

# Introduction to Computational Thinking

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Computational Thinking and Programming (A.Y. 2017/2018)

Second Cycle Degree in Digital Humanities and Digital Knowledge

Alma Mater Studiorum - Università di Bologna



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# Historic hero: Noam Chomsky

Founders of the cognitive science field

Father of the modern linguistics

Provided a classification for *formal grammars*



A *formal grammar* is a mathematical tool for defining a language (e.g. English) according to a finite set of production rules, that allows one to construct any syntactic valid sentence of such language

# Types of formal grammars

- regular grammars (the least expressive)
- context-free grammars
- context-sensitive grammars
- recursively enumerable grammars (the most expressive)

All specify constraints on the way one can use *terminal* and *non-terminal symbols*

- terminals are elementary symbols of the language (e.g. words), e.g. "write"
- non-terminals (e.g. <sentence>) can be replaced by a combination of terminal and non-terminal symbols

# Example of formal grammar

A simple grammar defined using the Backus-Naur form

```
<sentence> ::= <pronoun> "write"  
<pronoun> ::= "I"  
<pronoun> ::= "you"
```

Is the sentence “*I write*” part of the language defined by the aforementioned grammar?

```
<sentence> =>  
<pronoun> "write" =>  
"I" "write"
```

The sentence “*I write*” is part of the language

# Meaning: part 1

## Computational Thinking and Programming

Definition of *computational* (Oxford Dictionary): using or relating to computers

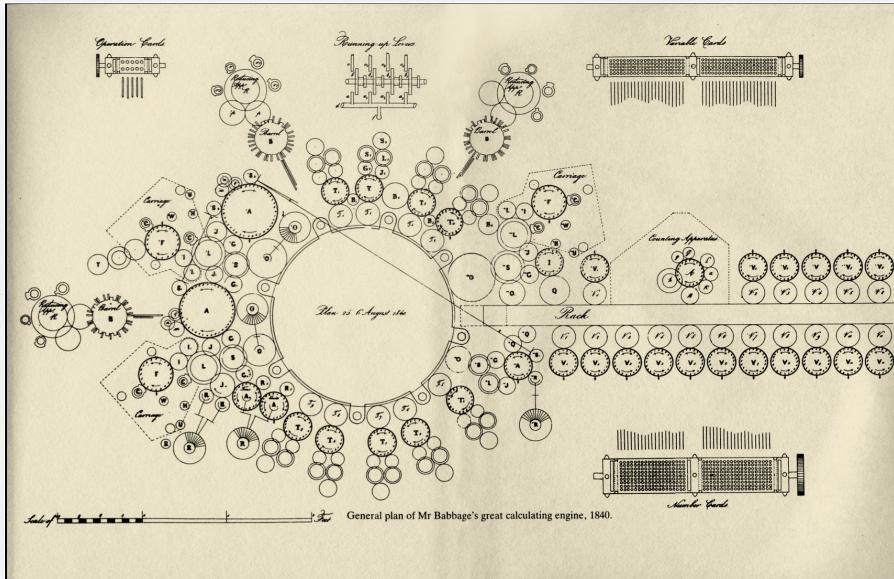
A computer (today): electronic device

A computer (before advent of electronic computers): a person who performs mathematical calculations

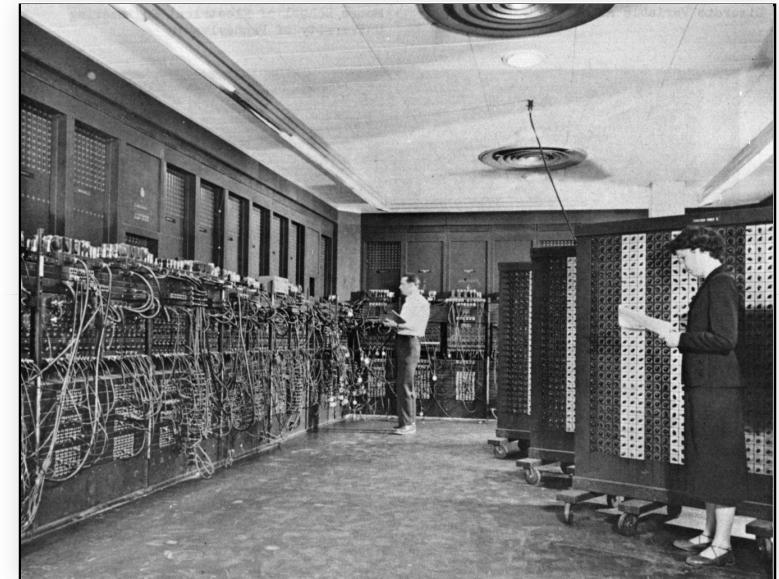
In this course, with *computer* we mean any agent (i.e. anything that can act if appropriately instructed, such as a **person or a machine**) that is able to make calculations and to produce some output starting from input information

