 0x0E << 26: // rt, rs, immediate
            GET_REGISTER(rt)
            GET_REGISTER(rs)
            GET_IMME
            CHECKEND
            immeOrOffset &= 0xFFFF;
            break;
        case 0x04 << 26:
        case 0x05 << 26: // rs, rt, label
            GET_REGISTER(rs)
            GET_REGISTER(rt)
            GET_LABELORINNE
            CHECKEND
            immeOrOffset &= 0xFFFF;
            break;
        case 0x01 << 26:
            if (strcmp(mnemonic, "bgez") == 0)
```

```
            {
                rt = 0x1;
            }
        case 0x07 << 26:
        case 0x06 << 26: // rs, label
            GET_REGISTER(rs)
            GET_LABELORINNE
            CHECKEND
            immeOrOffset &= 0xFFFF;
            break;
        case 0x20 << 26:
        case 0x24 << 26:
        case 0x21 << 26:
        case 0x25 << 26:
        case 0x23 << 26:
        case 0x31 << 26:
        case 0x28 << 26:
        case 0x29 << 26:
        case 0x2B << 26:
        case 0x39 << 26: // rt, immediate(rs)
            GET_REGISTER(rt)
            GET_IMME
            GET_REGISTER(rs)
            CHECKEND
            immeOrOffset &= 0xFFFF;
            break;
        case 0x0F << 26: // rt, immediate
            GET_REGISTER(rt)
            GET_IMME
            CHECKEND
            immeOrOffset &= 0xFFFF;
            break;
        }
        asmRecorderPtr->code |= immeOrOffset;
        asmRecorderPtr->code |= (rt << 16);
        asmRecorderPtr->code |= (rs << 21);
        return;
    }
#undef GET_REGISTER
#undef CHECKEND
#undef GET_SYMBOLORIMME
#undef GET_IMME
}
```

3、使用方法：

在命令行中不带参数直接执行程序或执行程序参数有误时，即可获得使用方法，如下：

```
                                >asmer.exe
Usage:
  asmer.exe <filename1> <filename2>
  filename1: the name/address of the input file.
  filename2: the name/address of the output file.
  e.g. asmer.exe input.asm output.bin
                    By: Haotian_Ren 3150104714
```

本程序中的错误信息目前共有以下 16 种：

1	Mallocating failed.
2	Unable to open file %s
3	Unable to create file %s
4	Line %d: Too many symbols.
5	Line %d: Symbol '%s' has been defined in line %d.
6	Line %d: Wrong mnemonic.
7	Line %d: The line is too long.
8	Line %d: Brackets not matched.
9	Line %d: Wrong register name '%s'.
10	Line %d: Wrong instruction format.
11	Line %d: Unsupported mnemonic.
12	Line %d: Symbol '%s' is not defined.
13	Line %d: '%s' is not an integer.
14	Line %d: Wrong symbol format.
15	Line %d: Symbol is too long.
16	Too many lines.

4、实例分析

在此列举一例实例，以下仅进行运行，不讨论汇编代码具体含义，汇编代码如下（test.asm）：

```
# Test function over here:
    addiu $a0, $0, -25       # Load base addr
    addiu $a1, $0, 10        # Load length
    jal MYFUNc           # Call function
    li $v0, 0xABCDE
```

```
6
7   myFunc: addiu $t0, $0, 0        # Init counter
8   startLoop:  beq $t0, $a1, endLoop       # Check if end condition reached
9       addu $t1, $a0, $t0      # Calculate offset address
10      lb $t2, 0($t1)      # Load value
11
12      lbu $t3, -3($s2)
13      addiu $t2, $t2, 1       # Increment by one
14      or $a0, $a1, $a3
15      li $t0, 3
16      slt $a2, $t1, $t0
17      sltu $a2, $t1, $t0
18      sll $t3, $t2, 31
19
20  random: ori $t3, $t2, 291
21      lui $t3, 532
22      sb $t2, 0($t1)
23      sw $t2, -32768($t1)
24      lw $t3, 32767($t1)
25      blt $t3, $t2, myFunc
26
27      addiu $t1, $t1, 1       # Increment counter
28      j startLoop
29  endLoop:    jr $ra
30      bne $t3, $a0, myFunc
31
```

执行结果如下图所示：

