

Activity 8: Programming Languages

Model 1 Low-Level Languages

The following program, shown in three different languages, calculates the sum of numbers from 1 to 10. In other words, it adds $1 + 2 + \dots + 10 = 55$.

Machine Code (1st Generation)	Y86-64 Assembly (2nd Generation)	Standard C (3rd Generation)
0x000: 0x000: 70000100000000000000	.pos 0 code jmp _start	
0x100: 0x100: 0x100: 30f00b0000000000000000 0x10a: 30f3010000000000000000 0x114: 30f1020000000000000000 0x11e: 30f2010000000000000000	.pos 0x100 code _start: irmovq \$0xb, %rax irmovq \$0x1, %rbx irmovq \$0x2, %rcx irmovq \$0x1, %rdx	int main() { int upper = 11; int sum = 1; int val = 2;
0x128: 2017 0x12a: 6107 0x12c: 73460100000000000000	rrmovq %rcx, %rdi subq %rax, %rdi je done	while (val < upper) { sum = sum + val; val++; }
0x135: 0x135: 6013 0x137: 6021	loop: addq %rcx, %rbx addq %rdx, %rcx	}
0x139: 2017 0x13b: 6107 0x13d: 74350100000000000000	rrmovq %rcx, %rdi subq %rax, %rdi jne loop	
0x146: 0x146: 00	done: halt	

Questions (15 min)

Start time: _____

1. Compare the length of each program. Do not count labels (e.g, 0x000:, .pos 0 code) or punctuation (e.g., {, }).

a) How many instructions of machine code? 14

b) How many instructions of assembly code? 14

c) How many non-blank, non-brace lines of C code? 7

2. All data values for this program are stored in registers named `%rax`, `%rbx`, etc.

a) In which register is the sum stored? `%rbx`

b) In which register is the next value to add stored? `%rcx`

3. The instruction `irmovq` means “move immediate value to register”. Immediate values begin with a dollar sign (`$`), and registers begin with a percent sign (`%`).

a) What is the value 11 in assembly code? `$0xb`

b) Does assembly use decimal or hexadecimal? `hexadecimal`

c) Does Standard C use decimal or hexadecimal? `decimal`

4. In terms of the machine, what does an assignment statement do? As part of your answer, name the instructions in Model 1 that perform assignment.

Assignment updates the register (or memory location) that corresponds to the variable being assigned. In this program, the `irmovq` and `addq` perform assignment.

5. Consider the line `rrmovq %rcx, %rdi`. The instruction `rrmovq` means “move (copy) register to register”.

a) What is stored in register `%rcx`? `The next value to be added`

b) Where is this value copied to? `Register %rdi`

6. The instruction `subq` means “subtract”. Given two registers R and T , `subq` performs $R - T$ and stores the result in T .

a) What is stored in register `%rax`? `The value 11, which is the upper limit.`

b) In what case would `%rax - %rdi` be zero? `When their values are equal.`

7. The instruction `je` means “jump if the last operation’s result equals 0”, and the instruction `jne` means “jump if the last operation’s result does not equal 0”. Circle the portion of assembly code that corresponds to the while loop in C.

Eight instructions should be circled, starting from the first `rrmovq` and ending with `jne`.

Model 2 High-Level Languages

In addition to adding the numbers from 1 to 10, this program prints (displays) the result on the screen using Standard I/O.

Standard C (3rd Generation)

```
#include <stdio.h>

int main()
{
    int upper = 11;
    int sum = 1;
    int val = 2;

    while (val < upper)
    {
        sum = sum + val;
        val++;
    }

    printf("Sum = %d\n", sum);
}
```

Python (4th Generation)

```
upper = 11
isum = 1
val = 2

while val < upper:

    isum = isum + val
    val = val + 1

print("Sum = " + str(isum))
```

Questions (10 min)

Start time: _____

8. Compare the C code with the Python code.

a) Circle the lines of C code that were not present in Model 1. `#include` and `printf`

b) Which lines of C are not present (i.e., needed) in Python? `#include` and `int main`

c) What punctuation used in C is not required in Python? `braces`, `semicolons`, `parens`

9. Without using braces, how does Python know which lines are part of the `while` loop?

It uses indentation (and a colon to indicate the start of a new block).

10. Why does Python use the name `isum` instead of `sum`? Hint: type `sum` into a Python shell.

In Python, `sum` is a built-in function. It's best to avoid using these names for variables.

11. In Python, the range function can be used to generate a sequence of numbers. Use a Python shell to answer this question.

a) What is the result of `list(range(5))`? `[0, 1, 2, 3, 4]`

b) What is the result of `str(range(5))`? `'[0, 1, 2, 3, 4]'`

c) What do the `list` and `str` functions do? `Convert to list or string`

d) What is the result of `sum(range(5))`? `10`

e) What does the `sum` function do? `It adds the given numbers`

12. Rewrite the entire program of Model 2 using one line of Python code. Hint: you'll need to use `print`, `str`, `sum`, and `range`.

```
print("Sum = " + str(sum(range(11))))
```

13. Based on Model 1 and Model 2, what does it mean to be low-level vs high-level?

Low-level languages mimic the hardware and require a lot of simple instructions. High-level languages focus more on the big picture, using fewer and more complex instructions.