UNIT 1B
A Brief History Of Computing

Electronic Computing (1800's to the Present)

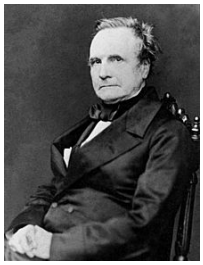
Last Lecture

- Course overview and logistics
  - Learn how to navigate the class Web page
  - Sign on Piazza
  - Find out about labs and office hours
- History of computing
  - Human-operated devices (abacus, Napier's bones)
  - Early mechanical devices (machines of Pascal and Leibniz)

Today's Lecture

- Continue with mechanical devices
  - Babbage, Hollerith
- Electromechanical computing
  - Harvard Mark 1

Charles Babbage (1791-1871)



- Mathematician, industrialist, philosopher, politician
- Frustrated by the many errors in printed mathematical tables (sines, cosines, logs, etc.) used in navigation and engineering.
- Observed that many long computations consist of operations that were regularly repeated.

The Difference Engine (1822)

- Computes the value of a polynomial such as

$$f(x) = ax + bx^2 + cx^3 + dx^4 + ex^5$$

  for lots of different values of x.
- Intended to be steam-powered, fully automatic

Who Cares About Polynomials?

- Taylor's Theorem: any differentiable function can be approximated by a polynomial.
  - The more terms in the polynomial, the more accurate the approximation.
  - Example: for x values between around -4 and +4, sin(x) can be well approximated by

$$f(x) = x - x^3/6 + x^5/120 - x^7/5040 + x^9/362880$$

Polynomials Without Multiplication

- Polynomials require multiplication, and even worse, exponentiation.
- Multiplication is difficult for mechanical calculators. Can we get rid of it?
- Yes, if…
  - We want to evaluate f(x) for a series of evenly-spaced values f(a), f(a+1), f(a+2), etc.
  - We're willing to compute a few special values by hand: f(a), $\Delta f(a)$, $\Delta^2 f(a)$, $\Delta^3 f(a)$, etc.

Method of Finite Differences

$f(x) = 2x^3 + 5x^2 - 4x + 3$

$\Delta f(x) = f(x+1) - f(x) = 2(x+1)^3 + 5(x+1)^2 - 4(x+1) + 3$
$\quad -(2x^3 + 5x^2 - 4x + 3)$
$\quad = 6x^2 + 16x + 3$

$\Delta^2 f(x) = \Delta f(x+1) - \Delta f(x) = 12x + 22$

$\Delta^3 f(x) = \Delta^2 f(x+1) - \Delta^2 f(x) = 12$ constant

Compute these initial values by hand

To get f(x+1) from f(x), use Δ as the increment:

$f(x+1) = f(x) + \Delta f(x)$

$\Delta f(x+1) = \Delta f(x) + \Delta^2 f(x)$

$\Delta^2 f(x+1) = \Delta^2 f(x) + \Delta^3 f(x)$

$\Delta^3 f(x+1) = \Delta^3 f(x)$ (because it is a constant)

Method of Finite Differences

$f(x) = 2x^3 + 5x^2 - 4x + 3$

x	$\Delta^3 f(x)$	$\Delta^2 f(x)$	$\Delta f(x)$	$f(x)$
0	12	22	3	3
1	12			
2	12			
3	12			

Method of Finite Differences

$f(x) = 2x^3 + 5x^2 - 4x + 3$

x	$\Delta^3 f(x)$	$\Delta^2 f(x)$	$\Delta f(x)$	$f(x)$
0	12	22	3	3
1	12	34	25	6
2	12			
3	12			

Method of Finite Differences

$f(x) = 2x^3 + 5x^2 - 4x + 3$

x	$\Delta^3 f(x)$	$\Delta^2 f(x)$	$\Delta f(x)$	$f(x)$
0	12	22	3	3
1	12	34	25	6
2	12	46	59	31
3	12			

