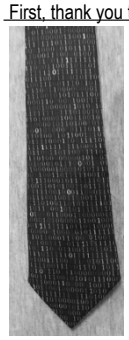
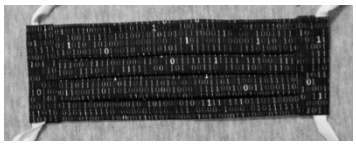
First, thank you to someone special





 1

A Retrospective
from
My Perspective

WALTER E. BROWN, PH.D.

< webrown.cpp @ gmail.com >

A little about me

- B.A. (math's); M.S., Ph.D. (computer science).
- Professional programmer for over 50 years, programming in C++ since 1982.
- Experienced in industry, academia, consulting, and research:
  - Founded a Computer Science Dept.; served as Professor and Dept. Head; taught and mentored at all levels.
  - Managed and mentored the programming staff for a reseller.
  - Lectured internationally as a software consultant and commercial trainer.
  - Retired from the Scientific Computing Division at Fermilab, specializing in C++ programming and in-house consulting.
- Not dead — still doing training & consulting. (Email me!)

 3

Emeritus participant in C++ standardization

- Written ~170 papers for WG21, proposing such now-standard C++ library features as gcd/lcm, cbegin/cend, common_type, and void_t, as well as all of headers <random> and <ratio>.
- Influenced such core language features as *alias templates*, *contextual conversions*, and *variable templates*; recently worked on *requires-expressions*, operator<=>, and more!
- Conceived and served as Project Editor for *Int'l Standard on Mathematical Special Functions in C++* (ISO/IEC 29124), now incorporated into C++17's <cmath>.
- Be forewarned: Based on my training and experience, I hold some rather strong opinions about computer software and programming methodology — these opinions are not shared by all programmers, but they should be! ☺

 4

What's This Talk About?

First things first,
but not necessarily in that order.

— DR. WHO

As a boy, I was an indifferent student of history, but ...

- "The older you get, the more interested you are in history."

  — William Brobeck

- "Why should we look to the past in order to prepare for the future?

  Because there is nowhere else to look."

  — James Burke

- "If you want the present to be different from the past, study the past."

  — Benedictus de Spinoza

 6

In today's talk

- A number of snapshots of our discipline's evolution:
  - A curated (by me) history of calculation & computing, …
  - From ancient times to my time (in a sometimes hyper-linked order, rather than strictly chronologically), …
  - Featuring factoids re people and accomplishments (some well-known, others less so) that I have found interesting, …
  - And that bear on our field's origins.
- I will highlight a few of which I have direct knowledge:
  - Some people, …
  - Some experiences, and …
  - Some recollections of programming almost 60 years ago.

 7

A caveat

- "It is a fact of life that oversimplified accounts of the development of science are often necessary ….
- "This necessitates the distilling of certain events and personalities from the melee …
- "[keeping only] those who are deemed to have made the most important contributions.
- "…. But it often leaves behind forgotten geniuses and unsung heroes."

— Jim Al-Khalili, 2011

 8

So …

- If I omit mention of your favorite personage of yore:
  - Or of your favorite mathematical, technical, or scientific advance of yore,
  - Or of your favorite algorithm of yore,
  - Or of your favorite anything else of yore, …
- Then ① please do accept, in advance, my apologies.
- But also ② please do keep in mind that *I'm a programmer, Jim, not a historian*:
  - I want only to share a few historical nugget
  - That I've found meaningful/interesting/enl
  - But nearly every page is worthy of its own talk!

 9

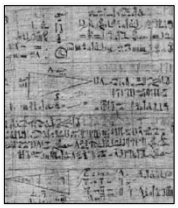
Calculating through the Ages

… I am ill at these numbers.
I have not art to reckon….

— *Hamlet*

The oldest known homework-like math problems

- Alex. Rhind's Egyptian Papyrus (~1650 BCE) is a hieratic palimpsest (33 cm × 5+ m long) that's a copy, by "Ahmes the Scribe," of a still-older work.
- 87 partly-worked problems make up ~⅔ of the work:
  - *E.g.*, "Divide 100 loaves among 10 men including a boatman, a foreman and a doorkeeper, who receive double portions. What is the share of each?"



 12

A millenium later …

- When Greece started trading at ports on the river Nile, Thales and his student Pythagoras each visited Egypt, absorbing geometry ("earth measure," ~685..~525 BCE):
  - Pythagoreans later contributed new techniques of abstraction and generalization, and of reasoning deductively and demonstrably.
  - Coined μάθημα ("knowledge, study, learning").
- "Everything is expressible in terms of numbers."
  - "The fact that you could describe reality in terms of numbers was … probably the most fundamental breakthrough ever."

