COMP 102: Computers and Computing
Lecture 1: Introduction

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Class web page: www.cs.mcgill.ca/~jpineau/comp102

Outline for today

- What are computers? What is computing?
- What will this course contain?
- Interesting success stories from the field of computer science.
- A brief history of computers and computing.

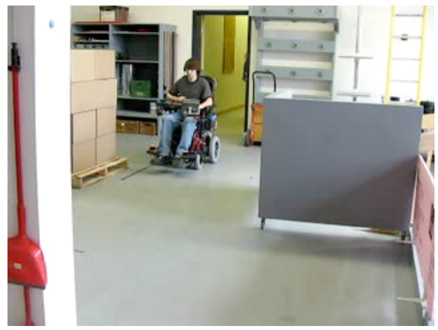
About You (as of Aug.29 2011)

- 20 Freshman Program
- 7 (Micro)-Biology
- 5 Education
- 3 Economics
- 3 Undeclared
- 2 Psychology
- 1 Music
- 1 Art history
- 1 Physics
- 1 Computer science
- 1 Kinesiology
- 1 Physiology
- 1 Environment

About Me

- Academic background:
  - B.A.Sc. in Engineering (U.Waterloo) 1993-1998
  - Ph.D. in Robotics (Carnegie Mellon U.) 1998-2003
  - Prof at McGill 2004-
- Other teaching activities:
  - Artificial Intelligence (COMP-424), Planning Algorithms (COMP-765)
- Research interests:
  - Robotics
  - Artificial Intelligence
  - Machine learning
  - Personalized medicine and health-care

SmartWheeler project

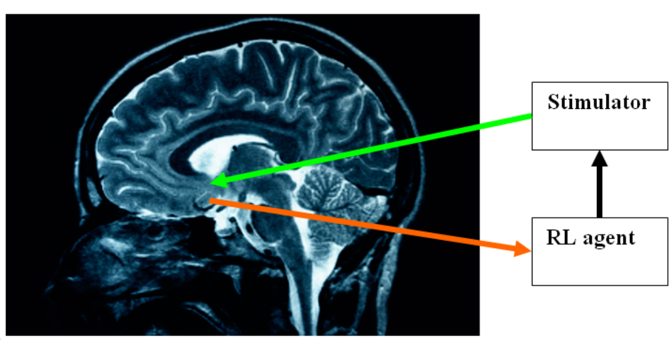


Adaptive treatment design

Background: Deep brain stimulation is a new treatment for epilepsy.

Problem: Existing devices do not adapt to the patient's condition.

Idea: Create an improved class of devices with adaptive control.



Am I taking the right course?

- I want to learn how to program.
- I want to know how to use Word and Excel.
- I want to build intelligent robots.
- I want to design a cooler Web page.

Goals for the course

- Discuss interesting facts and ideas related to *computers and computing.*
  - How computers represent data.
  - How we can give instructions to computers.
  - What problems computers can (or not) solve.
- Develop your Computational Thinking
  - What is Computational Thinking? Ability to solve problems logically, algorithmically, recursively, efficiently, scientifically, innovatively.
- Explore modern applications of computer science.

Course Syllabus

Part 1: What do we know about computers and computation?

- Storing information (bits, bytes, memory, databases)
- Manipulating data (searching, sorting and more)
- Hiding data (how and why)
- Examining what problems can be solved and how fast.

Part 2: What can we do with computers and computation?

- Designing simulations and games
- Building robots and artificial intelligence
- Solving problems in biology
- Music, images and graphics

Evaluation method

- Weekly assignments (40%)
  - Individual work.
  - Some theory, some application.
  - No formal programming required.
  - Late assignments will NOT be accepted (no exception). But only the marks from the 8 best assignments (out of 11) will count.
- One midterm examination, in class (20%).
- One final examination (40%).

Other details about the course

- **Textbook: None required.**

  Suggested reading: *The Information: A History, a Theory, a Flood* by James Gleick

  (Available in most local and online bookstores.)

