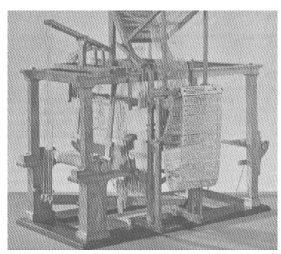
15-292 History of Computing

Computing in the 1800s: Charles Babbage and Herman Hollerith

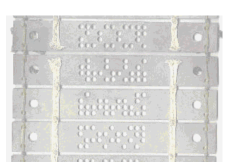
Based on slides originally published by Thomas J. Cortina in 2004 for a course at Stony Brook University. Revised in 2013 by Thomas J. Cortina for a computing history course at Carnegie Mellon University.

Jacquard Loom



- Developed in 1801 by Joseph-Marie Jacquard.
- The loom was controlled by a loop of punched cards.
- Holes in the punched cards determined how the knitting proceeded, yielding very complex weaves at a much faster rate.

[Jacquard-card Making.]



•from Columbia University Computing History http://www.columbia.edu/

Charles Babbage

- 1792-1871
- Known as the "(grand)father of computing"
- Mathematician, industrialist, philosopher, politician
- He wrote On the Economy of Manufactures (1832)
- He enjoyed fire.
  - he once was baked in an oven at 265°F for 'five or six minutes without any great discomfort'
  - on another occasion was lowered into Mount Vesuvius to view molten lava
- In 1837 he published his Ninth Bridgewater Treatise, to reconcile his scientific beliefs with Christian dogma.
  - He investigated biblical miracles.
  - made the assumption that the chance of a man rising from the dead is one in 10^{12}

Charles Babbage

- He hated music
- Neighbors hired musicians to play outside his windows
- When Babbage went out, children followed and cursed him
- He hated street musicians and pushed for the enforcement of Babbage's Act (1864) to silence them, causing much ridicule.
- Little known when he died
- In 1908, after being preserved for 37 years in alcohol, Babbage's brain was dissected by Sir Victor Horsley of the Royal Society
- While alive, he was belittled & marginalized by the British Press
- Years after his death, the press blamed the British government for not having the foresight to encourage (& fund) his work

- Ref: http://tergestesoft.com/~eddysworld/babbage.htm

The Table-Making Industry

- De Prony used human computers to calculate the Tables du Cadastre (1790)
  - Logarithmic tables using metric system to survey land & assess taxes for Napoleon's France
  - Devised his table-making operation using the principles of mass production
- Babbage worked on table-making project for the Nautical Almanac
  - For astronomers & navigators
  - Found the work tedious & error-prone
  - Key step in calculations: the method of differences

Method of Finite Differences

- Babbage's first computational machine was based on the method of finite differences.
  - For a polynomial f(x) of degree n, evaluated for successive integer values of x, the differences between successive values of the polynomial are values of a polynomial of degree n-1, the differences of these are values of a polynomial of degree n-2, etc., and the differences of order n are constant.
  - Given a polynomial has constant differences of order n, and the initial values of the differences of each order of the original polynomial, we can derive the values of f(x) for successive values of x using only addition.

Method of Finite Differences

Example

- $f(x) = x^2 + x + 1$
- First order difference $\Delta f(x)$
- $= f(x+1) - f(x) = (x+1)^2 + (x+1) + 1 - (x^2 + x + 1) = 2x + 2$
- Second order difference $\Delta^2 f(x)$
- $= \Delta f(x+1) - \Delta f(x) = 2(x+1) + 2 - (2x + 2) = 2$
- Given: $f(0) = 1$, $\Delta f(0) = 2$, $\Delta^2 f(0) = 2$ (note: all $\Delta^2 f(x) = 2$)
  - $\Delta f(1) = \Delta f(0) + \Delta^2 f(0) = 2 + 2 = 4$
  - $f(1) = f(0) + \Delta f(0) = 1 + 2 = 3$ $(f(1) = 1^2 + 1 + 1 = 3)$
  - $\Delta f(2) = \Delta f(1) + \Delta^2 f(1) = 4 + 2 = 6$
  - $f(2) = f(1) + \Delta f(1) = 3 + 4 = 7$ $(f(2) = 2^2 + 2 + 1 = 7)$
  - $\Delta f(3) = \Delta f(2) + \Delta^2 f(2) = 6 + 2 = 8$
  - $f(3) = f(2) + \Delta f(2) = 7 + 6 = 13$ $(f(3) = 3^2 + 3 + 1 = 13)$
  - etc.