— Alexander Stepanov

 13

Soon thereafter …

- Euclid (~325..~265 BCE) organized all then-known math's in *The Elements* (the all-time 2nd best-seller, in 13 vol's).
- A few years later, among much other work, Archimedes of Syracuse (287..212 BCE) proved numerous theorems re bounded shapes and areas, very nearly discovering the integral calculus.
- A 10th-century copy of Archimedes' *On the Method of Mechanical Theorems* was (in 1229) "unbound, scraped and washed," then "folded in half, rebound and reused" for a liturgical text written at right angles to the original. (Sigh.)

 14

A lost work, rediscovered and reclaimed

- Modern imaging has managed to recover most of the original text.
- It's still the only known copy of this (previously-lost) work that introduced the idea of *infinitesimals*.

 15

Zu Chongzhi 祖沖之 (429..500)

- Also known as Wenyuan, he was "a Chinese astronomer, mathematician, politician, inventor, and writer."
- Using only counting rods, calculated that π lay between 3.1415926 and 3.1415927, accuracy "which would not be surpassed for 800 years."
- $\pi \approx 355/113$ is to this day known as Zu Chongzhi's pi ratio or simply as Zu's fraction.
- His other insights include the volume of a sphere and numerous highly accurate astronomical calculations.

 16

Brahmagupta (~598..~668)

- Indian mathematician and astronomer.
- Authored *Brahmasphuṭasiddhanta* (628), the 1st book re calculating with zero and with negative numbers:
  - The "earliest known text to treat zero as a number in its own right, rather than as simply a placeholder digit …."
  - Provided rules for all 4 fundamental operations, as well as much more original work in algebra and geometry.
  - Considered "an important milestone" and a "decisive step" in the development of mathematics.
  - Originally in Sanskrit, this book was translated into Arabic by Muhammad al-Fazari ~100 years later.

 17

Pierre-Simon, marquis de Laplace (1749..1827)

- French polymath who influenced "engineering, mathematics, statistics, physics, astronomy, and philosophy."
- "It is India that gave us the ingenious method of expressing all numbers by means of ten symbols,
- "… each symbol receiving a value of position as well as an absolute value; … a profound and important idea which appears so simple to us, now, that we ignore its true merit."

 18

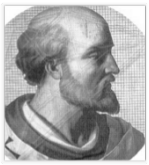
Muḥammad ibn Mūsā al-Khwārizmī (~780..~850)

- Influential Persian scholar:
  - "That fondness for science … has encouraged me to compose a short work on calculating …
  - "… by *al-jabr* [completion; moving a subtracted quantity to the other side of an equation] …
  - "… and *al-muqabala* [balancing; subtracting equal amounts from both sides of an equation]…."

- A Latin translation (1145) of this book was the principal math text in European universities for ~400 years.

 19

Gerbert of Aurillac, Pope Sylvester II (~946..1003)

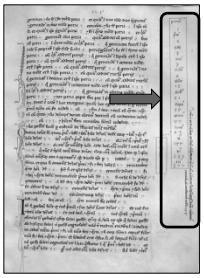


- A prolific French scholar and teacher.
- He "learned Arabic numerals at al-Qarawiyyin University in Fes/Fez, Morocco" ("the oldest existing, continually operating higher educational institution in the world").
- He subsequently "endorsed and promoted study of Arab and Greco-Roman arithmetic, mathematics, and astronomy."

 20

Leonardo of Pisa, son (*filius*) of Bonacci (~1170..~1245)

- Described as "the most talented Western mathematician of the Middle Ages."
- Wrote *Liber Abaci* (*Book of Calculation,* 1202, 1223 [2nd ed.]):
  - Introduced Hindu-Arabic numerals to the West.
  - Showed numerous (mostly business) applications of same.
  - Also "posed and solved a problem involving the growth of a population of rabbits …."

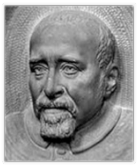


 21

Robert Recorde (~1512..1558)

- Welsh mathematician & physician.
- Advocated + [Nicole Oresme, 1360] and − [Johannes Widmann, 1489] symbols with their modern meanings (1540).
- Wrote the first English-language books on algebra (1543, 1557).
- Originated the equals sign (1557), explaining:

  "And to avoide the tediouſe repetition of theſe woordes : is equalle to : I will … vſe, a paire of paralleles, or Gemowe [twin] lines of one lengthe, thus: ═, bicauſe noe .2. thynges, can be moare equalle."



