Introduction to Scientific Computing I

Lecture 3

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Announcements

- Lab 1 reminder
- Clinic reminder
- Laptops

Programming

- Each CPUs understands its own instruction sets.
- Low level operations:
  - Copy in/out data from memory into registers.
  - Perform operations on registers.
  - Conditional (if/then) and Control flow (jump)
  - Manage a stack (where small sets of data can be shared between different blocks of code)
- Each instruction are each assigned a specific binary value and are not human readable…
- Assembly is a human-read language that most closely mirrors Machine Language.

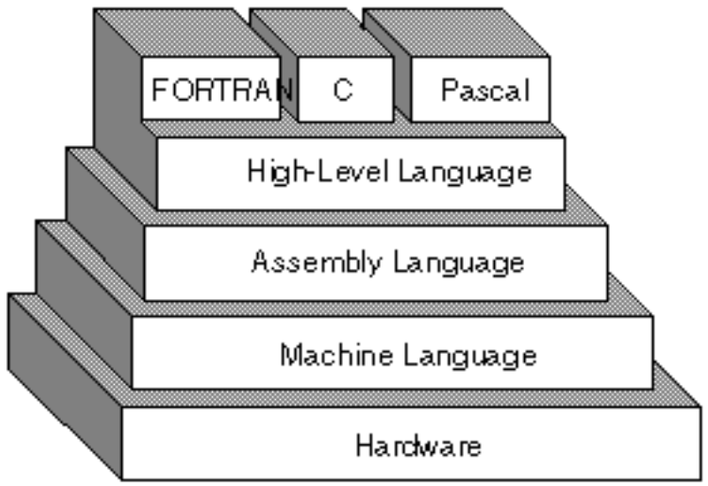
```
x3000 LD R1, x006          ; load data pointer
x3001 LDR R2, R1, #0       ; load data value
x3002 BRz x005             ; branch to end if zero
      ;
      ; repeating statements go here
      ;
x3003 ADD R1, R1, #1       ; increment data pointer
x3004 BRnzp x001           ; branch back to top
x3005 HALT
      ;
      ; data section
      ;
x3006 x4000 ; address of data

; The translation into LC-2 Machine Code
      0011 0000 0000 0000      ; load at x3000
X3000 0010 001 0 0000 0110     ; LD R1, x006
x3001 0110 010 001 000000      ; LDR R2, R1, #0
x3002 0000 010 0 0000 0101     ; BRz x005
      ;
      ; repeating statements go here
      ;
x3003 0001 001 001 1 00001     ; ADD R1, R1, #1
x3004 0000 111 0 0000 0001     ; BRnzp x001
x3005 1111 0000 0010 0101      ; HALT
      ;
      ; data section
      ;
x3006 0100 0000 0000 0000      ; x4000
```

from: http://www.eecs.umich.edu/courses/eecs284/example1.htm

Programming Languages

- Writing Assembly (Machine) code requires
  - knowledge of the specific CPU,
  - working at level of very small operations and
  - awareness of registers, memory, and hardware.



- High-level languages provide high level abstractions and human friendlier syntax for programming.
- Two types:
  - ***Compiled***: The text of the high level language is converted by a *compiler* into machine code. The machine code is run subsequently.
  - ***Interpreted***: A program runs that reads the text of the high level language and performs the operations.

High-level Language

- 3 Fundamental Elements of any programing language:

    1. Primitives:

        - Numbers, Characters, …
        - Mathematical Operations: +, -, *, /, …
        - Logical Operations: and, or, …
        - Conditionals: if-then-else, …

    2. ***Means of Combination***: e.g. list

    3. ***Means of Abstraction***:

        - Assignment: x = 1
        - Definition: def x: 1
        - Function: def f(x): x

- Beyond these, there are universal programming concepts and patterns (e.g. object oriented programming) that enable or facilitate building sophisticated software.

- While we will learn these in python, look beyond the syntax and specifics of the programming language.

Why Python?

- Interpreted: no complication time. Multi-platform.
    - Expense of speed, but the time consuming code are often in complied libraries.
- Large library: almost any package out there has a python API.
- Easy to read. Convenient syntax.
- Convenient data structures that are simple to build.
    - Advanced data structures: list, dictionaries, sets…
    - Dynamic typing: no need to declare the type of a variable.
    - Built-in memory management (reference counting + garbage collection): No need to worry about memory addresses or allocating/freeing memory.
    - Dynamic name resolution (late binding): same code can be reused for different data.
- Multi-paradigm:
    - structured programming: functions, sub-routines, etc…
    - functional programming: filter, map, reduce, lambda, generators, …
    - object-oriented programming: class, inheritance, …
    - …
- Language of choice for Data Science.

Python

- It's an ***interpreted language***.
    - Your code is not compiled to machine language.
    - Your code is executed on the fly via calls to compiled code.
    - Consequences:
        - python is slower than compiled code
        - no strict casting
            - e.g. same function can do something else everything it's called.
- We use it as "glue" and for "pipelining".
    - The software we use have python interfaces, so you can call their functions (e.g. algorithms) in python.
    - No speed penalty, as long as the sophisticated computations are done in the functions at not in python.
    - So we do our computations by chaining calls in python to various compiled functions…. or "pipelining".
- If you don't know python… first lab forces you through a primer.
    - We will use notebooks, but you can run python yourself…
    - You can ssh to our cluster and run python…
    - MacOS, just start terminal and type python