- **Office hours:**
  - Joelle Pineau: McConnell 106N. *Tues. 1-2pm.*
  - Robert Vincent: McConnell 111. *Wed. 2-3pm.*
  - Athena Kardehi Moghaddam: McConnell 111. *Thurs. 10-11am.*

- Course material and announcements available on class website:

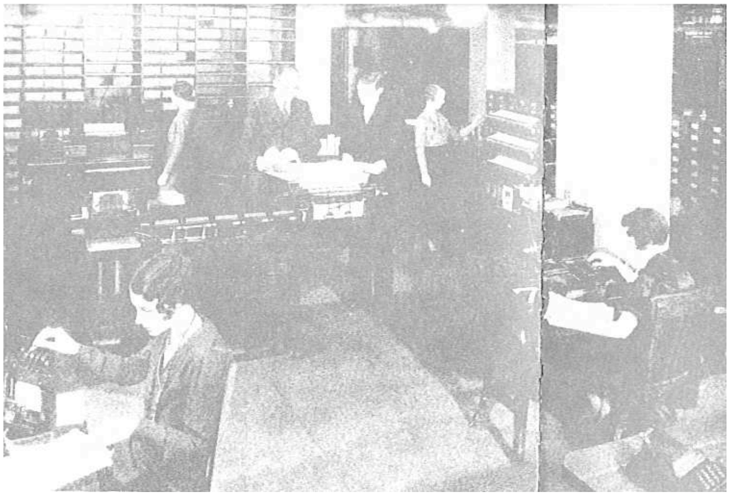
  www.cs.mcgill.ca/~jpineau/comp102

What is this?

The Antikythera Mechanism, built by the Greeks some time between 140 and 100 B.C., predicted solar eclipses and organized the calendar in the four-year cycles of the Olympiad, forerunner of the modern Olympic Games.

(Antikythera Mechanism Research Project)

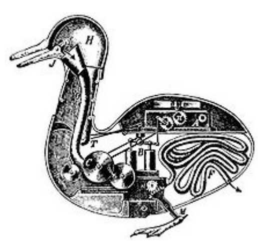
Back when *computers* were people



The ancestors of the computer

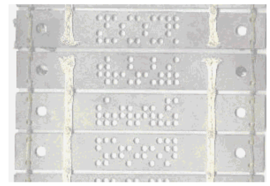
- Counting machines (abacus, etc.)
- Analog computers to perform astronomical calculations.
- Intricate mechanical automatons.

Why aren't these computers? What's missing?



Jacquard's innovation

- In 1801, Joseph Marie Jacquard invented a machine that could weave a specific pattern based on information automatically read from punched wooden cards.



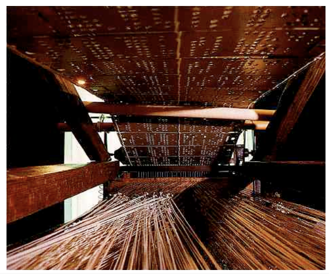
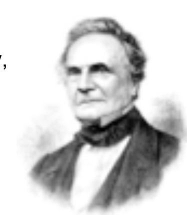


Image of tapestry woven by Jacquard loom.

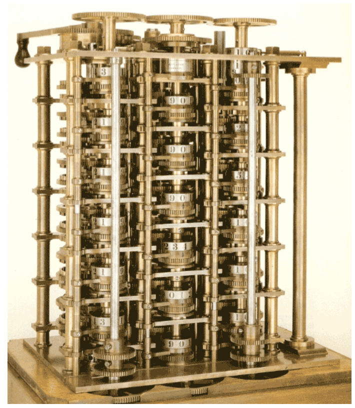
Charles Babbage (1791-1871)



