CS 61C Fall 2019

RISC-V Control Flow

Discussion 4: September 23, 2019

1 RISC-V with Arrays and Lists

Comment what each code block does. Each block runs in isolation. Assume that there is an array, `int arr[6] = {3, 1, 4, 1, 5, 9}`, which starts at memory address `0xBFFFFF00`, and a linked list struct (as defined below), `struct ll* lst`, whose first element is located at address `0xABCD0000`. Let `s0` contain `arr`'s address `0xBFFFFF00`, and let `s1` contain `lst`'s address `0xABCD0000`. You may assume integers and pointers are 4 bytes and that structs are tightly packed. Assume that `lst`'s last node's `next` is a NULL pointer to memory address `0x00000000`.

```
struct ll {
    int val;
    struct ll* next;
}
```

1.1
```
lw  t0, 0(s0)   t0 = arr[0]
lw  t1, 8(s0)   t1 = arr[2]
add t2, t0, t1  t2 = t0 + t1 => t2 = arr[0] + arr[2]
sw  t2, 4(s0)   arr[1] = t2  which is what this is,
```

Sets `arr[1]` to `arr[0]` + `arr[2]`

1.2
```
loop: beq  s1, x0, end  <- s1 is null if the next is null aka end of list.
      lw   t0, 0(s1)    <- take val in struct
      addi t0, t0, 1    <- add one to it
      sw   t0, 0(s1)    <- put the new value back.
      lw   s1, 4(s1)    <- load the next structre to s1,
      jal  x0, loop     <- jump back to loop & do not store return address
 end:
```

Increments all values in the linked list by 1.

1.3
```
      add  t0, x0, x0   t0 = 0
loop: slti t1, t0, 6    t1 = (t0 < 6) ? 1 : 0  <- These check for if we have gone through 6 elm of the linked list
      beq  t1, x0, end  <- if end node, it is NULL
      slli t2, t0, 2    <- set t3 to next int of linked list
      add  t3, s0, t2
      lw   t4, 0(t3)    <- load that value
      sub  t4, x0, t4   <- negate it
      sw   t4, 0(t3)    <- put it back
      addi t0, t0, 1    <- increment the counter
      jal  x0, loop     <- jump back to loop & repeat
 end:
```

Negates all elements in `arr`

2 RISC-V Calling Conventions

2.1 How do we pass arguments into functions?

Use the 8 arguments registers `a0` - `a7`

2.2 How are values returned by functions?

Use `a0` and `a1` as the return value registers as well

2.3 What is `sp` and how should it be used in the context of RISC-V functions?

add = free
sub = allocate

`sp` stands for stack pointer. We subtract from `sp` to create more space and add to free space. The stack is mainly used to save (and later restore) the value of registers that may be overwritten.

2.4 Which values need to saved by the caller, before jumping to a function using `jal`?

look at green sheet!

