Algorithms and calculators

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Outline

1. Algorithms
2. Early calculators
3. von Neumann Model
4. Credits

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Something to think about

> *“Computer science is no more about computers than astronomy is about telescopes”*

– Edsger Dijkstra

What else might it be about?

Algorithms, programs, processes

- Algorithm:
  - It is a logical procedure thought to solve a certain problem
  - It is informally specified as a sequence of elementary steps that an *execution machine* must follow to solve the problem
  - it is not necessarily expressed in a formal programming language!
- Program:
  - It is the implementation of an algorithm in a programming language, that can be executed by an autonomous machine (calculator)
  - It can be executed several times, every time with different inputs
- Process:
  - An instance of a program that, given a set of input values, produces a set of outputs

Algorithm

- Given a *computational* problem, it is necessary to find a *procedure*, consisting of a *finite set of simple steps* that will produce the solution of the problem.
- Such a procedure is called “Algorithm” in honor of arab mathematician Mohammed ibn-Musa al-Khuwarizmi (VIII century AC)

Figure: al-Khuwarizmi

Examples:

- How to prepare a coffe
- How to buy a coffe from the vending machine
- How to calculate the square root of a number

Calculators

- An algorithm needs a machine to execute it
- Machine here is intended in the abstract sense
  - It can also be a human being, or group of people
  - However, it is important that the algorithm it is *described* so that the machine can execute it without further instructions, or wrong interpretation of what to do
  - Therefore, the steps must be simple, and precisely described

Coffe time!

- Example: in the description of the algorithm to prepare a coffe:
  - we must specify how much coffe to put, so that the *machine* cannot be wrong in preparing it
  - If the *machine* is a calculator (a *stupid* machine!), then we must tell it *exactly* how much coffe to put
  - If the machine is *smart*, we can be less precise, for example, put “coffee” until the machine is full

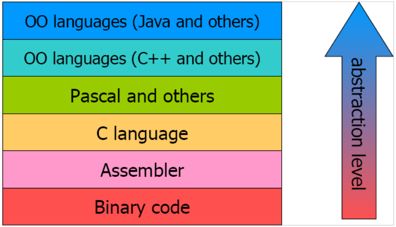
Programs

- In this course, we are interested in describing an algorithm so that a *computer* can understand and execute it
- How to communicate with a computer?

- We need to use a language that the computer can understand
  - A programming language is not so much different than any human language
  - The main difference is that the interpretation of a *sentence* expressed in a programming language must be unambigous
  - Human languages instead allow plenty of ambiguities!

Languages

- But the computer only *understands* two symbols: 0 and 1!
    - Then, every language must be *coded* in binary
    - However, coding in binary is tedious and prone to errors
    - No problem: we can translate from a *high level language* (close to human communication) to a *low level language* (coded in binary, and suitable to computers)



OO languages (Java and others)

OO languages (C++ and others)

Pascal and others

C language

Assembler

Binary code

abstraction level

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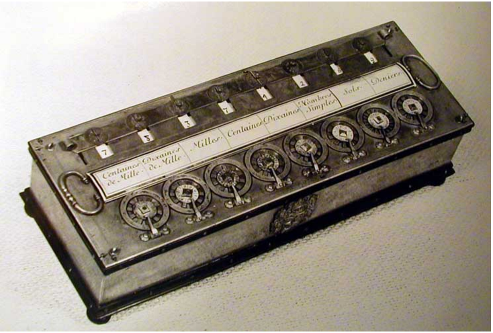
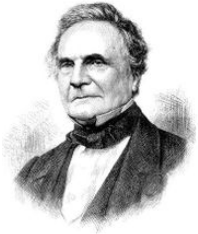
Pascaline



- This machine was invented by Blaise Pascal
- Could be used to add integer numbers by *dialing* the numbers

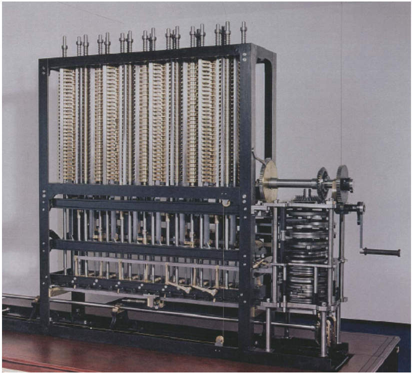
Charles Babbage

- Numerical tables were calculated by humans called ’computers’.
- Babbage saw the high error rate of the people computing the tables



- Babbage wanted to calculate the tables mechanically, removing all human error. He began in 1822 with what he called the difference engine, made to compute values of polynomial functions.
- The first difference engine needed around 25,000 parts of a combined weight of fifteen tons standing eight feet high. Although he received much funding for the project, he did not complete it.

Babbage – II



- Babbage started designing a different, more complex machine called the Analytical Engine, which could be programmed using punch cards, an idea unheard of in his time.
- Several features subsequently used in modern computers, including sequential control, branching, and looping

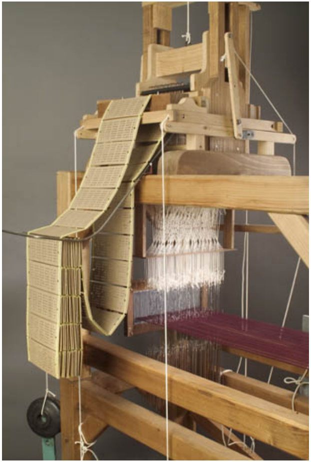
Lady Ada Lovelace

- Ada Lovelace, (Augusta Ada King, Countess of Lovelace (December 10, 1815 – November 27, 1852))
- Ada was the only legitimate child of the poet Lord Byron and his wife, Annabella Milbanke

- She was an impressive mathematician and one of the few who understood Babbage's vision,
- She created a program for the Analytical Engine.
- Based on this work, Ada is now credited as being the first computer programmer and, in 1979, a contemporary programming language was named Ada in her honour.

