What is **computing** then?

We will learn in this course!

Computing is everywhere

Computing sounds perhaps something abstract and foreign, but it is everywhere:

- Internet, e-mail and WWW
- Mobile phones
- DNA sequencing and human genome mapping
- Magnetic Resonance Imaging (MRI)
- GPS systems

Computing is everywhere

- Social networking (e.g., Facebook)
- E-commerce and online shopping
- Cryptography and digital signature
- Media file compression (e.g., jpeg, mp3)
- Digital photography and videography
- Bar codes and scanners
- ATMs
- Toll collection (e.g., E-Zpass, FastLane)
- ...

Computing is old

Computing is critical to these technologies, but computing is actually a really old idea…

At the heart of computing is this notion of

algorithms

Algorithm

A precise sequence of simple instructions that can be automated.

Examples.

- The procedure to add any given two large numbers.
- The procedure (recipe) to cook clam chowder.
- …

Algorithm

The study of algorithms has a long history, predating the birth of computers.

- Rooted in ancient civilizations of the Middle East.
- Named after the Islamic mathematician (astronomer, astrologer and geographer) Muḥammad ibn Mûsâ al-Khwârizmî (circa 780–850), who is also well-known for the invention of *algebra*.

Abu 'Abd Allâh Muḥammad ibn Mûsâ al-Khwârizmî
أبو عبد الله محمد ابن موسى الخوارزمي

http://www.mapquest.com/

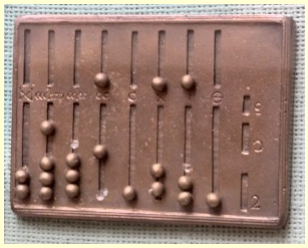
Abu 'Abd Allâh Muḥammad ibn Mûsâ al-Khwârizmî
أبو عبد الله محمد ابن موسى الخوارزمي

http://www.routard.com/

Abu 'Abd Allâh Muḥammad ibn Mûsâ al-Khwârizmî
أبو عبد الله محمد ابن موسى الخوارزمي

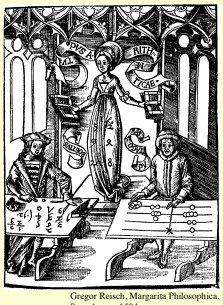
http://www.wikipedia.org/

Abacus



http://www.wikipedia.org/

The abacist versus the algorist



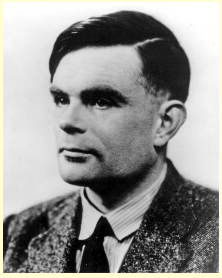
Gregor Reisch, Margarita Philosophica, Strassbourg, 1504

On to modern computer science…

Fathers of computer science

Deschutes Hall, University of Oregon, Eugene

Alan Turing (1912–1954)



http://www.turing.org.uk/

Turing is best known for:

- During WWII, he lead a team of cipher-breakers to crack the German *Enigma* code and hastened the end of the war.
- He invented a basic prototype of today's computers. This elegant mathematical model of computation is called the *Turing machine*.

Decision problem

In essence, it asks whether reasoning can be reduced to computation.

- Originally considered by Leibniz in the 17th century.
- Formalized by mathematician Hilbert in 1928.

Decision problem

Is there a mechanical procedure to determine whether any given proposition is true?

Proposition?

A proposition is a statement that is either true or false.

Examples.

- The sum of two odd numbers is even.
- If $x < y$, then $-y < -x$.
- The area of a circle with radius r is πr^2
- If a program P has a syntax error, then P has a semantic error.

Non-examples.

- The Boston Red Sox won the World Series in 2009.
- My clam chowder tastes good.
- How are you?
- Please open the door for me.
- Keep it up, Joe!

Decision problem

Is there a mechanical procedure to determine whether any given proposition is true?

If the answer were YES, then mathematicians and most scientists would lose their jobs.

Luckily, the answer is NO, according to Turing's work.

Mechanical procedure?

A mechanical procedure is a sequence of very simple activities that can be automated.

Examples.

- The procedure to add any given two large numbers.
- The procedure (recipe) to cook clam chowder.
- …

Mechanical procedure?

A mechanical procedure is a sequence of very simple activities that can be automated.

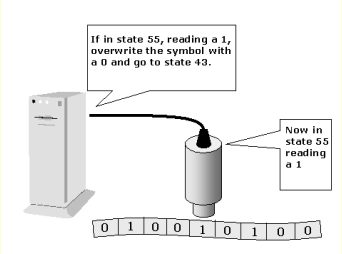
To formalize the notion of mechanical procedures, Turing considered a little machine…

Turing machine (1937)

A Turing machine is comprised from:

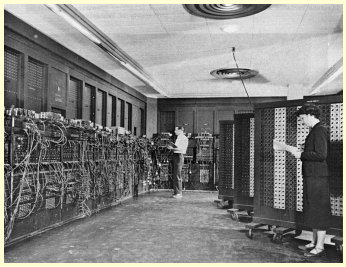
- A *tape* of infinite length, divided into small cells. A cell can store a single letter.
- A *tape head* to read/write one letter at a time.
- A finite number of *states*, where each state is equipped with a very simple instruction.

Turing machine (1937)



http://www.lambdaassociates.org/

ENIAC (1946)



http://www.wikipedia.org/

Hardware layers of a computer

A computer may look very complex, but its hardware is comprised of layers of simple components.

- bits
- switches
- gates
- circuits
- the processor and memory

Bits

A bit is the smallest unit of information used in computers. A bit is either 0 or 1.

Information of any format (numbers, texts, images, sounds, etc.) is represented in a collection of bits; that is, a sequence of 0's and 1's.

Binary notation

For example, numbers are represented in 0's and 1's in the following way.

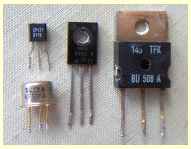
0	⇔	0
1	⇔	1
2	⇔	10
3	⇔	11
4	⇔	100
5	⇔	101
	...	

Swiches

A switch is a device that changes the status of a bit from 0 to 1 and vice versa.

In the early days (1940s and 1950s), *vacuum tubes* and *transistors* were used as switches.

http://www.tablix.org/

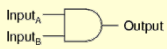


http://www.wikipedia.org/

Gates

A gate is a tiny device made out of switches designed to perform a very simple task.

2-input AND gate

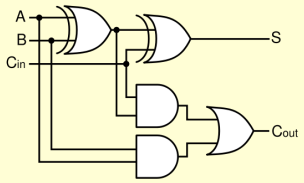


A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

http://www.eng.cam.ac.uk/

Circuts

A circuit is a tiny device made out of gates designed to perform a simple task.



http://www.wikipedia.org/

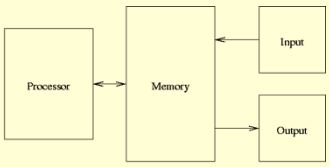
The processor and memory

The processor and memory are the most critical components of a computer. Both are made out of circuits.

- A *processor* executes computer programs (which are basically algorithms written in a computer language).
- *Memory* stores a large amount of information (in bits). Programs as well as data are stored in memory.

von Neumann model

All computers share the following basic design called the *von Neumann* model (named after the Hungarian/American mathematician John von Neumann (1903–1957)).



John von Neumann
Margittai Neumann János Lajos

http://www.wikipedia.org/

Instruction cycle

Under this model, the processor executes a program by repeating the following cycle.

1. fetch — reads an instruction from the memory
2. decode — decodes the instruction to figure out its meaning.
3. execute — performs the task specified in the instruction.
4. store — stores the result of the above execution in the memory.