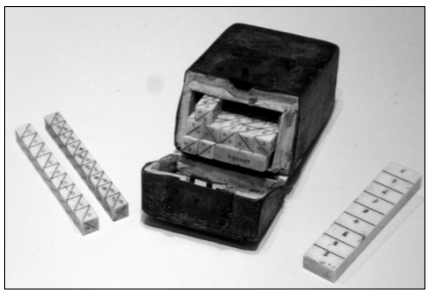
 22

John Napier of Merchiston (1550..1617)

- Scottish mathematician, physicist, and astronomer:
  - "Seeing there is nothing … so troublesome … tha[n] the multiplications [and] divisions … of great numbers, which besides the tedious expence of time, are … subject to many slippery errors, I began, therefore, to consider … by what … art I might remove these hindrances."
  - Invented devices for calculating products and quotients: *Napier's bones* (based on *rabdology*) and the *promptuary*.
- Originated the logarithm (1614):
  - Not today's natural log (*ln*), as …
  - *e* wasn't known until J. Bernoulli (1683).

 23

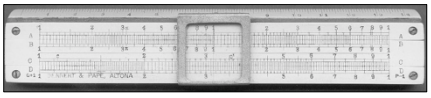
Napier's bones (ivory, ~1650)



 24

William Oughtred (1574..1660)

- English mathematician and Anglican clergyman, who:
  - Invented the slide rule (~1622).
  - Originated (~1631) the × symbol for multiplication.
  - Originated the abbrev's *sin* and *cos*.
- Wrote *Clavis Mathematicae* (*Key to Math's*), which became the standard English-language algebra text.



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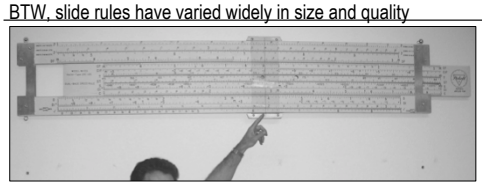
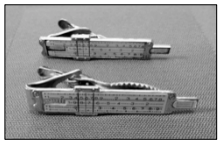
BTW, slide rules have varied widely in size and quality





 26

Johann Heinrich Rahn (1622..1676)

- Swiss mathematician who held many administrative posts in Zürich:
  - Was tutored in algebra by English mathematician John Pell (who was then Oliver Cromwell's representative to the Protestant cantons).
- Best remembered for his German book *Teutsche Algebra* (1659), on which Pell collaborated:
  - First appearance of ÷ (an obelus) as division symbol.
  - First appearance of ∴ to mean therefore.
  - English translation replaced Oughtred's book in teaching.

 27

Blaise Pascal (1623..1662)

- French mathematician, physicist, and theologian, perhaps best known for his contributions to probability theory.
- He also worked (1642) on calculating machines, building 50 prototypes in 3 years, and then built "20 finished machines [later known as *Pascalines*] over the following 10 years."

 28

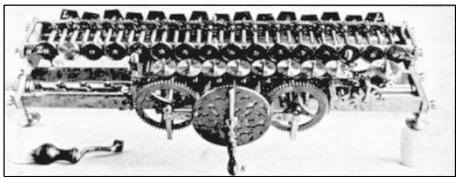
Gottfried Wilhelm von Leibniz (1646..1716)

- German polymath, best known for his inception of the calculus (contemporaneous with but independent of Newton), and whose notation is preferred to this day.
- He also "simplified the binary [number] system and articulated logical properties such as

  - ▪ "conjunction, ▪ disjunction, ▪ negation, ▪ … inclusion, and ▪ the empty set."
- Also invented (~1672..1694) a device "that could execute all four arithmetic operations" (although carries did not work reliably, alas).

 29

Leibniz' *stepped reckoner* (housing removed)



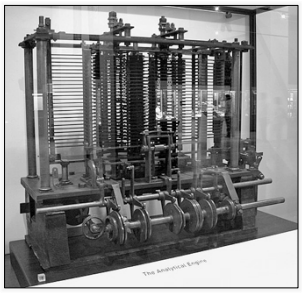
 30

Charles Babbage (1792..1871)

- "I wish to God these calculations had been executed by steam."
  — 1821
- "As soon as an Analytical Engine exists, it will necessarily guide the future course of science.
- "… the question will then arise—By what course of calculation can these results be arrived at by the machine in the *shortest time*?"
  — 1864

 31

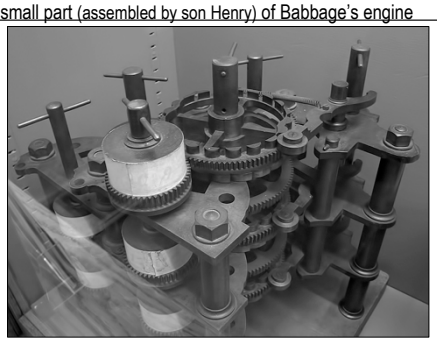
Babbage's trial model of (part of) his "Analytical Engine"



- Featured an arithmetic-logic unit, conditional branching and looping, and memory.
- All mechanical, but never finished by Babbage, nor by his son Henry.

