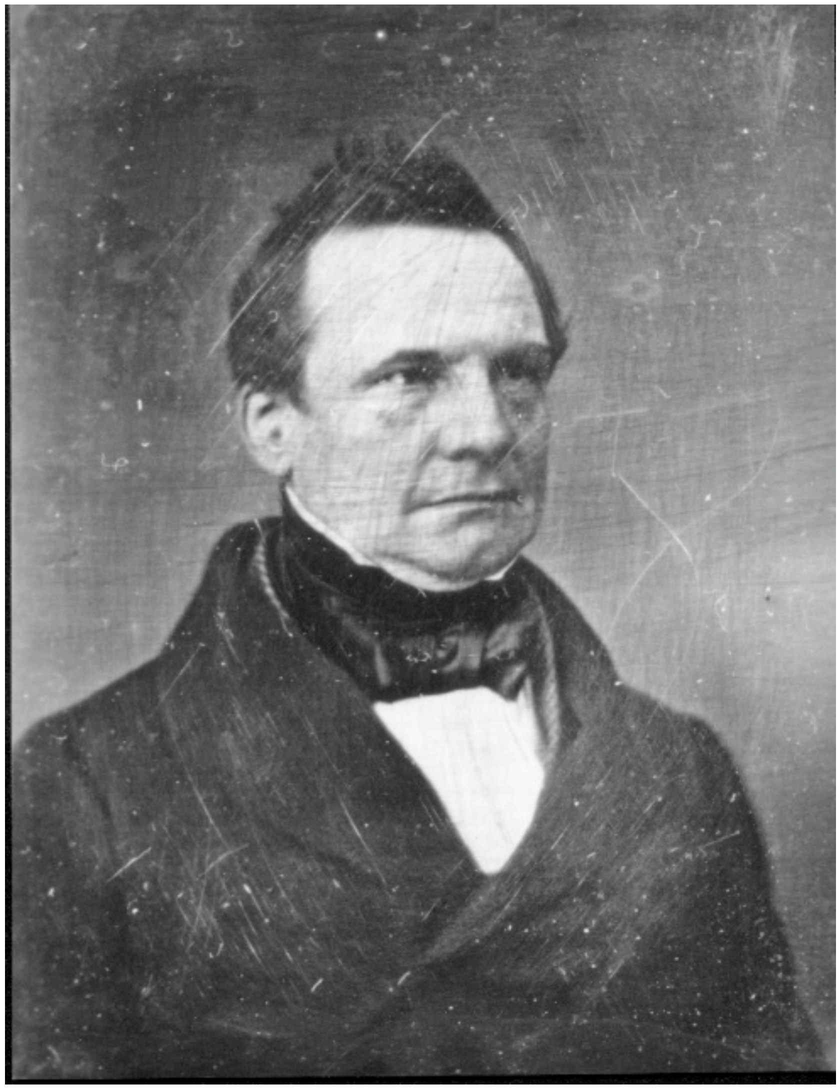
An Incomplete History of Computation

Charles Babbage 1791-1871

Lucasian Professor of Mathematics,
Cambridge University, 1827-1839



Charles Babbage

- *Difference Engine* 1823
- *Analytic Engine* 1833
  - The forerunner of modern digital computer!

Application

- Mathematical Tables – Astronomy
- Nautical Tables – Navy

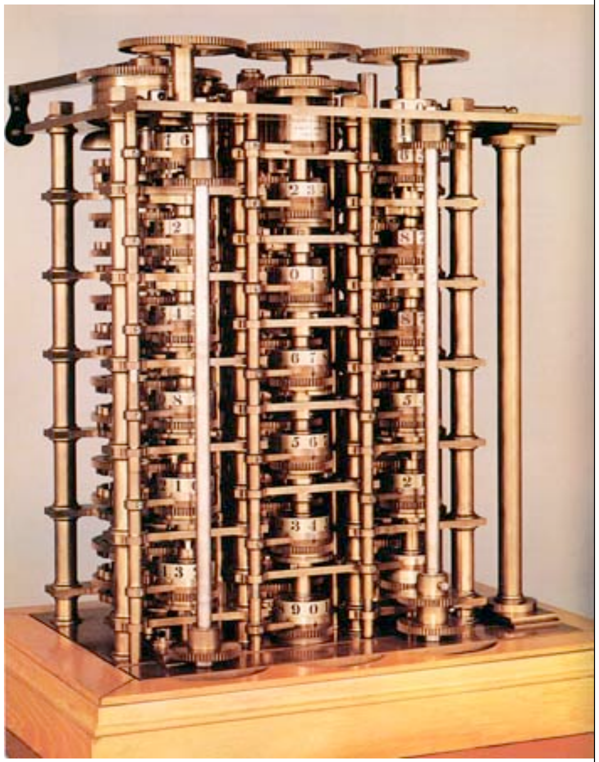
Background

- Some efforts at mechanical calculators in the past.

Technology

- mechanical - gears, Jacquard's loom, simple calculators

Difference Engine



1823
- Babbage's paper is published

1834
- The paper is read by Scheutz & his son in Sweden

1842
- Babbage gives up the idea of building it;he is on to the Analytic Engine!

