Machine Programming with Assembly

COMP201 Lab Session
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KOÇ UNIVERSITY

GDB Recap

- Gdb is a debugger for C (and C++), which allows:
  - Run the program up to a certain point,
  - Pause execution and see the current state,
  - Continue execution step by step

- Higher level debugging
  - Simpler to interpret,
  - but not always useful

- **What if we want to dive deeper?**

Debugging using Assembly Language

- Debugging can be easier if we can see what actually happens under the hood:
  - the individual CPU operations,
  - registers,
  - or the memory.

- To go deeper, one must look at the Assembly code.

- The command in GDB command line: ‘disassemble’ outputs the assembly translation of the function currently being executed, or the translation of a target function if one is supplied.

  - `disassemble`
  - `disassemble [Function]`

Assembly

- A Low-level programming language

- Designed for a specific type of processor

- It may be produced **by compiling** source code from a high-level programming language (such as C/C++)

- It can also be written from scratch.

- Assembly code can be converted to machine code using an assembler.

Assembly Language

- Assembly languages differ between processor architectures
- Often similar instructions and operators
- Below are some examples of instructions supported by x86 processors:
  - `mov  - copy data from one location to another`
  - `add  - add two values`
  - `sub  - subtract a value from another value`
  - `push - push data onto a stack`
  - `pop  - pop data from a stack (will be covered later)`
  - `jmp  - jump to another execution point`
  - `int  - interrupt a process`
  - `cmp  - compares two operands`

Registers

- Registers are data storage locations directly on the CPU
- Usually, the size, or width, of a CPU's registers define its architecture
- In a 64-bit CPU, the registers will be 64 bits wide
- The same is true of 32-bit CPUs (32-bit registers), 16-bit CPUs, and so on.
- Registers are very fast to access and are often the operands for arithmetic and logic operations.
  - `%rbp` and `%rsp` are special purpose registers
  - `%rbp` is the base pointer, which points to the base of the current stack frame
  - `%rsp` is the stack pointer, which points to the top of the current stack frame
  - `%rbp` always has a higher value than `%rsp` because the stack starts at a high memory address and grows downwards.

Understanding Assembly

Consider the following Assembly code:

```
pushq %rbp
movq  %rsp, %rbp
movl  %edi, -4(%rbp)
movl  -4(%rbp), %eax
imull -4(%rbp), %eax
popq  %rbp
ret
```

Understanding Assembly

- Normally these are the first 2 instructions of all Assembly codes:

```
pushq %rbp

movq  %rsp, %rbp
```

- The first two instructions are called the function **prologue** or preamble.

- First we **push** the **old base pointer** onto the stack to save it for later.

- Then we **copy** the value of the **stack pointer to** the **base pointer.**

- After this, %rbp **points to the base of main**'s stack frame.

Understanding Assembly

```
movl %edi, -4(%rbp)
```

- The first integer argument is passed in the edi register.
- So this line copies the argument to a local (offset -4 bytes from the frame pointer value stored in rbp).

```
movl -4(%rbp), %eax
```

- This copies the value in the local to the eax register.

Understanding Assembly

```
imull -4(%rbp), %eax
```

- Multiply the contents of eax register with eax register

```
popq %rbp
```

- pop original register out of stack

```
ret
```

- return

Let’s Revisit

```
square:
    pushq %rbp
    movq %rsp, %rbp
    movl %edi, -4(%rbp)
    movl -4(%rbp), %eax
    imull -4(%rbp), %eax
    popq %rbp
    ret
```

Yes, it is just simple squaring function:

```
int square(int num) {
    return num * num
}
```

Example 1:

What is the equivalent C code?

```
    cmpq %rbx, %rax

    ja L1

    jmp next

  L1:

    cmpq %rcx, %rbx

    ja L2

    jmp next

  L2:

    movq $1, %rdx
next
```

Example 2:

What is the equivalent C code?

```
    cmpl $0x0A, %eax
    jg end
beginning:
    addl $1, %eax
    cmpl $0x0A, %eax
    jle beginning
end:
```

Example 3:

What is the equivalent C code?

```
    movl $0, %ecx
for:

    cmpl $100, %ecx

    je endfor

    movl $0, %eax

    movl (%edx, %ecx, 4), %eax

    addl $1, %ecx

    jmp for

endfor:
```

Example 4:

Seems familiar?

```
    movl $0, %eax
    movl $1, %ebx
L1:
    movl %eax, %ecx
    addl %ebx, %ecx
    movl %ebx, %eax
    movl %ecx, %ebx
    jmp L1
```

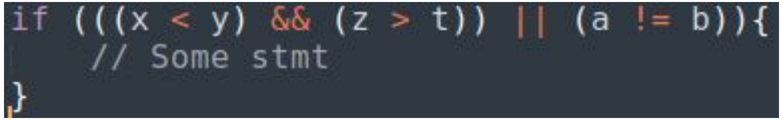
Example 5:

What is the equivalent C code?

```
   pushq  %rbp
   movq   %rsp, %rbp
   movl   %edi, -20(%rbp)      # -20(rbp) = num1
   movl   -20(%rbp), %eax      # eax = -20(rbp)        # eax = num1
   addl   $1, %eax             # eax += 1
   movl   %eax, -8(%rbp)       # -8(rbp) = eax ------- #  x = num1 + 1
   cmpl   $2, -20(%rbp)        #
   jle    .L2                  # if num1 <= 2, then jump to L2
   movl   -20(%rbp), %eax      # eax = num1
   subl   $1, %eax             # eax -= 1
   movl   %eax, -4(%rbp)       # -4(rbp) = eax         # y = num1 - 1
.L2:                           #
  movl   -8(%rbp), %eax        # eax = -8(rbp)         # y = x
  imull  -4(%rbp), %eax        # eax *= -4(rbp)        # y *= y_old
  movl   %eax, -12(%rbp)       # -12(rbp) = eax        # = y*y_old = y*x
  movl   -12(%rbp), %eax       # eax = -12(rbp)        # z = ans
  popq   %rbp                  # function end
  ret
```

Example 6:

What is the equivalent assembly code?



```
if (((x < y) && (z > t)) || (a != b)){
    // Some stmt
}
```

Example 7:

Write an assembly code to find the **max** of array of 100 elements