Difference Engine

- Babbage demonstrated in 1822 that this concept was feasible and could be built with enough funds.
  - Partially funded by British government for promise to improve table-making process (both cost and reliability)
  - Unfortunately, the engineering was more difficult than the conceptualization
  - Two tasks: design the Difference Engine & develop the technology to manufacture it
- A prototype was built in 1833 but a complete functioning machine was never built because:
  - Babbage was a perfectionist
  - Babbage lost interest
- 1853 – Georg and Edvard Scheutz of Sweden create the first complete difference engine and the first calculator in history to be able to print out its results.

Babbage Difference Engine

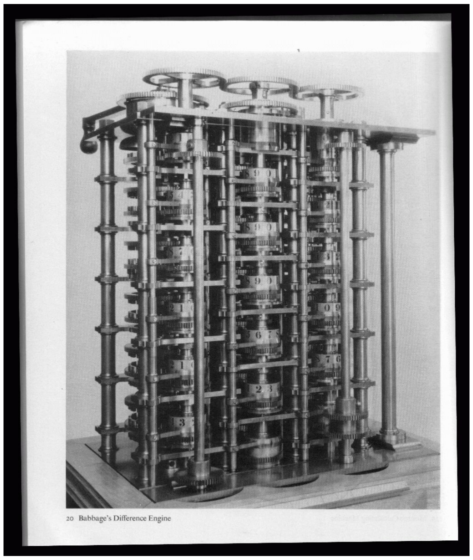
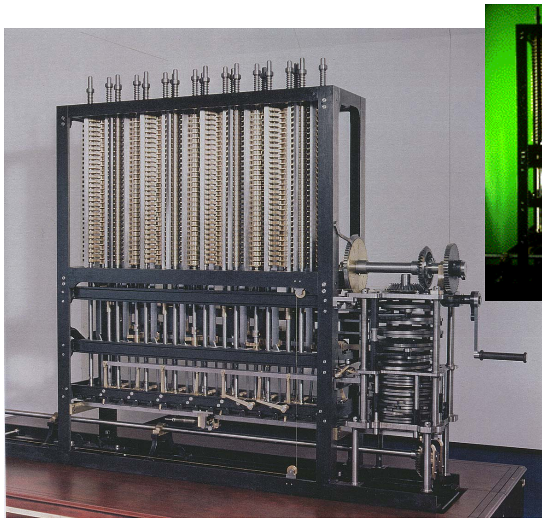


Photo of the
1832 Fragment
of a Difference Engine

fragment made by
H.P.Babbage
from parts of
Difference Engine No.1

Babbage Difference Engine



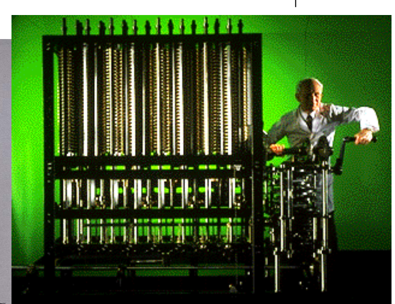


Photo of Babbage
Difference Engine No. 2
constructed in 1991

On display at London's
Science Museum

Information Processing

- Industry demands for high-volume information processing grew greatly in 1800s
  - Census tabulations (nothing new)
  - Industrial revolution & mass production
  - Centralized financial institutions
  - Railway management
  - Telegram management
  - Insurance industry
    - The "thrift movement" & shift from agricultural to industrial societies were contributing factors

Analytical Engine

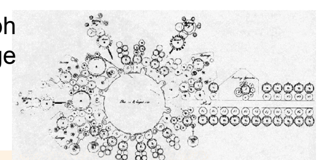
- Designed around 1834 to 1836
  - was to be a universal machine capable of any mathematical computation
  - embodies many elements of today's digital computer
  - a control unit with moveable sprockets on a cylinder that could be modified
  - separated the arithmetic operations (done by the mill) from the storage of numbers (kept in the store)
    - store had 1000 registers of 50 digits each
  - Babbage incorporated using punched cards for input
    - idea came from Jacquard loom
- Never built by Babbage due to lack of funds and his eventual death in 1871