```
>asmer.exe test.asm testout.bin
Error: Line 5: Unsupported mnemonic.
```

我们可以注释掉第 5、15、25 行不支持的三个指令，则程序的运行结果如下图所示：

```
>asmer.exe test.asm testout.bin
Done!
```

程序输出“Done!”代表已经汇编成功，我们可以打开生成的二进制文件查看其中的内容，如下所示：

```
e7ff 0424 0a00 0524 0100 000c 0000 0824
1000 0511 2148 8800 0000 2a81 fdff 4b92
0100 4a25 2520 a700 2a30 2801 2b30 2801
c05f 0a00 2301 4b35 1402 0b3c 0000 2aa1
```

```
0080 2aad ff7f 2b8d 0100 2925 f1ff ff0b
0800 e003 eeff 6415
```

对照后我们亦可得出进行汇编过程所使用机器，即 asmer.exe 所运行机器使用小端存储的方式存储数据。

我们最终所使用的测试 MIPS 汇编代码如下：

```
# Test function over here:
    addiu $a0, $0, -25      # Load base addr
    addiu $a1, $0, 10       # Load length
    jal MYFUNc          # Call function
    #li $v0, 0xABCDE

myFunc: addiu $t0, $0, 0        # Init counter
startLoop:  beq $t0, $a1, endLoop       # Check if end condition reached
    addu $t1, $a0, $t0      # Calculate offset address
    lb $t2, 0($t1)      # Load value

    lbu $t3, -3($s2)
    addiu $t2, $t2, 1       # Increment by one
    or $a0, $a1, $a3
    #li $t0, 3
    slt $a2, $t1, $t0
    sltu $a2, $t1, $t0
    sll $t3, $t2, 31

random: ori $t3, $t2, 291
    lui $t3, 532
    sb $t2, 0($t1)
    sw $t2, -32768($t1)
    lw $t3, 32767($t1)
    #blt $t3, $t2, myFunc

    addiu $t1, $t1, 1       # Increment counter
    j startLoop
endLoop:    jr $ra
    bne $t3, $a0, myFunc
```

MIPS Disassembler 简介

1、所支持的反汇编指令：

```
R
add     rd, rs, rt  10 0000 0x20
addu    rd, rs, rt  10 0001 0x21
and     rd, rs, rt  10 0100 0x24
break               00 1101 0x0D
div         rs, rt  01 1010 0x1A
divu        rs, rt  01 1011 0x1B
jalr    rd, rs      00 1001 0x09
jr          rs      00 1000 0x08
mfhi    rd          01 0000 0x10
mflo    rd          01 0010 0x12
mthi        rs      01 0001 0x11
mtlo        rs      01 0011 0x13
mult        rs, rt  01 1000 0x18
multu       rs, rt  01 1001 0x19
nor     rd, rs, rt  10 0111 0x27
or      rd, rs, rt  10 0101 0x25
sll     rd, rt, sa  00 0000 0x00
sllv    rd, rt, rs  00 0100 0x04
slt     rd, rs, rt  10 1010 0x2A
sltu    rd, rs, rt  10 1011 0x2B
sra     rd, rt, sa  00 0011 0x03
srav    rd, rt, rs  00 0111 0x07
srl     rd, rt, sa  00 0010 0x02
srlv    rd, rt, rs  00 0110 0x06
sub     rd, rs, rt  10 0010 0x22
subu    rd, rs, rt  10 0011 0x23
syscall             00 1100 0x0C
xor     rd, rs, rt  10 0110 0x26

