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

Computers and Programs

Hardware & Software

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.

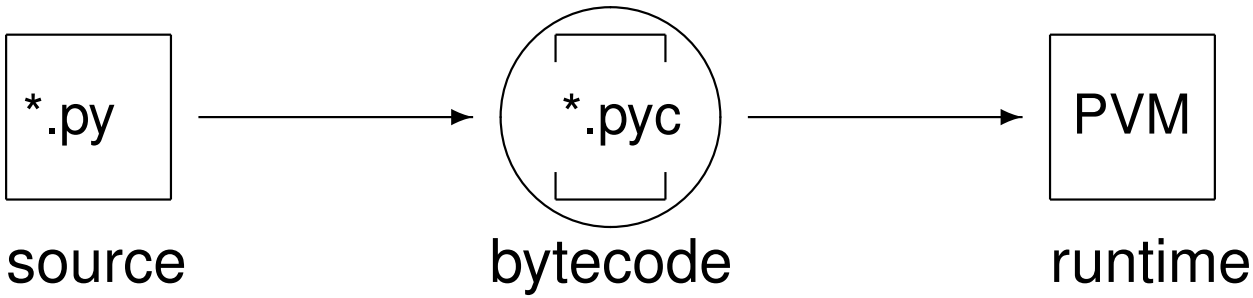
We use JupyterLab to develop our programs.

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

Image taken from `www.alanturing.net`.

+ 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.

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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, $i = m, m-1, \ldots, 1, 0$, $0 \leq c_i < B$:

$$n = c_m B^m + c_{m-1} B^{m-1} + \cdots + c_1 B^1 + c_0 B^0.$$

- From base five to decimal notation:

$$\begin{array}{rcccccccc} 2104_5 & = & 2 \times 5^3 & + & 1 \times 5^2 & + & 0 \times 5^1 & + & 4 \times 5^0 \\ & = & 250 & + & 25 & + & 0 & + & 4 \\ & = & 279_{10} & & & & & & \end{array}$$

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:

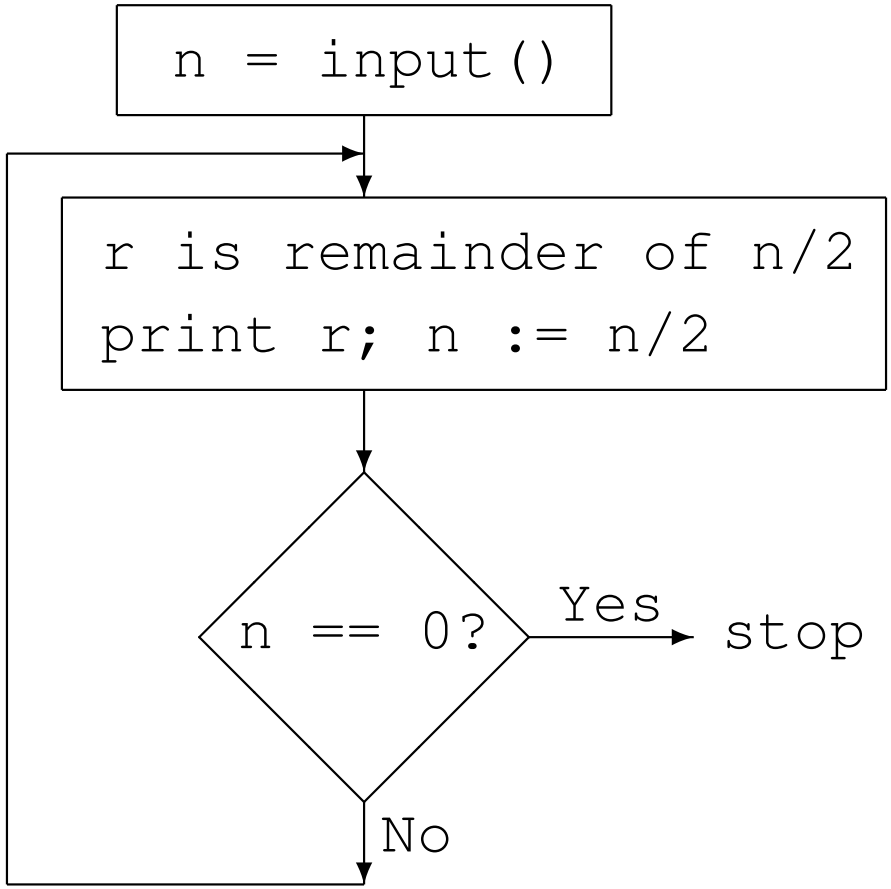
n	$n/2$	$n \bmod 2$	
123	61	1	$123 = 61 \times 2 + 1$
61	30	1	$61 = 30 \times 2 + 1$
30	15	0	$30 = 15 \times 2 + 0$
15	7	1	$15 = 7 \times 2 + 1$
7	3	1	$7 = 3 \times 2 + 1$
3	1	1	$3 = 1 \times 2 + 1$
1	0	1	$1 = 0 \times 2 + 1$

$$
\begin{aligned}
123 &= 1 + 2 \times 61 = 1 + 2 \times (1 + 2 \times 30) \\
&= 1 + 2 \times (1 + 2 \times (0 + 2 \times 15)) \\
&= 1 + 2 \times (1 + 2 \times (0 + 2 \times (1 + 2 \times 7))) \\
&= \ldots
\end{aligned}
$$

So 123 = 1111011 = 7B.

Flowchart

conversion algorithm



Exercises

1. Explain the main difference between installing software *from source* and installing a *binary* of the software.
2. Write a scripts 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?