 32

A small part (assembled by son Henry) of Babbage's engine



 33

Ada (née Byron) King, Countess of Lovelace (1815..1852)

- "The Analytical Engine does not occupy common ground with mere 'calculating machines.' It holds a position wholly its own…."
- "The Analytical Engine has no pretensions whatever to *originate* anything. It can do *whatever we know how to order it* to perform."

 34

In My Grandmother's Time: From Calculating to Computing

Never send a human
to do a machine's job.

— *The Matrix*

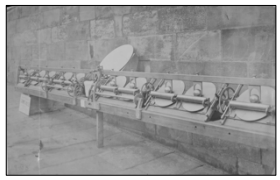
Office desktop mechanical calculators (mid- to late-1800s)

- Shown:
  - ① An Arithmometer,
  - ② A Comptometer,
  - ③ A Dalton adding machine,
  - ④ A Sundstrand, and
  - ⑤ An Odhner Arithmometer.
- "Each one has a different user interface."

 36

James (1822..1892) & William (Lord Kelvin, 1824..1907) Thomson

- Via descriptions in three papers, invented the differential analyser (1876), "a mechanical analogue computer designed to solve differential equations …, using wheel-and-disc mechanisms to perform the integration."



 37

Jean-Maurice-Émile Baudot (1845..1903)

- French telegraph engineer and telecommunications pioneer.
- Invented the *Baudot telegraph code*, "the first means of digital communication" (1870):
  - A 5-bit code for transmitting the Latin alphabet, punctuation, and control signals.
  - Also patented a multiplexing printing telegraph (1874), improved to use punched tape input (1897).

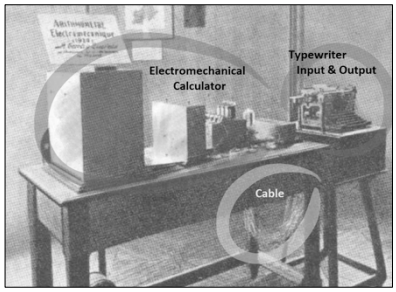
 38

Leonardo Torres y Quevedo (1852..1936)

- Spanish civil engineer/mathematician.
- Presented "the idea of floating point arithmetic" in *Essays on Automatics* (1913), but did not anticipate how important his idea would become.
- Built *El Ajedrecista* (*The Chessplayer*), an automaton that is today "considered the world's first computer game" (1914).
- Showed that "electromechanical parts" could implement "all of the cogwheel functions of a [Babbage-like] calculating machine" (1914, 1920).

 39

Torres' 1920 electromechanical arithmometer



 40

Herman Hollerith (1860..1929)

- Founded the *Tabulating Machine Company*, 1896.
- Amalgamated with 3 other companies to form the *Computing-Tabulating-Recording Company* (CTR), 1911.
- CTR was renamed the *International Business Machines Corporation* (IBM), 1924.

 41

Hollerith's motivation and inventions

- The U.S. 1880 census data took ~8 years to process:
  - At that rate, the 1890 census data would not be processed before it was time for the 1900 census.
- To assist with census data processing, Hollerith invented such unit record machines as the keypunch, sorter, and tabulator.
  - The U.S. 1890 census data took only ~6 years to process.
- "Prior uses of machine readable media had been for lists of instructions (not data) to drive programmed machines such as Jacquard looms and mechanized musical instruments."

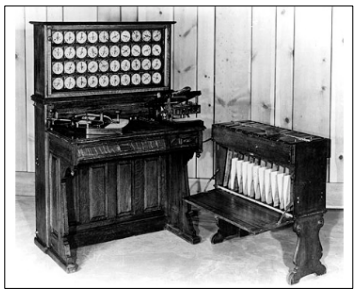
 42

The beginning of modern data processing

- Hollerith's insight:
  - "A key idea was that a datum could be recorded by the presence or absence of a hole at a specific location on a card.
  - "[He] determined that data in specified locations on a card … could be counted or sorted electro-mechanically."
- How was this accomplished early on?
  - "A tabulating machine processed these cards by pushing pins through the holes to … cups of mercury beneath.
  - "This completed an electrical circuit, advancing a dial on the tabulator."