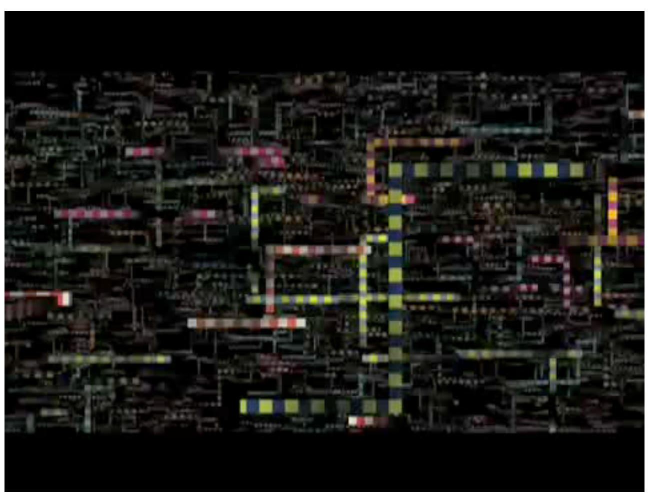
- Lived in England.
- He was a polymath (solved problems from Astronomy to Zoology, in particular mathematics, philosophy, engineering).
- Travelled across England, studying looms, forges, glassworks.
- Invented:
  - The cowcatcher,
  - Flat-rate postage,
  - Operations research
- Held the Lucasian Professorship of Mathematics at Cambridge (formerly Newton's chair).
- His design for the analytical engine presaged much of the design of modern digital computers.

The Difference Engine

- Originally a **<u>computer</u>** was a job description of a person who created numerical tables, e.g. $log_2(x)$
- Babbage had a scheme to **<u>automate table creation</u>** using **<u>finite differences</u>**.
  - The Difference Engine No.1 required 25,000 parts, 15 tons, 8 feet high, and was never built.
  - His redesigned Difference Engine No.2 was built in 1990 and actually worked!



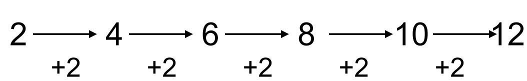
The Difference Engine



Difference Engine: Main idea

- Let’s play a game:
- 0, 1, 2, 3, 4, …?
- 3, 5, 7, 9, 11, …?
- 1, 4, 9, 16, 25, …?
- 1, 3, 6, 10, 15, ….?

Generating Even Numbers



- Instructions:
  1. Start with **2**.
  2. To get the next number, add **2** to the previous one.

Generating Squares

1 → 4 → 9 → 16 → 25 → 36

3 → 5 → 7 → 9 → 1

+2 +2 +2 +2

- Instructions:
  1. Start with **1**.
  2. Start the increment with 3.
  3. To get the next square, add the increment.
  4. To get the next increment, add 2 to the previous increment.

Naming the sequences

- The Evens: “2 2”

2 → 4 → 6 → 8 → 10 → 12

+2 +2 +2 +2 +2

- The Squares: “1 3 2”

1 → 4 → 9 → 16 → 25 → 36

3 → 5 → 7 → 9 → 1

+2 +2 +2 +2

Programming the Different Engine

- To produce the Evens, we enter “2 2” into the Difference Engine and turn the crank.
- For the Squares, enter “1 3 2”
- For the Triangle numbers, enter “1 2 1”

Why is this “programming”?

- There’s a way to say what you want to say, in a way the machine understands.
- Simple operations (in this case, repeated addition) used to build up more complex objects.

Limitations of the Difference Engine

- It was engineered for a very specific task.
  - It can only compute polynomial functions.
  - Some other functions (e.g. log, trig functions) can be approximated by polynomials.
  - To perform very different calculations, we would need to re-build the machine.

The Analytical Engine

- Much more general, with many of the characteristics of a modern-day computers.
  - Input: program and data can be entered through punched cards.
  - Output: through printer, curve plotter and bell.
  - Internal memory.
  - Arithmetical unit, capable of basic mathematical operations.
- Introduced the notion of a *conditional statement.*
  - *"If you observe condition X, apply operation Y."*
- Never built, more of a thought experiment.

The first programmer: Ada Lovelace (1815-1852)

- Ada August, Countess of Lovelace
  - Daughter of the writer Lord Byron.
- Designed many sequences of Babbage's machine's basic operations.
- Was the first to see it as an *engine of information* (not just an engine of numbers).
- Used a number of modern software design elements, e.g. the loop, the variable.

Loop = Repeat an operation until a specified condition is met.

Variable = A receptacle, capable of storing a number.