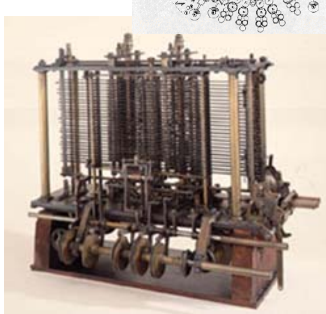
Analytical Engine

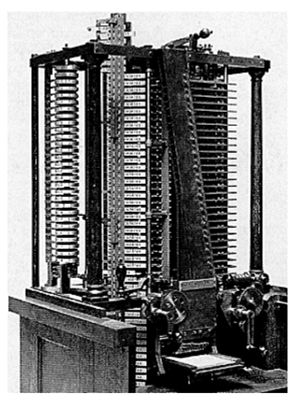
- Design included a means to perform conditional branching (decision making capabilities)
  - based on whether the difference between two values was positive or negative.
- Example: Repeat calculation if 423 < 511.
- This means check if 423 – 511 < 0 (negative)
- 00000 00423
- – 00000 00511
- 999999 99912
- Instructions for the Engine would be stored on punch cards strung together with loops of string to form a continuous chain.

Analytical Engine

lithograph by Babbage







Analytic Engine completed by Babbage's son, Henry

- Portion of the mill of the Analytical Engine with printing mechanism, under construction at the time of Babbage's death.

Going to London? Go to the Science Museum

- Portion of Babbage's calculating machine (Difference Engine) (1832)
- Portion of Analytical Engine, under construction at the time of Babbage's death (1871)
- Difference Engine No. 2, built by the Science Museum (1991)
- Experimental models and moulds from Charles Babbage's work on calculating machines (1870)
- Scheutz Difference Engine (1843)
- Difference Engine No. 2, trial piece made in the Science Museum Workshop (1989)

Ada Augusta Byron, Countess Lovelace

- 1815-1852
- Daughter of poet Lord Byron
- Mathematician who assisted Babbage in his work
  - much admired by Babbage, she understood the significance of his work, which others did not
- Translated Menabrea's Sketch of the Analytical Engine to English (described Babbage's machine)
  - quadrupled its length by adding lengthy notes and detailed mathematical explanations
- Some refer to as the world's first programmer
  - recently, historians have disputed this moniker, including our authors
    - says most of the technical content & all of the programs were Babbage's
  - Ada programming language named for her
  - Weaved coded instructions on punched cards
    - based on a language that was compatible with the Analytical Engine.

Carrying on the Vision

- Others made their own analytical engines, updating Charles Babbage's design
  - Henry P. Babbage (son)
    - created an assemblage of part of the Engine in 1910 (the mill and the printer)
  - Percy Ludgate, accountant (1883-1922)
    - replaced punched cards with perforated paper roll
    - electric motor used to drive main cyclinder
  - Torres y Quevedo
    - used electromagnetic relays to create an elementary analytical engine exhibited in Paris in 1914.

The U.S. in the 1800s

- 20-30 years behind Europe in economic development
  - While Europe was becoming industrialized in the 1830s, the U.S. was still mainly agricultural
  - After U.S. Civil War (1860s), American companies began to develop big offices
  - This delay (compared to Europe) allowed American companies to take full advantage of emerging office technologies
    - Timing is everything
  - Another important factor: American companies' "love affair with office machinery"
    - America was "gadget crazy"
    - American companies were more likely to buy useful or useless machinery than their European counterparts
    - America soon became the leading producer of information technology goods
      - Dominated type-writer, record keeping, & adding machine industries

U.S. Census

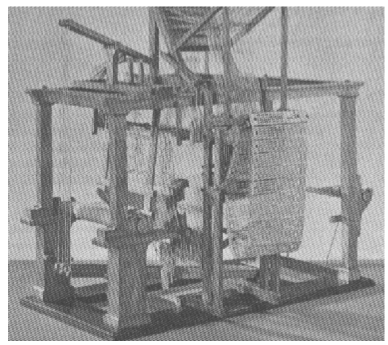
- Steadily increasing population
  - Early census had little info collected concerning demographics
- 1790 – 3.9 million
- 1840 – 17.1 million
  - 28 clerks in the Bureau of the Census
- 1860 – 31.4 million
  - 184 clerks
- 1870 – 38.6 million
  - 438 clerks
  - census report 3473 pages
- 1880 – 50.1 million
  - 1495 clerks
  - census report 21,000 pages
  - took 7 years to compile

Herman Hollerith

- Born Feb. 29, 1860 in Buffalo, NY
- Son of immigrant parents from Germany
- Schooled at home privately
- Worked at the US Census Bureau as in 1880
- Joined MIT as a mechanical engineering lecturer in 1882.
- Joined the U.S. Patent Office in Washington DC in 1884.