 43

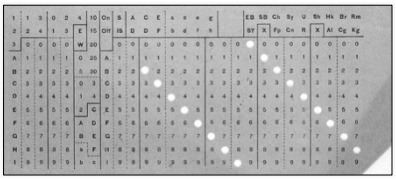
Hollerith's tabulator and sorter



 44

Hollerith's punch card

- 45 columns, with round holes.
- 3¼ × 7⅜ in., sized to match U.S. currency of that era, to take advantage of existing drawers, etc.



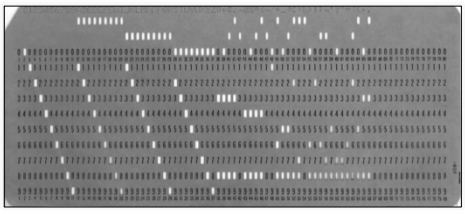
 45

Hollerith's Pantographic Card Punch

 46

IBM's 80-column punch card was introduced in 1928

- Kept the 3¼ × 7⅜ in. dimensions of Hollerith's cards, …
- But now with (patented!) rectangular holes in 12 positions/column (10 until 1930).



 47

IBM 026 printing keypunch machine (1949)

- Upper-case only.
- A typo was fatal; had to discard the card.
- But sometimes could save time by dup-ing the correct columns and rekeying only the wrong ones.

 48

Another view of an IBM 026 keypunch

 49

IBM 082 card sorter (1949) (based on radix sort)

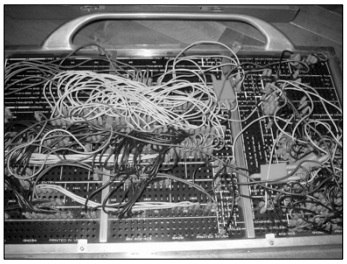
 50

Unit record equipment later became "programmable"

- "The earliest machines were hard wired for specific applications.
- "Control panels [also known as wiring panels or plugboards] were introduced [by Hollerith!] in 1906 ….
- "Removable control panels were introduced … in the 1920s.
  - "Applications then could be wired on separate control panels, and inserted … as needed.
  - "Removable control panels [were] used [when] the machines' … different applications required rewiring."

 51

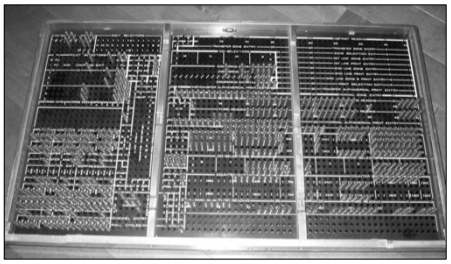
Plugboard from an IBM 402 Accounting Machine (front view)



- Dates from ~1948.
- Note the patch cords.
- Plugged into hubs/ jacks/ sockets.
- Heavy! The handle is sized for two hands!

 52

Plugboard from an IBM 402 Accounting Machine (rear view)



 53

The "obstacle of the plugboard"

- "[T]he plugboard [was] a spaghetti-like array of cords and plugs that tell a machine what to do — move this information here, perform this action on that output and so forth.
- "These control panels … were nightmarishly constructed Gordian knots of complexity and confusion.
- "They were slow, time-consuming, and above all, expensive."

— attributed to Francis Underwood
(who had worked w/ Arnold Spielberg, Steven 's father)

 54

The Advent of Modern Computing

"You'd make a splendid computer, Mr. Spock."
"That is very kind of you, Captain."

— *Star Trek*, "The Return of the Archons"

Vannevar Bush (1890..1974)

- American engineer, holding a joint doctorate from MIT and Harvard.
- Among his many accomplishments:
  - Authored the seminal textbook *Operational Circuit Analysis* (1927).
  - Designed the *differential analyzer*, a mechanical analog computer (1931).
  - Administered numerous agencies, thus significantly influencing U.S. scientific research for decades.
  - Created "the idea of computer networks and hypertext" (1945).

 61

Bush's 1931 *differential analyzer*

 62

Programming the *differential analyzer*

- Applied the same principles to integrate differential eq'ns as did the Thompsons' 1876 machine, but independently invented/differently constructed.
- Used "a series of gears and shafts to engage cogs until the equation was solved":
  - "Setting it up to work one equation could take two to three days; solving the same equation could take equally as long, if not longer.
  - "In order to work a new problem, the entire machine, … several hundred feet of floor space, had to be torn apart and reset to a new mechanical configuration."