Method of Finite Differences

$f(x) = 2x^3 + 5x^2 - 4x + 3$

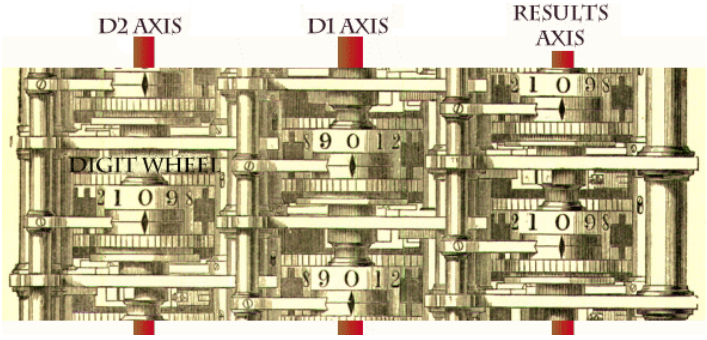
x	$\Delta^3 f(x)$	$\Delta^2 f(x)$	$\Delta f(x)$	$f(x)$
0	12	22	3	3
1	12	34	25	6
2	12	46	59	31
3	12	58	105	90

Method of Finite Differences

- $f(x) = 15x^2 + 110$
- $\Delta f(x) = f(x+1) - f(x) =$
- $\Delta^2 f(x) = \Delta f(x+1) - \Delta f(x) =$

x	$\Delta^2 f(x)$	$\Delta f(x)$	$f(x)$
0			
1			
2			
3			

Babbage's Difference Engine Computed 7th Degree Polynomials to 31 Digits



http://www.culture.com.au/brain_proj/CONTENT/BABBAGE.HTM

Building the Difference Engine

Photo of the
1832 Fragment
of a Difference Engine

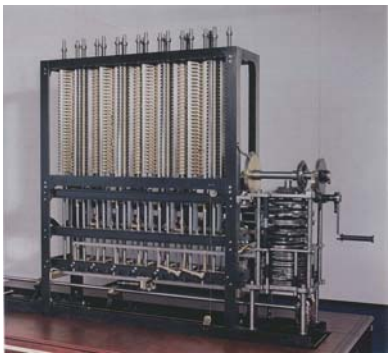


Photo of Babbage Difference Engine No. 2
constructed in 1991

(See video)

Charles Babbage: A Computing "Rock Star"

- Difference Engine (1822)
  - Never built (he ran out of money)
- Analytical Engine (1834-1836)
  - Babbage's more general "computer"
  - Never built, but its design is considered to be the foundation of modern computing
  - Had all the crucial features:
    - Arithmetic and logical operations
    - Digital data storage
    - Programs stored in memory

Ada Lovelace

- 1815-1852
- Daughter of poet Lord Byron
- Translated Menabrea's *Sketch of the Analytical Engine* to English
  - Quadrupled its length by adding lengthy notes and detailed mathematical explanations
- Referred to as the world's first programmer
  - Described how the machine might be configured (programmed) to solve a variety of problems.

Herman Hollerith

& The Hollerith Census Machine

- 1880 U.S. Census
  - The amount of data that needed to be analyzed was growing so quickly due to immigration
  - Required almost a decade to compute 1880 Census
- In 1882, Hollerith investigated a suggestion by Dr. John Shaw Billings, head of the division of Vital Statistics for the Census Bureau
  - "There ought to be some mechanical way of [tabulating Census data], something on the principle of the Jacquard loom, whereby holes in a card regulate the pattern to be woven."