1855
- Scheutz displays his machine at the Paris World Fare
- Can compute any 6th degree polynomial
- *Speed:* 33 to 44 32-digit numbers per minute!

Now the machine is at the Smithsonian

Analytic Engine

The first conception of a general purpose computer

1. The *store* in which all variables to be operated upon, as well as all those quantities which have arisen from the results of the operations are placed.
2. The *mill* into which the quantities about to be operated upon are always brought.

An operation in the *mill* required feeding two punched cards and producing a new punched card for the *store.*

An operation to alter the sequence (i.e., a branch) was also provided!

Analytic Engine

1833: Babbage's paper was published

- *conceived during a hiatus in the development of the difference engine*

Inspiration: *Jacquard Looms*

- looms were controlled by punched cards
  - The set of cards with fixed punched holes dictated the pattern of weave ⇒ *program*
  - The same set of cards could be used with different colored threads ⇒ *numbers*

1871: Babbage dies

- The machine remains unrealized.

It is not clear if the analytic engine could be built even today using only mechanical technology

Linear Equation Solver

John Atanasoff, Iowa State University

1930's:

- Atanasoff built the Linear Equation Solver.
- It had 300 tubes!

Application:

- Linear and Integral differential equations

Background:

- Vannevar Bush's Differential Analyzer --- *an analog computer*

Technology:

- Tubes and Electromechanical relays

Atanasoff decided that the correct mode of computation was by electronic digital means.

Harvard Mark I

- Built in 1944 in IBM Endicott laboratories
  - Howard Aiken – Professor of Physics at Harvard
  - Essentially mechanical but had some electro-magnetically controlled relays and gears
  - Weighed *5 tons* and had *750,000* components
  - A synchronizing clock that beat every *0.015* seconds

Performance:

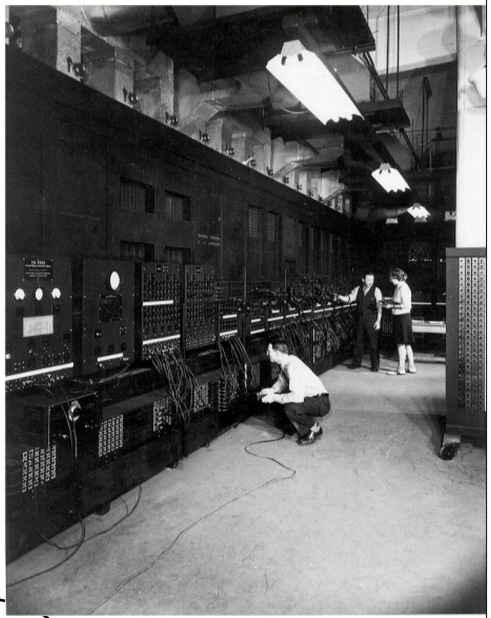
0.3 seconds for addition
6 seconds for multiplication
1 minute for a sine calculation

Broke down once a week!

Adapted from Arvind and Asanovic's MIT course 6.823, Lecture 1

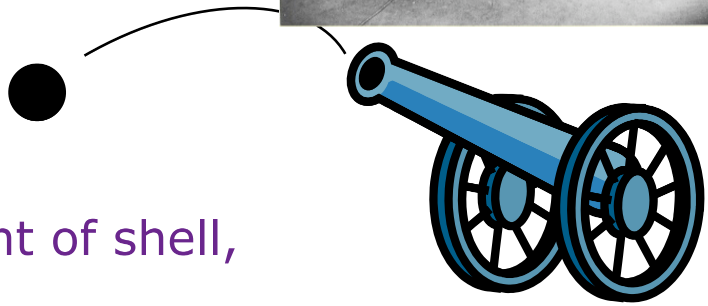
Electronic Numerical Integrator and Computer (ENIAC)

- Inspired by Atanasoff and Berry, Eckert and Mauchly designed and built ENIAC (1943-45) at the University of Pennsylvania
- The first, completely electronic, operational, general-purpose analytical calculator!
  - 30 tons, 72 square meters, 200KW
- Performance
  - Read in 120 cards per minute
  - Addition took 200 μs, Division 6 ms
  - 1000 times faster than Mark I
- Not very reliable!



WW-2 Effort

Application: Ballistic calculations



angle = f (location, tail wind, cross wind,
air density, temperature, weight of shell,
propellant charge, ...)

