CSE 30: Computer Organization and Systems Programming

Lecture 13: Control Transfer Instructions

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Ways to change Control flow in C

1. goto <label>
2. if (condition) { //do something }
3. if-else
4. Loops
   I. do-while
   II. for
   III. while
   IV. switch
Labels

• Any instruction can be associated with a label
• Example:
  
  ```
  start  ADD r0,r1,r2 ; a = b+c
  next   SUB r1,r1,#1 ; b--
  ```

• In fact, every instruction has a label regardless if the programmer explicitly names it
  – The label is the address of the instruction
  – A label is a pointer to the instruction in memory
  – Therefore, the text label doesn’t exist in binary code
ARM goto Instruction

• The simplest control instruction is equivalent to a C goto statement
• goto label (in C) is the same as:
• B label (in ARM)
• B is shorthand for “branch”. This is called an unconditional branch meaning that the branch is done regardless of any conditions.
• There are also conditional branches:
Conditional Branch

• To perform a conditional branch,
  1. First set the condition bits (N,Z,V,C) in the program status register
  2. Then check on these condition bits to branch conditionally
Conditional Branch

• How can we set the condition bits in the cpsr register?
  – Append S to arithmetic/logical instruction
  – Use a ‘Comparison Instruction’
Comparison Instructions

- **CMP** — Compare and set condition bits
  - subtracts a register or an immediate value from a register value and updates condition codes
  - Unlike SUB, it doesn’t store the result anywhere

- **Examples:**
  - CMP r3, #0 ; set Z flag if r3 == 0
  - CMP r3, r4 ; set Z flag if r3 == r4
Comparison Instructions

• **CMP** — Compare and set condition bits
  – subtracts a register or an immediate value from a register value and updates condition codes
  – Unlike SUB, it doesn’t store the result anywhere

• **Examples:**
  – `CMP r3, #0 ; set Z flag if r3 == 0`
  – `CMP r3, r4 ; set Z flag if r3 == r4`

All flags are set as result of this operation, not just Z
Conditional branches often preceded by CMP
Recall: Conditional Branch

• To perform a conditional branch,

1. First set the condition bits (N,Z,V,C) in the program status register

2. Then check on these condition bits to branch conditionally

• How can we check on condition bits?
ARM Decision Instructions

• ARM has variants of the branch instruction that only goto the label if a certain condition is TRUE

• Examples:
  – BEQ label ; BRANCH EQUAL
  – BNE label ; BRANCH NOT EQUAL
  – BLE label ; BRANCH LESS THAN EQUAL
  – BLT label ; BRANCH LESS THAN
  – BGE label ; BRANCH GREATER THAN EQUAL
  – BGT label ; BRANCH GREATER THAN
  – Plus more ...

• The condition is T/F based upon the fields in the Program Status Register
ARM Condition codes

- If a condition code is appended to an instruction with a condition code, the instruction is conditionally executed by checking the flags in the CPSR register.

**Condition Flags tested**
- **EQ**: $z=1$
- **NE**: $z=0$
- **LE**: $z=1$ or $n=!v$
- **LT**: $n=!v$
- **GE**: $n=v$
- **GT**: $z=0$ & $n=v$
- Plus more ...

- The condition is T/F based upon the fields in the Program Status (CPSR) Register.
C Code

\[
\begin{align*}
\text{If}(X == 0) \\
X &= Y + Z;
\end{align*}
\]

Assume X, Y, and Z are integers in registers r0, r1, and r2, respectively.

Q: Which one is the equivalent assembly code?

A

\begin{align*}
\text{CMP} & \text{ r0, #0} \\
\text{BEQ} & \text{ Label} \\
\text{ADD} & \text{ r0, r1, r2} \\
\text{Label:}
\end{align*}

B

\begin{align*}
\text{CMP} & \text{ r0, #0} \\
\text{BNE} & \text{ Label} \\
\text{ADD} & \text{ r0, r1, r2} \\
\text{Label:}
\end{align*}

C – Neither of these is correct.
If...else

if (x==y)
    x=x+y;
else
    x=x-y;
While loops

while (a<0)
    a++;
For loops

for (i=0;i<10;i++){
    a++;
    b--;
}