Hollerith's Census Machine

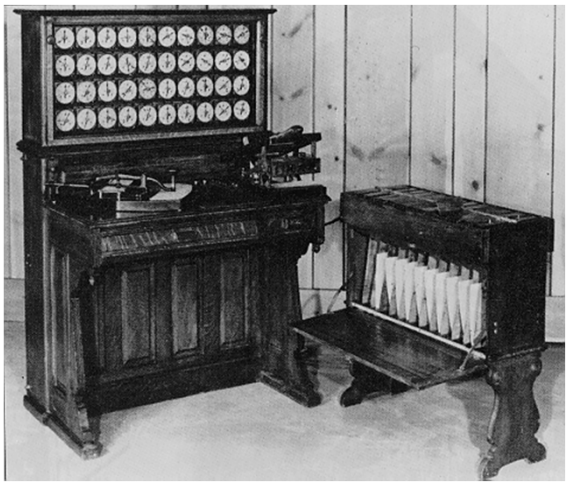


Photo: IBM

Hollerith's Census Machine

Photo of Pantographic Card Punch plate: from US Library of Congress

Photo from 1920 Census: Austrian, Geoffrey, *Herman Hollerith: Forgotten Giant of Information Processing*, Columbia University Press (1982).

Hollerith's Census Machine

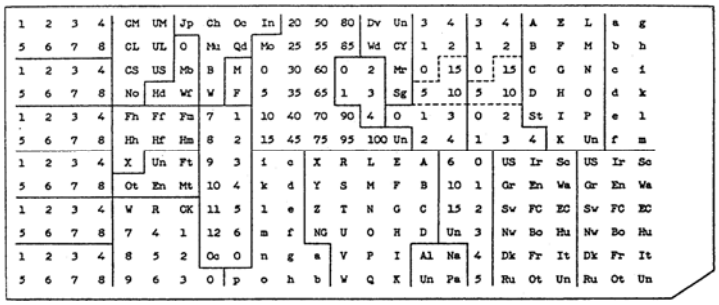
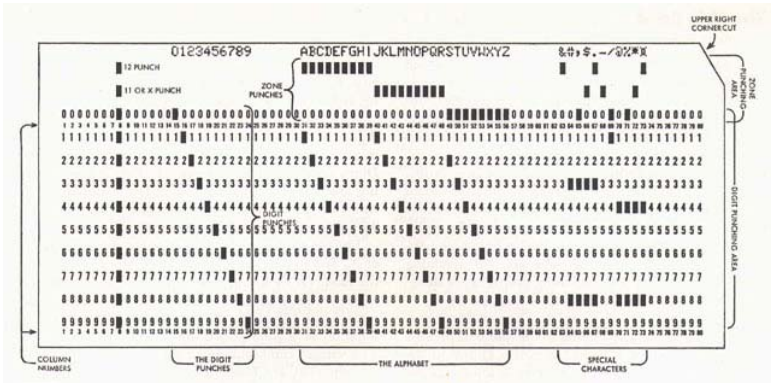


Photo of a punch card for the Hollerith machine, from *John McPherson, Computer Engineer*, an oral history conducted in 1992 by William Aspray, IEEE History Center, Rutgers University, New Brunswick, NJ, USA.

- The entire 1890 census data was processed in 3 months and complete 1890 data was published in 1892.
- Total population of the U.S.: 62,622,250

The Birth of IBM



An IBM punch card used from 1928 until the 1970s.

- Hollerith forms the Tabulating Machine Company in 1896 which eventually becomes IBM in 1924 through a merger and several name changes.

Alan Turing

- Considered the "father" of modern computer science.
- Presented formalisms for the notions of computation and computability in the 1930's.
- Worked at Bletchley Park in Great Britain during WWII to develop Collossus to help break the German Enigma Code.
- Developed the notion in 1950 of a test for machine intelligence now called the Turing Test.
- The Turing Award, the highest award in computing, is named in honor of Alan Turing.

Harvard Mark I

IBM Automatic Sequence Controlled Calculator

- Developed by Howard Aiken
- Contained more than 750,000 components
  - over 50 feet long
  - 8 feet tall
  - weighed ~5 tons
- Sounded like a "roomful of ladies knitting"

Harvard Mark I (IBM Archives)

Aiken

Electromechanical computer

First major American development in the computing race

Next Lecture

- Purely mechanical (Leibniz, Babbage)
- Electro-mechanical (Aiken's Harvard Mark I)
- Purely electronic (vacuum tubes)
  - 1000 times faster than electro-mechanical
- Stored-program digital computers
- Integrated circuits
- Microprocessors
- Quantum computers (in development)