A strage kind of computer

Jacquard Loom

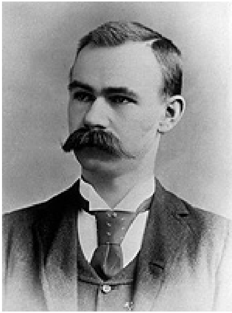


This machine takes instructions by using *punched cards* (like early computers), to produce weavings:

Note the repetitive nature of the task

Hermann Hollerith

- American engineer Herman Hollerith developed a substantial business in punch card punching, sorting and tabulating machines, based on his patents, which were used in the US census quite early.



- His company, the Tabulating Machine Company, became International Business Machines (IBM), still the largest corporation in computing.
- However, true computing as Babbage envisioned it did not become practical for a century.

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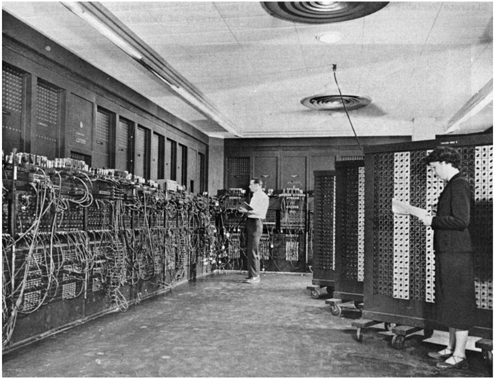
ENIAC (1946)



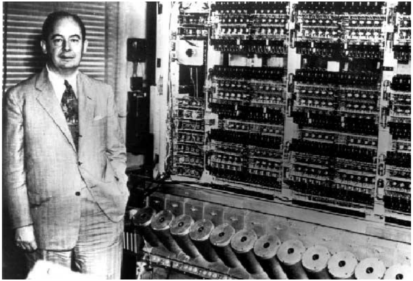
- ENIAC, short for Electronic Numerical Integrator And Computer was the first general-purpose electronic computer.
- ENIAC contained 17,468 vacuum tubes, 7,200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors and around 5 million hand-soldered joints. It weighed 27 tons.
- The basic machine cycle was 200 microseconds

ENIAC Architecture

- It was digital computer capable of being reprogrammed to solve a full range of computing problems.
- ENIAC was designed to calculate artillery firing tables for the U.S. Army's Ballistic Research Laboratory, but its first use was in calculations for the hydrogen bomb.
- ENIAC was not able to *store* a program in memory
    - Reprogramming was done by setting switches and re-wiring the machine
    - It could take up to 3 weeks!
    - Most of the programming was done by six women, now in the history of computers

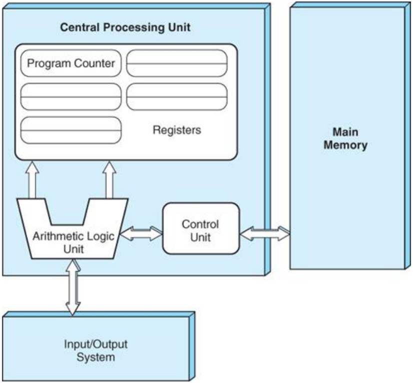
EDVAC

- Mathematician John von Neumann worked at ENIAC, and later proposed the general model known as von Neuman architecture, first implemented on EDVAC, and still used today



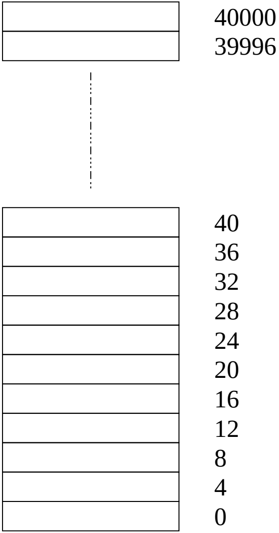
von Neuman Architecture

- von Neuman proposed to store the program in memory, together with data
- It performs a cycle where:
  - the processor first *loads* instructions from memory (fetching)
  - decodes them
  - if necessary loads the operands (data)
  - performs the operation
  - if necessary, stores results in memory



Memory

- The memory is organized as a sequential list of binary words
- In 32-bit architectures, a word corresponds to 4 bytes (32 bits)
- A processor can read one word at every cycle



Instruction set architecture

- The processor has an instruction set (i.e. a set of pre-defined commands, coded in binary)
    - This is hard-wired on the processor: different processors (Intel, Motorola, ARM, etc.) will have different instruction sets
    - They cannot communicate with each other
- A program is a set of binary words, each one codes a command, or its operands
- Here is an example of program, described in a symbolic language called assembly, which has a 1-1 relationship with the machine code

```
LD  R0, 0x5AF85C42
ADD R0, R1
```

Programs and data

- In the von Neumann machine, programs can be treated as data
  - they can be automatically produced by other programs
  - they can be stored on files on the hard disk, and later they can be loaded in memory
  - they can self-modify!
  - They can be modifies by other programs (program updates, virus, ...)

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- Thanks to Michael Tobis for the historical slides and pictures
  - `http://webpages.cs.luc.edu/~mt/CS150/M1.html`