 63

Claude E. Shannon, Jr. (1916..2001)

- American mathematician, electrical engineer, and cryptographer; a distant cousin of Thomas Edison.
- Among his many accomplishments:
  - Laid the foundation, in his master's thesis (1937), of all digital circuit design, demonstrating a full adder, among many other circuits.
  - Founded information theory (1944, 1948), "a broad and deep [discipline]," which coined ***bit*** as the fundamental unit of information.
  - Invented "a Roman numeral computer called THROBAC, juggling machines, and a flame-throwing trumpet." 😄

 64

Howard H. Aiken (1900..1973)

- Physicist, designer of IBM's ASCC (Automatic Sequence Controlled Calculator, a.k.a. the Mark I, installed 1944 at Harvard).
  - Mostly mechanical: ~51' x 8' x 8'.
  - Aiken's *Harvard architecture* segregated instruction memory from data memory.
  - Programmers included Lt. (later Adm.) Dr. Grace Hopper.
- "Originally one thought that if there were a half dozen large computers in [the U.S.A.], hidden away in research laboratories, this would take care of all requirements we had throughout the country." — 1952

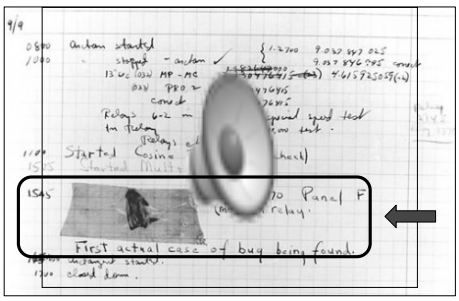
 65

Grace B. Hopper (née Murray, 1906..1992)

- Taught math at Vassar until joining the U.S. Navy Reserves, the start of a 42-year Navy career, initially working for Aiken.
- At the Eckert–Mauchly Computer Corp., helped develop the UNIVAC I, "the first large-scale electronic computer … on the market in 1950."
  - Wrote some of the earliest linker and loader software.
  - Then [1951] "I decided data processors ought to be able to write their programs in English, and the computers would translate them into machine code. That was the beginning of COBOL …."

 66

Logbook page documenting the 1st bug (1947)



 67

USS *Hopper* (commissioned 1997)

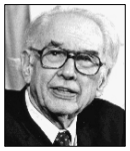
 68

Konrad Zuse (1910..1995)

- A German civil engineer (by training), inventor, and businessman.
- Between 1935 and 1945/50, he devised & built four binary floating-point calculating machines (the Z1, Z2, Z3, and Z4), largely relay-based with some limited programmability.
  - Zuse thought vacuum tubes a „*Schnapsidee*" (crazy idea).
  - The Z3 is now considered the 1st *Turing-complete* machine.
- In 1945, he designed "the first high-level programming language, Plankalkül (*Plan Calculus*) [and demonstrated it by coding] the first real computer chess engine."

 69

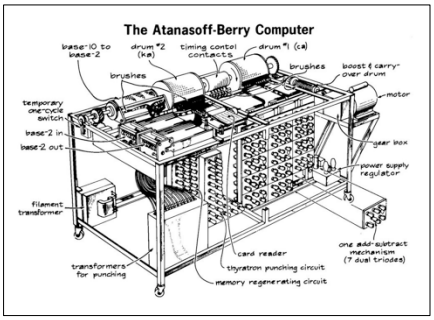
At Iowa State College (Ames, Iowa, USA)



- Motivated by students' need to solve difficult differential eq'ns, …
- Prof. (of Physics & Mathematics) John V. Atanasoff designed and built the world's first electronic digital computer (1937-1941).
- Assisted by engineering graduate student Clifford E. Berry, …
- J.V.'s new device was named the ABC: the *Atanasoff-Berry computer*.

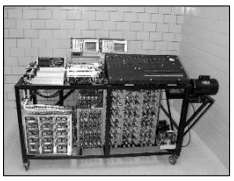
 70

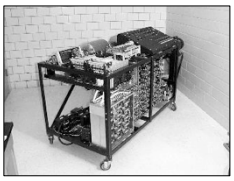
ABC schematic; designed to solve differential eq'ns



 71

A modern replica of the ABC





- It "was the size of a desk, weighed 700 pounds, had over 300 vacuum tubes, and contained a mile of wire.
- "It could [do] about one operation every 15 seconds."

 72

Where the ABC was born

 73

What is the ABC's historical sigificance?

"The ancestry of all electronic digital systems
appears to be traceable
to … the Atanasoff-Berry Computer."

— R. K. Richards,
Electronic Digital Systems,
1966

 74

Did the ABC really work?