# Computers

Human computers: in France, creation of mathematical tables for converting values from the old imperial system of measurement to the new metric system



Babbage's Analytical Engine



ENIAC

# Meaning: part 2

Computational Thinking and **Programming**

The word *programming* stands for *programming language*

Natural language: ordinary language (e.g. English), either written or oral, that has evolved naturally in humans, usually without a specific and premeditated planning – expressive but ambiguous

Programming language: formal-born languages (Chomsky's context-free languages, usually) - less expressive but not ambiguous by construction

# Kinds of languages 1/2

## Machine language

```
1000101101010100001001000000100  
010000011111101000000000011101  
11000001101011100000000000000000  
00000000000000000000110000111000  
001111110100000001001110111000  
00110101110000000000100000000000  
000000000000000011000011010100111  
01110110000000100000000000000000  
0000000010111001000000010000000  
000000000000000010001101000001  
000001100110000011111101000000  
0110111011000000111100010111101  
1001100010011100000101001010111  
01011111000101011011110000011
```

## Low-level programming language

```
fib:  
    mov edx, [esp+8]  
    cmp edx, 0  
    ja @@  
    mov eax, 0  
    ret  
  
@@:  
    cmp edx, 2  
    ja @@  
    mov eax, 1  
    ret  
  
@@:  
    push ebx  
    mov ebx, 1  
    mov ecx, 1
```

```
@@:  
    lea eax, [ebx+ecx]  
    cmp edx, 3  
    jbe @@  
    mov ebx, ecx  
    mov ecx, eax  
    dec edx  
    jmp @@  
  
@@:  
    pop ebx  
    ret
```

# Kinds of languages 2/2

## High-level programming language

```
unsigned int fib(unsigned int n) {  
    if (n <= 0)  
        return 0;  
    else if (n <= 2)  
        return 1;  
    else {  
        unsigned int a,b,c;  
        a = 1;  
        b = 1;  
        while (1) {  
            c = a + b;  
            if (n <= 3) return c;  
            a = b;  
            b = c;  
            n--;  
        }  
    }  
}
```

## Natural language

The function for calculating the nth Fibonacci number takes as input an integer "n". If "n" is less than or equal to 0, then 0 is returned as result. Otherwise, if "n" is less than or equal to 2, then 1 is returned. Otherwise, in all the other cases, associate the value "1" to two distinct variables "a" and "b". Then, repeat indefinitely the following operations: set the variable "c" as the sum of "a" plus "b"; if "n" is less than or equal to 3 then return "c", otherwise assign the value of "b" to "a" and the value of "c" to "b", and finally decrease the value of "n" by 1 before repeating.

# Meaning: part 3

## Computational **Thinking** and Programming

To think (definition, Oxford Dictionary): use one's mind actively to form connected ideas

1. Agree on which language to use for the communication between us and a computer (either human or machine)
2. Think about possible instructions that, if followed systematically, can return the expected result to a certain problem

# Abstraction is the key

Identify patterns that depict a possible solution for a set of abstractly-homogeneous situations

Reuse the same strategy for reaching our goal, if that strategy has been successful in the past



# What is Computational Thinking

An approach for solving problems, designing systems and understanding human behaviour that draws on concepts fundamental to computing

Reshape the abstractions we have ingested as consequence of our life experiences – that we are unconsciously reusing

Being again fully conscious of such abstractions, we can use an appropriate language for making them understandable to a computer, in order to automatise them

Final goal of Computational Thinking: think like a Computer Scientist, even when dealing with common tasks

# END

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