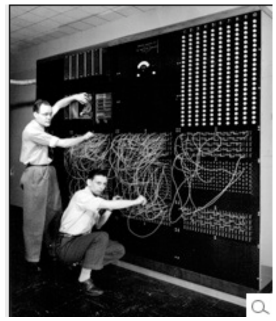
1940: First demo of remote computing

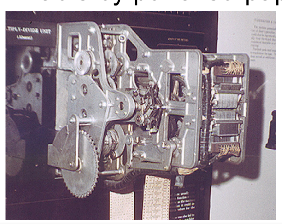
- The Complex Number Calculator.
- Designed by Bell Telephone Labs.
- On its own, just a fancy calculator.
- Noteworthy because <u>calculations were performed remotely</u> (NYC - Darthmouth) using a Teletype connected via phone lines.

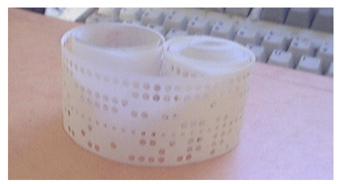
The Complex Number Calculator (CNC) close

1944: Room-sized computers

- Harvard's Mark-1.
- 765,000 component parts:
  - switches, relays, rotating shafts, clutches
  - hundreds of miles of wire
- Used to produce mathematical tables.
- Programmable by punched-paper tape.

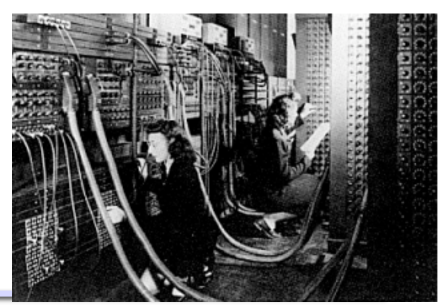






1948: ENIAC

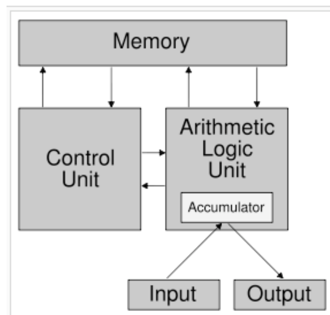
- The Electronic Numerical Integrator And Computer (ENIAC)
- First purely electronic digital computer.
- Built at University of Pennsylvania to calculate artillery firing tables for the US Army.
- 80 feet wide, 27 tons, 120,000 pieces.
- 300 times faster than the Mark 1 at addition.
- Programmable by rewiring
  (switches and cables).
- No memory.



1945: von Neumann's stored-program computer

John von Neumann in the 1940s

- Early computers had fixed programs.
- Key idea is to <u>hold the program in memory</u> as a series of instructions.
- The control unit (i.e. "computer") treats these instructions in the same way as other data.
- <u>Allows the program to change</u> (even as it is running.)

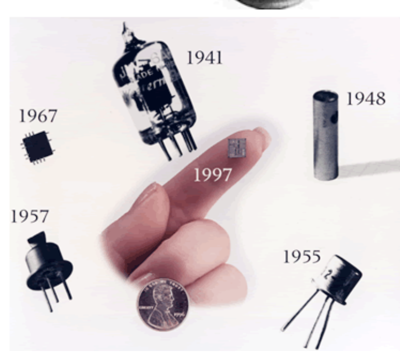


Design of the von Neumann architecture

The Transistor Revolution

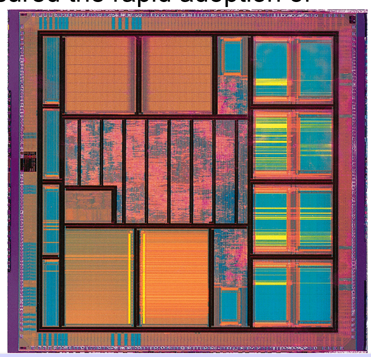
- Early days: computers worked with vacuum tubes.
  - Think of this as an "on/off" switch.
  - Switch is caused by electrons.
  - So we call this "electronics".
  - Vacuum tubes were about size of a modern light bulb.
  - ENIAC had 17,000 vacuum tubes.