I
addi    rt, rs, immediate   00 1000 0x08
addiu   rt, rs, immediate   00 1001 0x09
andi    rt, rs, immediate   00 1100 0x0C
beq     rs, rt, label       00 0100 0x04
bgez    rs, label           00 0001 0x01  rt = 00001
bgtz    rs, label           00 0111 0x07  rt = 00000
blez    rs, label           00 0110 0x06  rt = 00000
bltz    rs, label           00 0001 0x01  rt = 00000
bne     rs, rt, label       00 0101 0x05
lb      rt, immediate(rs)   10 0000 0x20
lbu     rt, immediate(rs)   10 0100 0x24
lh      rt, immediate(rs)   10 0001 0x21
lhu     rt, immediate(rs)   10 0101 0x25
```

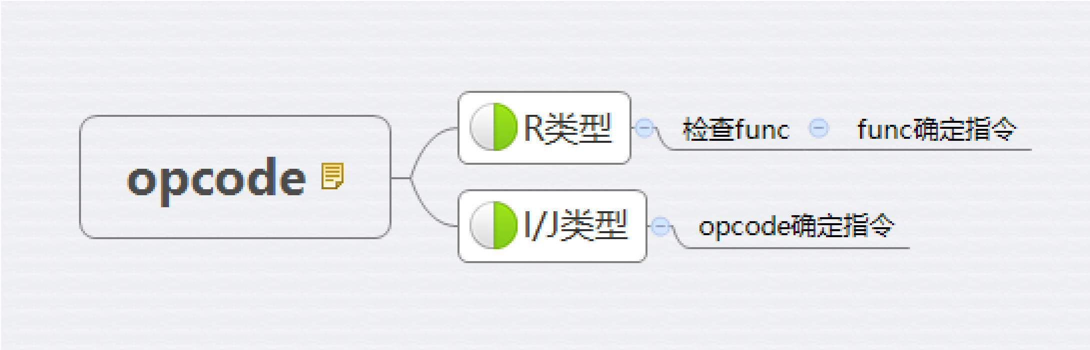
```
lui     rt, immediate       00 1111 0x0F
lw      rt, immediate(rs)   10 0011 0x23
lwc1    rt, immediate(rs)   11 0001 0x31
ori     rt, rs, immediate   00 1101 0x0D
sb      rt, immediate(rs)   10 1000 0x28
slti    rt, rs, immediate   00 1010 0x0A
sltiu   rt, rs, immediate   00 1011 0x0B
sh      rt, immediate(rs)   10 1001 0x29
sw      rt, immediate(rs)   10 1011 0x2B
swc1    rt, immediate(rs)   11 1001 0x39
xori    rt, rs, immediate   00 1110 0x0E

J
j   label   000010  coded address of label 0x02
jal label   000011  coded address of label 0x03
```

本反汇编器所支持的指令在代码开始处的宏进行统一管理，由机器码到汇编代码的翻译在 void disassembleNode(InstrNode* instrNode)函数中进行，因此若要扩展反汇编器所支持的指令，只需对代码开头的宏进行修改并在 void disassembleNode(InstrNode* instrNode)函数中增加相应的处理即可。

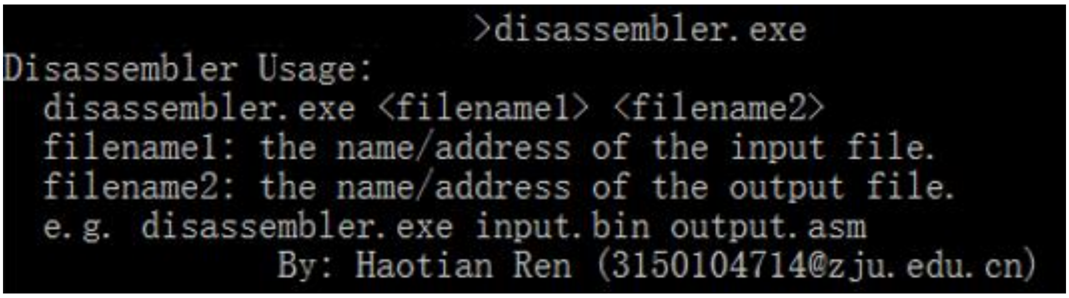
2、算法逻辑：

反汇编的算法较为简单，大致可以描述如下：



3、使用方法：

在命令行中不带参数直接执行程序或执行程序参数有误时，即可获得使用方法，如下：