Registers `a0` - `a7`, `t0` - `t6`, and `ra`

2.5 Which values need to be restored by the callee, before returning from a function?

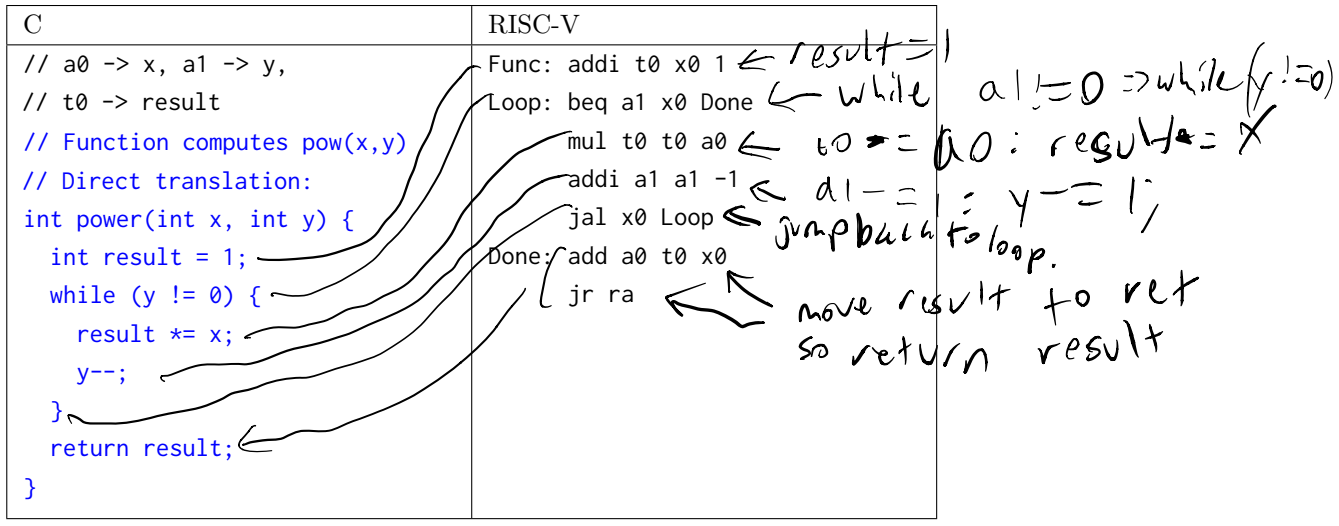
Registers `sp`, `gp` (global pointer), `tp` (thread pointer), and `s0` - `s11`. Important to note that we don't really touch `gp` and `tp`

3 More Translating between C and RISC-V

3.1 Translate between the RISC-V code to C. What is this RISC-V function computing? Assume no stack or memory-related issues, and assume no negative inputs.

C	RISC-V

`// a0 -> x, a1 -> y,`
`// t0 -> result`
`// Function computes pow(x,y)`
`// Direct translation:`
`int power(int x, int y) {`
`  int result = 1;`
`  while (y != 0) {`
`  result *= x;`
`  y--;`
`  }`
`  return result;`
`}`
	`Func: addi t0 x0 1`
	`Loop: beq a1 x0 Done`
	`mul t0 t0 a0`
	`addi a1 a1 -1`
	`jal x0 Loop`
	`Done: add a0 t0 x0`
	`jr ra`



4 Writing RISC-V Functions

4.1 Write a function `sumSquare` in RISC-V that, when given an integer `n`, returns the summation below. If `n` is not positive, then the function returns 0.

$$n^2 + (n-1)^2 + (n-2)^2 + \ldots + 1^2$$

For this problem, you are given a RISC-V function called `square` that takes in a single integer and returns its square.

First, let's implement the meat of the function: the squaring and summing. We will be abiding by the caller/callee convention, so in what register can we expect the parameter `n`? What registers should hold `square`'s parameter and return value? In what register should we place the return value of `sumSquare`?

```
        add  s0, a0, x0   # Set s0 equal to the parameter n
        add  s1, x0, x0   # Set s1 (accumulator) equal to 0
loop:   bge  x0, s0, end  # Branch if s0 is not positive
        add  a0, s0, x0   # Set a0 to the value in s0, setting up
                          # args for call to function square
        jal  ra, square   # Call the function square
        add  s1, s1, a0   # Add the returned value into s1
        addi s0, s0, -1   # Decrement s0 by 1
        jal  x0, loop     # Jump back to the loop label
end:    add  a0, s1, x0   # Set a0 to s1 (desired return value)
```

4.2 Since `sumSquare` is the callee, we need to ensure that it is not overriding any registers that the caller may use. Given your implementation above, write a prologue and epilogue to account for the registers you used.

```
prologue: addi sp, sp -12   # Make space for 3 words on the stack
          sw   ra, 0(sp)    # Store the return address
          sw   s0, 4(sp)    # Store register s0
          sw   s1, 8(sp)    # Store register s1
```

```
epilogue: lw   ra, 0(sp)    # Restore ra
          lw   s0, 4(sp)    # Restore s0
          lw   s1, 8(sp)    # Restore s1
          addi sp, sp, 12   # Free space on the stack for the 3 words
          jr   ra           # Return to the caller
```

put from save location on stack

free stack

jump to restored ra