- 1947: engineers at Bell Laboratories invent the transistor.
  - Also an electronic on/off switch.
  - Much smaller, less hot, less expensive.
- Today:
  - Intel's recent processors: 781 million transistors.



Integrated Circuits

- Integration of large numbers of tiny transistors into a small chip
- Mass production capability, reliability, and building-block approach to circuit design ensured the rapid adoption of standardized ICs



Personal Computing

- By late 1970's, price of computer processors was much more affordable. Companies were starting to produce "microcomputers".
  - But not clear whether there was a market for personal computers.
  - Computers were still seen as "number-crunchers".
- In early 80's, hobbyists starting buying machines like Apple II and IBM PC.
- Two key developments:
  - Graphical User Interfaces ("GUI")
  - Application software

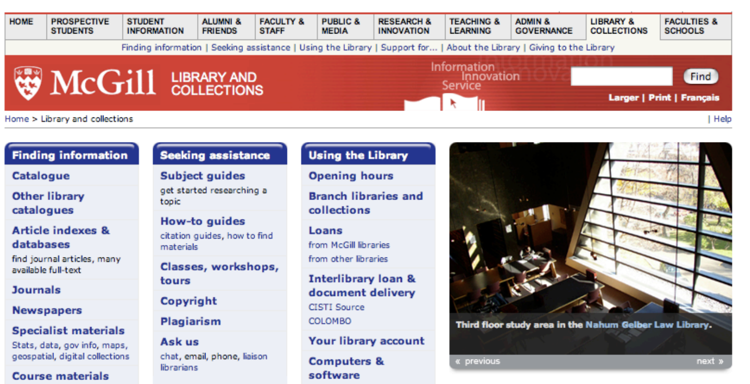
What came next?

- **1946**: "At most six electronic digital computers should be sufficient to satisfy the computing needs of the entire United States." Howard Aiken, principal designer of the Mark I.
- **1977**: "There is no reason for any individual to have a computer in his home." Ken Olsen, CEO of Digital Equipment Corporation
- **2011**: How many computers have you used today?

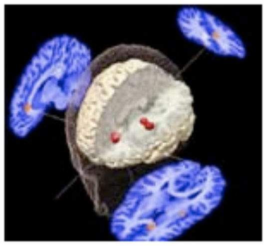
Computers and your education

Google

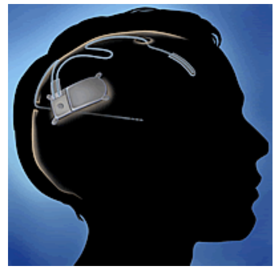
WIKIPEDIA



Computers and your health



www.wisc.edu



www.bcm.com

www.davincisurgery.com

Computers and your social life

facebook

YouTube
Broadcast Yourself

myspace.com
a place for friends

Computers and the entertainment industry

Godzilla, 1954

Godzilla, 1998

Let's start with a few basic concepts

- What is **computing**?
  - Take an input
    e.g. text, numbers, image, sound
  - Calculate for a while
    e.g. add/subtract, filter/amplify, summarize
  - Produce an output
    e.g. new text, new numbers, error message
  - Store the results
- The **computer** is the machine which allows us to do all of this.

We begin the course by trying to understand these different components.

Something to think about

- Define computer science's contribution to the world in one-word:

  REDUCTION

  – Computer scientists solve problems by reducing them to simpler problems.
  – Use simple operations to build up more complex objects.

"We are trying to build a machine to do all kinds of different things simply by programming rather than by the addition of extra apparatus," Turing, 1947.

We will see this concept arise in a number of instances throughout the semester.

Take-home message

- You should understand:
  – how the difference engine works.
  – the link between what we can compute
    - polynomials vs full weather prediction

    and how we compute it
    - difference engine vs modern computer with millions of transistors
- For the rest of the semester, we explore the current state of computing.
  – Minor emphasis on hardware&engineering, more emphasis on the science behind computer science.
- Coming up next:
  – What is data, and how is it represented?