```
                    >disassembler.exe
Disassembler Usage:
  disassembler.exe <filename1> <filename2>
  filename1: the name/address of the input file.
  filename2: the name/address of the output file.
  e.g. disassembler.exe input.bin output.asm
              By: Haotian Ren (3150104714@zju.edu.cn)
```

4、实例分析

首先使用汇编器程序将汇编代码转化为机器码，随后再使用反汇编器对机器吗进行反汇编。所使用的测试汇编代码如下：

```
# Test function over here:
    addiu $a0, $0, -25       # Load base addr
    addiu $a1, $0, 10        # Load length
    jal MYFUNc           # Call function
    li $v0, 0xABCDE

myFunc: addiu $t0, $0, 0        # Init counter
startLoop:  beq $t0, $a1, endLoop       # Check if end condition reached
    addu $t1, $a0, $t0       # Calculate offset address
    lb $t2, 0($t1)       # Load value

    lbu $t3, -3($s2)
    addiu $t2, $t2, 1        # Increment by one
    or $a0, $a1, $a3
    li $t0, 3
    slt $a2, $t1, $t0
    sltu $a2, $t1, $t0
    sll $t3, $t2, 31

random: ori $t3, $t2, 291
    lui $t3, 532
    sb $t2, 0($t1)
    sw $t2, -32768($t1)
    lw $t3, 32767($t1)
    blt $t3, $t2, myFunc

    addiu $t1, $t1, 1        # Increment counter
    j startLoop
endLoop:    jr $ra
    bne $t3, $a0, myFunc

```

对由该汇编代码生成的机器码进行反汇编的结果如下：

```
                          >disassembler.exe test.bin out.asm
Done!
```

程序输出“Done!”表示反汇编成功。

在 out.asm 文件中可以查看生成的汇编代码，如下：

```
                              >type out.asm
addiu $a0, $zero, -25    # MachineCode: 0x2404FFE7
addiu $a1, $zero, 10     # MachineCode: 0x2405000A
jal 1   # MachineCode: 0x0C000001
addiu $t0, $zero, 0      # MachineCode: 0x24080000
beq $t0, $a1, 16         # MachineCode: 0x11050010
addu $t1, $a0, $t0       # MachineCode: 0x00884821
lb $t2, 0($t1)  # MachineCode: 0x812A0000
lbu $t3, -3($s2)         # MachineCode: 0x924BFFFD
addiu $t2, $t2, 1        # MachineCode: 0x254A0001
or $a0, $a1, $a3         # MachineCode: 0x00A72025
slt $a2, $t1, $t0        # MachineCode: 0x0128302A
sltu $a2, $t1, $t0       # MachineCode: 0x0128302B
sll $t3, $t2, 15         # MachineCode: 0x000A5FC0
ori $t3, $t2, 291        # MachineCode: 0x354B0123
lui $t3, 532    # MachineCode: 0x3C0B0214
sb $t2, 0($t1)  # MachineCode: 0xA12A0000
sw $t2, -32768($t1)      # MachineCode: 0xAD2A8000
lw $t3, 32767($t1)       # MachineCode: 0x8D2B7FFF
addiu $t1, $t1, 1        # MachineCode: 0x25290001
j -15   # MachineCode: 0x0BFFFFF1
jr $ra  # MachineCode: 0x03E00008
bne $t3, $a0, -18        # MachineCode: 0x1564FFEE
```

说明反汇编结果正确。