Computers, Programs, Numbers

1. Computers and Programs
   - hardware components
   - programming environments

2. Number Systems
   - decimal and binary notations
   - converting from decimal to binary

MCS 260 Lecture 2
Introduction to Computer Science
Jan Verschelde, 12 June 2023
A computer system consists of

1. **hardware**: physical components of a computer
   - computer: processor, memory, bus, ...
   - peripherals: printer, screen, keyboard, mouse, ...

and

2. **software**: programs executed by computer
   - basic software like the Operating System (OS)
     - either Unix (e.g.: GNU-Linux, Mac OS X)
     - or Windows (the OS of Microsoft);
   - application software needs an operating system to run.
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Hardware Components

**processor** (or CPU: Central Processing Unit) does the computing and coordinates the data transfer.

**memory** (or RAM: Random Access Memory) is used to store data and programs,
- of limited capacity, and
- volatile (lost if power off).

**storage** persistently stores large quantities of data and programs,
- slower access to storage than to memory,
- but larger than RAM

**peripherals** are needed to communicate with the computer

**system bus** connects CPU, RAM, storage, and peripherals
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Programming Environments
what it takes to run programs

editor is used to write source code
compiler translates source code into an object, an executable program — if the code is free of errors
interpreter translates and executes high level code directly
linker combines several objects into one single executable program
debugger helps user to locate errors, allowing a stepwise execution of the program

All are integrated into an IDE: Integrated Development Environment.

Python is an interpreted language. The IDE of Python is called IDLE.

We use JupyterLab to develop our programs.
Executing Programs
how programs are executed

- High level programming languages are oriented towards the convenience of the programmer.
- An assembler language offers symbols to the basic instructions for writing machine code.

The Python Virtual Machine (PVM):

The Python interpreter creates bytecode that is then executed by the Python Virtual Machine at runtime.
Alan Mathison Turing
computer pioneer, 1912-1954

+ Introduced in his 1936 paper ‘on computable numbers’ the universal computing machine, now known as the Turing machine.

+ Created the Turing test in 1950, can a computer imitate intelligence?

+ The A.M. Turing award is the ACM’s most prestigious award, the ‘Nobel Prize’ of computing.

Image taken from www.alanturing.net.
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Decimal Notation of Numbers

- The value of $284 = 2 \times 10^2 + 8 \times 10^1 + 4 \times 10^0$.
  - 2, 8, 4 are the digits of the number, 10 is the base.
  - The position of each digit determines its contribution to the value of the number.

- For any base $B$, a number $n$ is denoted by $m$ coefficients $c_i$, $i = m, m - 1, \ldots, 1, 0$, $0 \leq c_i < B$:
  
  $$n = c_mB^m + c_{m-1}B^{m-1} + \cdots + c_1B^1 + c_0B^0.$$  

- From base five to decimal notation:
  $$2104_5 = 2 \times 5^3 + 1 \times 5^2 + 0 \times 5^1 + 4 \times 5^0$$
  $$= 250 + 25 + 0 + 4$$
  $$= 279_{10}$$
Binary Numbers

- The base is two, the coefficients are bits $\in \{0, 1\}$.

- To write the first 16 natural numbers, we need 4 bits:
  
  $0000 = 0$  
  $0001 = 1$  
  $0010 = 2$  
  $0011 = 3$  
  $0100 = 4$  
  $0101 = 5$  
  $0110 = 6$  
  $0111 = 7$  
  $1000 = 8$  
  $1001 = 9$  
  $1010 = A$  
  $1011 = B$  
  $1100 = C$  
  $1101 = D$  
  $1110 = E$  
  $1111 = F$

- The hexadecimal ‘digits’ are 0, 1, 2, ..., 9, A, B, C, D, E, F.

- Converting
  
  - from hexadecimal into binary: expand hexadecimal digits into bits;
  - from binary and hexadecimal: starting from the right, replace each sequence of four bits by the corresponding hexadecimal digit.
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Converting Numbers — from decimal to binary

Convert 123 into binary format:

<table>
<thead>
<tr>
<th>( n )</th>
<th>( n/2 )</th>
<th>( n \mod 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>123</td>
<td>61</td>
<td>1</td>
</tr>
<tr>
<td>61</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

\[
123 = 1 + 2 \times 61 = 1 + 2 \times (1 + 2 \times 30) \\
= 1 + 2 \times (1 + 2 \times (0 + 2 \times 15)) \\
= 1 + 2 \times (1 + 2 \times (0 + 2 \times (1 + 2 \times 7))) \\
= \ldots
\]

So 123 = 1111011 = 7B.
Flowchart
conversion algorithm

1. Input `n`
2. Compute `r = n % 2`
3. Print `r` and update `n = n / 2`
4. Check if `n == 0`
   - Yes: Stop
   - No: Go back to step 2
Exercises

1. Explain the main difference between installing software from source and installing a binary of the software.

2. Write a script that asks the user for the first name and then in a second question for the last name. The script then prints a personalized greeting, e.g.: Hello John Doe! if the user entered John as answer to the first and Doe as answer to the second question.

3. Given the base and a sequence of coefficients of a number, draw the flowchart of the algorithm to evaluate the number.

4. Write pseudocode for the algorithm to compute the binary representation of a number.

5. Compute examples of general number conversions from any base to any other base. What is the algorithm for such general conversions?