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Electronic Discrete Variable Automatic Computer (EDVAC)

- ENIAC's programming system was external
  - Sequences of instructions were executed independently of the results of the calculation
  - Human intervention required to take instructions "out of order"
- Eckert, Mauchly, John von Neumann and others designed EDVAC (1944) to solve this problem
  - Solution was the *stored program computer*

    ⇒ *"program can be manipulated as data"*
- *First Draft of a report on EDVAC* was published in 1945, but just had von Neumann's signature!
  - In 1973 the court of Minneapolis attributed the honor of *inventing the computer* to John Atanasoff

Stored Program Computer

Program = A sequence of instructions

How to control instruction sequencing?

manual control	calculators
automatic control	
external (paper tape)	Harvard Mark I , 1944 Zuse's Z1, WW2
internal	
plug board	ENIAC 1946
read-only memory	ENIAC 1948
read-write memory	EDVAC 1947 *(concept)*

– The same storage can be used to store program and data

EDSAC 1950 Maurice Wilkes

first stored program computer

Adapted from Arvind and Asanovic's MIT course 6.823, Lecture 1

The Spread of Ideas

ENIAC & EDVAC had immediate impact

brilliant engineering: Eckert & Mauchley
lucid paper: Burks, Goldstein & von Neumann

IAS	Princeton	46-52	Bigelow
EDSAC	Cambridge	46-50	Wilkes
MANIAC	Los Alamos	49-52	Metropolis
JOHNIAC	Rand	50-53	
ILLIAC	Illinois 49-52		
	Argonne	49-53	
SWAC	UCLA-NBS		

UNIVAC - the first commercial computer, 1951

Alan Turing's direct influence on these developments is still being debated by historians. Much of his work classified until recently.

And then there was IBM 701

IBM 701 -- 30 machines were sold in 1953-54

IBM 650 -- a cheaper, drum based machine,
more than 120 were sold in 1954
and there were orders for 750 more!
- eventually sold about 2000 of them

Users stopped building their own machines.

Why was IBM late getting into computer technology?

IBM was making too much money!
Even without computers, IBM revenues were doubling every 4 to 5 years in 40's and 50's.

Dominant Problem: *Reliability*

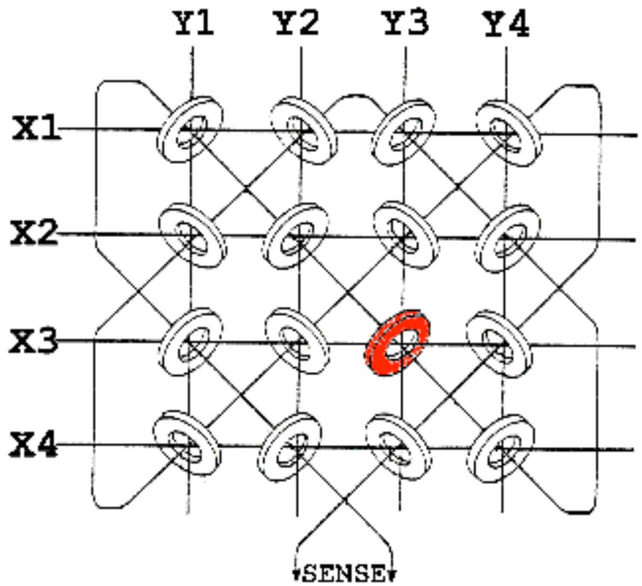
Mean time between failures (MTBF)

MIT's Whirlwind with an MTBF of 20 min. was perhaps the most reliable machine !

Reasons for unreliability:

1. Vacuum Tubes

2. Storage medium
   - acoustic delay lines
   - mercury delay lines
   - Williams tubes
   - Selections



Magnetic Core Memory J. Forrester 1951

-first cheap, reliable memory (~ 1 MHz)
-also called "core" (e.g., "core dump")
-non volatile!
-destructive read cycle
-array of ferrite toroids (or "cores")
-dominant memory technology until 70's (→ ICs)

Computers in mid 50's

- Hardware was expensive
- Stores were small (1000 words)
  - ⇒ No resident system-software!
- Memory access time was 10 to 50 times slower than the processor cycle
  - ⇒ Instruction execution time was totally dominated by the *memory reference time*.
- The *ability to design complex control circuits* to execute an instruction was the central design concern as opposed to *the speed* of decoding or an ALU operation
- Programmer's view of the machine was inseparable from the actual hardware implementation

Into the 60's…:

Compatibility Problem at IBM

By early 60's, *IBM had 4 incompatible lines of computers!*

701	→	7094
650	→	7074
702	→	7080
1401	→	7010

Each system had its own

- Instruction set
- I/O system and Secondary Storage: magnetic tapes, drums and disks
- assemblers, compilers, libraries,...
- market niche business, scientific, real time, ...

⇒ *IBM 360*

Adapted from Arvind and Asanovic's MIT course 6.823, Lecture 3

IBM 360 : Design Premises

http://www.research.ibm.com/journal/rd/441/amdahl.pdf

- Upward and downward, machine-language compatibility across a family of machines
- General purpose machine organization, general I/O interfaces, storage > 32K
- Easier to use (answers-per-month vs. bits-per-second)
- Machine must be capable of *supervising itself* without manual intervention →OS/360 (simple OS's in IBM 700/7000)
- Built-in *hardware fault checking* and locating aids to reduce down time
- Simple to assemble systems with redundant I/O devices, memories etc. for *fault tolerance*

… the use of the "ISA" as a compatibility layer

$5 billion project (1964 dollars)

The Amdahl .. from Amdahl's Law.

The Brooks .. from The Mythical Man-Month.