The 1880 U.S. Census

- The amount of data that needed to be analyzed was growing quickly
  - Required seven years to process 1880 Census
- In 1882, Hollerith investigated a suggestion by Dr. John Shaw Billings
  - "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."



The Hollerith Electric Tabulating System

- Initially tried to store data as holes punched on paper tape.
  - inspired by train ticket
  - switched to the punched card as a better solution.
  - one card for each citizen
- A pin would push through holes in a card into mercury placed below the card to complete an electrical connection, causing a counter to advance.
- First tested on tabulating mortality statistics in 1887
- U.S. Census Bureau held a contest for a mechanical device to be used to count 1890 census
  - 3 entries
  - Hollerith's device won contest and so was used

The Hollerith Electric Tabulating System

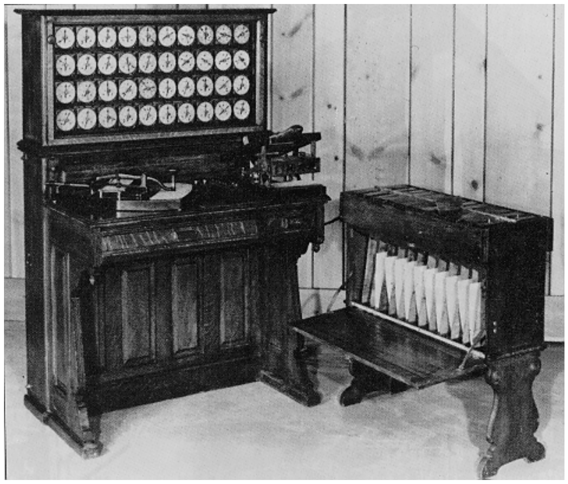
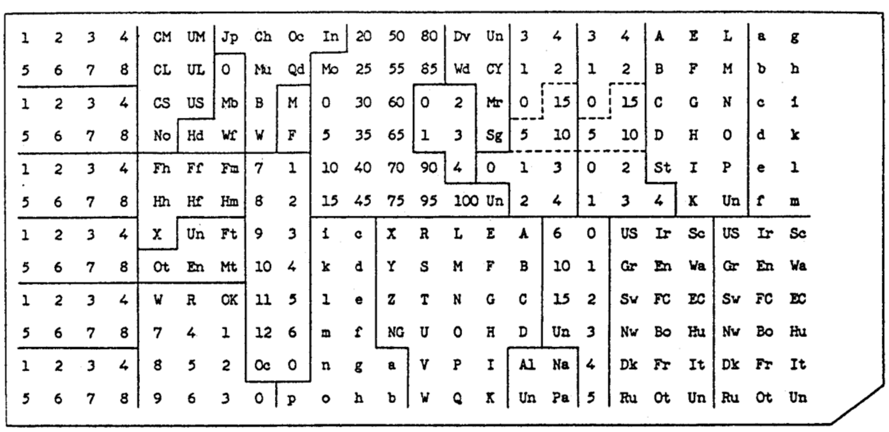


Photo: IBM

1890 U.S. Census Punched Card



1890 U.S. Census

- The Hollerith machine saved the U.S. Government $5 Million
  - 2000 clerks
- The population count was tallied in 3 months
  Data was processed in 2 ½ years
  - Total population of the U.S.: 62,622,250
  - System was also used for census work in Canada, Norway, Austria and the UK
- Awards:
  - Elliot Cresson Medal by the Franklin Institute
  - Gold Medal of the Paris Exposition
  - Bronze Medal of the World's Fair in 1893

The Press wasn't so enthused

- The public (and local politicians wanting more federal money) thought the 1890 count was inaccurate
- The press echoed these concerns
- "Useless Machines"
  - The Boston Herald
- "Slip Shod Work Has Spoiled the Census"
  - The New York Herald

The Birth of IBM

- Hollerith founded the Tabulating Machine Company in 1896.
- Machines used again in the 1900 U.S. Census
- Advanced machines made by rival James Powers used in 1910 U.S. Census
  - Powers forms Powers Tabulating Machine Company in 1911
- Hollerith's company merged into Computer Tabulating Recording Company (CTRC)
  - Hollerith serves as consulting engineer with CTRC until retirement in 1921.
- CTRC was renamed International Business Machines Corporation in 1924.

Modern Punch Cards

- Used from 1928 until the mid 1970s.
- Still used up to 2000 in voting machines in the U.S. Presidential election
  - leads to the "Hanging Chad" controversy