- "Some have claimed that no one ever used the original ABC for production computing. We have found evidence to the contrary.
- "[In particular,] Atanasoff collaborated with the well-known applied statistician [George] Snedecor at ISU.
  - "… Snedecor sent a steady stream of small linear systems to the ABC for solution, and [the machine] would have been very well suited to regression, least squares, curve-fitting problems.
  - "[The Math dept. sec'y] Clara Smith verified [by hand] some of the results for Snedecor…."

— John L. Gustafson

 75

What happened to the original ABC?

- Dr. Robert M. Stewart, Jr., became the founding chair of the Computer Science Department at Iowa State Univ. of Sci/Tech, my graduate *alma mater*.
- But in the late 1940s, Bob was a new physics graduate student at what was then Iowa State College:
  - He was told to clear out a corner of a laboratory for his use as an office and, while doing so, ...
  - He disassembled the ABC, the world's first electronic digital computer; other projects then reused those parts.
- After Bob told me this story, I urged him to submit it for publication in *Annals of the History of Computing*; it appeared in 1984 ("The End of the ABC," v6, #3)!

 76

Dr. Robert M. Stewart, Jr. (1924..2017)

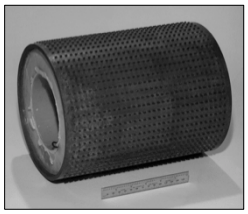
Professor of Physics,
Electrical Engineering,
and Computer Science;

Founding Chair,
Dept. of Computer Science,
Iowa State University
of Science and Technology;

In pacem requiescat.

 77

Drum memory, sole remnant of the ABC



- Stores 30 2's complement numbers in "columns" of 50 bits each, plus two spare columns.
- The columns operated in parallel.
- It is the first known use of DRAM, with capacitors storing 0s and 1s periodically refreshing their state.

 78

My encounters with J.V. Atanasoff

- When I first met J.V. (1973), he very kindly and patiently answered my question, "Why base 2?"
  - First, he said, he'd calculated that the optimal choice of encoding would have been base ***e*** ! (e = 2.71828…)
  - For practical reasons, though, that meant bases 2 and 3 were the only serious contenders.
  - He then explained that, at the time, bi-stable devices were both less expensive and more reliable than were tri-stable devices, hence his decision favoring base 2.
- The following decade, I submitted J.V.'s name as a candidate for a Sc.D. (*honoris causa*), a degree that was conferred later that year.

 79

J. V. Atanasoff being hooded, 1981

 80

Dr. John Vincent Atanasoff, OCM (1903..1995)

Prof. of Mathematics and Physics, Iowa State College;

Inventor of the electronic digital computer;

Recipient of the (U.S.) National Medal of Technology and the (Bulgarian) Order of Saints Cyril and Methodius, First Class;

In pacem requiescat.

 81

The ENIAC: Electronic Numerical Integrator and Computer

 82

About the ENIAC

- Contracted 1943 (renewed 9 times), announced 1946:
  - Initially designed by John Mauchly and J. Presper Eckert at Univ. of Pennsylvania's Moore School of Engineering.
  - Weighed 30 tons, spanned 80 feet, contained more than 17,400 vacuum tubes, and "calculated a [ballistics] trajectory in 30 seconds that took a human 20 hours."
- U.S. patent history (summary):
  - 1947 application, granted 1964, voided 1973 in "the longest trial in the history of the federal court system."
  - "Eckert and Mauchly did not themselves invent the automatic electronic computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff."

 83

John von Neumann (né Neumann János Lajos, 1903..1957)

- "Hungarian-American mathematician, physicist, computer scientist, and polymath." Also a computator.
- "There was a seminar for advanced students in Zürich that I was teaching and von Neumann was in the class.
  - "I came to a certain theorem, and I said it is not proved and it may be difficult. Von Neumann didn't say anything but after five minutes he raised his hand.
  - "When I called on him he went to the blackboard and proceeded to write down the proof. After that I was afraid of von Neumann." — George Pólya (*Pólya György)*

 84

Von Neumann's far-reaching contributions to computing

- Conceived (1945) the *stored-program concept*:
  - A new "computer architecture in which the data and the program are both stored in the computer's memory in the same address space." (Contrast to Aiken's Harvard arch.)
  - Then he upgraded the ENIAC per this new architecture so that "[c]omplicated programs could be developed and debugged in days rather than the weeks required for plugboarding the old ENIAC."
- Also devised numerous algorithms:
  - *E.g.* merge sort (1945; almost classified TOP SECRET!).
  - *E.g.*, the middle-square method of obtaining pseudo-random variates.

 85

What else did von Neumann innovate? (among much, much more)

- Coined *kiloton of TNT* as a measure of explosive force.
- With Stanisław Ulam, developed the *Monte Carlo method* (a code name), still used today, to simulate complicated phenomena via random variates.
- Founded game theory as a mathematical discipline (1928).
- Pioneered the field of cellular automata (1948).
- Foresaw the onset of global warming (1955).

 86

A few of the early von Neumann machines (1950 ± 3 yrs)

- The IAS was designed by Johnny himself:
  - "At the start in 1946 some people had considered that the computer's memory might best be embossed on wax, like an old gramophone or Dictaphone record."
- In the USA:
  - MANIAC (Los Alamos)
  - JOHNNIAC (Rand Corp)
  - AVID AC (Argonne)
  - ORDVAC (Aberdeen)
  - ORACLE (Oak Ridge)
  - ILLIAC (Univ of Illinois)
  - 701 (IBM)
- Internationally:
  - Manchester Baby & Mark 1
  - EDSAC (Cambridge)
  - SILLIAC (Univ of Sydney)
  - WEIZAC (Weizmann Inst)
  - PERM (Munich)
  - BESK (Sweden)
  - BESM (Acad of Sciences)

 87

Comparing a few of the early machines

Machine	$K	Memory	Examples of tech	Op's/sec
Z3 '41	6.5	64 x 22-bit flt-pt	Relays	0.5
ABC '42	7	64 x 50-bit words	300+ tubes, capacitors	32
ASCC '43 (Mark I)	500	132 x 23-digit words	Relays, plugboard	3.3
ENIAC '46	500	20 x 10-digit	Plugboard, 18K tubes, diodes	5000
EDVAC '51	467	1024 x 44-bit words	Mercury delay lines	1200

 88

Thomas J. Watson, Jr. (1914..1993)

- 2nd president of IBM, under whom the 701 became the "first production computer … for scientific calculations."
- In 1953, "IBM … took [its] paper plan [for the 701] to some 20 concerns that we thought could use such a machine.
  - "[T]he machine rents for between $12,000 and $18,000 a month, so it was not the type of thing that could be sold from place to place.
  - "… we expected to get orders for five machines, [but] we came home with orders for 18."

 89

The invention of core memory

- Vacuum tubes/valves (invented 1906) were replaced for computer memory by magnetic cores:
  - Separate patents by Frederick Viehe, An Wang, Jan Rajchman, and Jay Forrester (1947, 1949, 1950, 1951).
  - First used in MIT's Whirlwind computer (1953).
- According to Forrester:
  - "It took us about seven years to convince the industry that random-access magnetic-core memory was the solution to a missing link in computer technology.
  - "… Then we spent the following seven years in the patent courts convincing them that they had not all thought of it first."

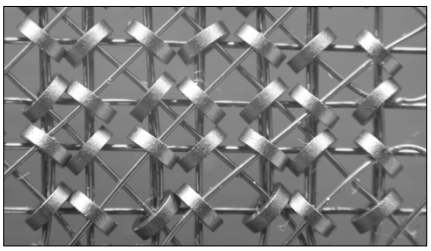
 90

Core memory operation

- Consisted of "Tiny donuts, made of magnetic material, [each] strung on wires into an array":
  - Each toroid corresponded to a single bit, magnetized one direction for 0 and the other direction for 1.
  - Some wires were used to select the desired bit, others to detect and/or to reverse its direction.
- "[M]anufacturing [core memory] was a delicate job, …
  - "entrusted mostly to women using microscopes and steady hands …
  - "to thread thin wires through holes about the diameter of a pencil lead."

 91

Distance between these cores is ~1 mm



 92

Adoption of core memory

- Quickly became the dominant memory technology, as far more reliable and longer-lasting than the vacuum tubes used by the ABC, ENIAC, and Colossus machines.
- Over ~20 years "The cost declined … from about $1 per bit to about 1 cent per bit":
  - Finally supplanted ~1975 by semiconductor technology.
  - In 1979, $5000 bought 128 kB (used) for a PDP-11/45 via a backplane, a power supply, and 9 circuit boards.
- But capturing a memory image (*e.g.*, of a failed program) is to this day still known as a *core dump*.

 93

And so, …

… the human adventure is just beginning.

— GENE RODDENBERRY

A closing thought (lightly edited)

"Since the beginning, many people have worked on computing, and many have furnished examples that were important.

"… What we each accomplish depends on not only our brains and energy, but also on the surrounds in which we work.

"… In a larger sense no one invents anything. We build and extend a little with our friends and on the shoulders of others."

— J. V. Atanasoff
1980

 117

A Retrospective
from
My Perspective

FIN

WALTER E. BROWN, PH.D.
< webrown.cpp @ gmail.com >