The Mechanical Monsters: Part II

Physical computational devices from the early part of the 20th century

James Tam

Bell Lab Relay Computers

- The Complex Number Calculator (Model I)
- The Relay Interpolators (Model II – VI)

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The Need For Complex Numbers

- The design of electrical devices and apparatus (e.g., telephone lines) involves extensive calculation and manipulation of complex numbers.
  - Awkward to work with complex numbers on a standard computer.
  - Consequently a telephone company (Bell) developed a specialized computer to work with this type of value.
  - (The problems involving the calculation of complex numbers began to hamper growth).

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George Stibitz (1904–1995)

www.dartmouth.edu.net

- Born in York, Pennsylvania.
- He received his bachelor's degree from Denison University, his master's degree from Union College in 1927, and his Ph.D. in mathematical physics in 1930 from Cornell University.
- In his later years (~late 1980s - 1990s) he turned to “non-verbal uses of the computer” (computer art: Commodore Amiga).
  - His artwork is on display at Denison University.

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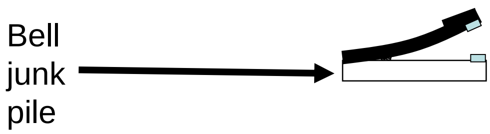
George Stibitz (2)

- In 1937: a mathematician working for Bell labs.
- Stibitz noted a similarity between telephone circuit diagrams and binary numbers.
- In his spare time and with cast-off parts he would experiment with electronics.



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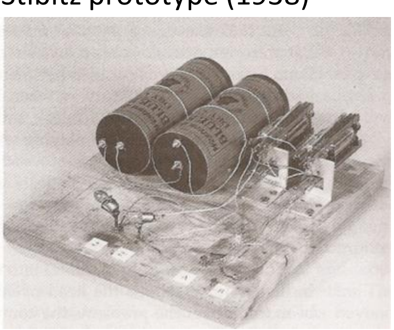
The Second Set Of Mechanical Monsters: The Bell Relay Based Computers

- Stibitz prototype (1938)



- Dr. T.C. Fry (head of Stibitz's group) just happened to be notified of the problems that the company was having dealing with its calculating load.

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Image: "A History of Computing Technology" (Williams)

The Complex Number Calculator

- Work began in late 1938 after S.B. Williams was appointed to oversee the project.
  - Stibitz: came up with the idea
  - Williams: had the necessary Engineering training to design the relay circuits.
- It was completed Jan 8, 1940 and remained in daily use until 1949.
- Operations (complex numbers): add, subtract, multiply and divide.

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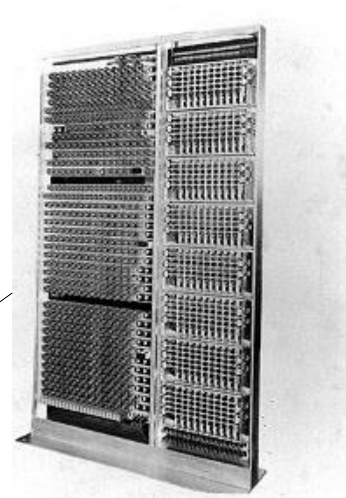
The Complex Number Calculator: Operation



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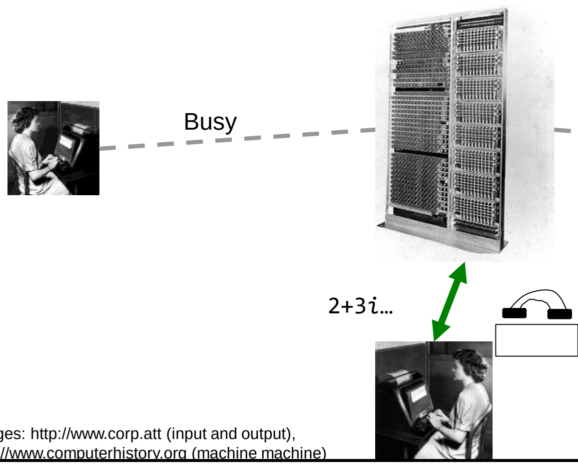
Images: http://www.corp.att (input and output), http://www.computerhistory.org (machine machine)

The Complex Number Calculator: Significance #1

- It was the first machine to allow for *more than one* terminal connection



Images: http://www.corp.att (input and output), http://www.computerhistory.org (machine machine)

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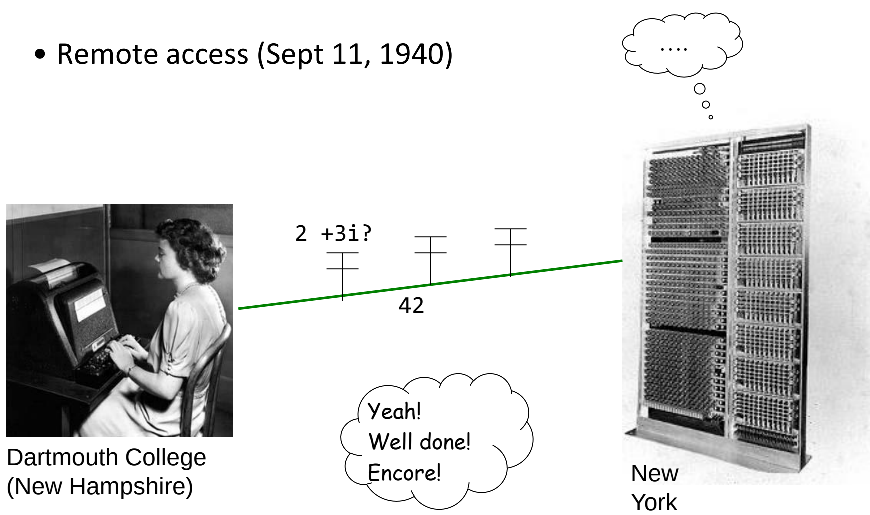
The Complex Number Calculator: Significance #2

- Remote access (Sept 11, 1940)



Images: http://www.corp.att (input and output), http://www.computerhistory.org (machine machine)

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The Complex Number Calculator: Details

- It only required 450 telephone relays!
- The logic was simplified by using a special form of binary (Binary coded decimal)
  - Harder U.I. for the operators, easier for the design of the hardware logic.

Decimal value	BCD value
0	0011
1	0100
2	0101
3	0110
4	0111
5	1000
6	1001
7	1010
8	1011
9	1100

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The Complex Number Calculator: Post Results

- The machine was a technical success but Bell Labs didn't think it would a commercial success ($20,000 to develop the first model).
- No other versions were developed.

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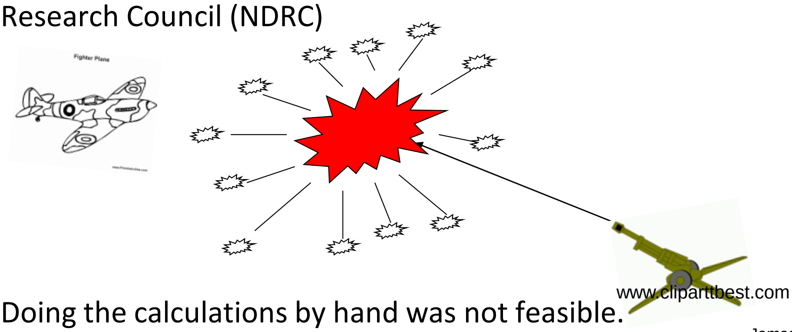
The Relay Interpolator

- After work on the Complex Number Calculator was over and Stibitz and Williams returned to their 'day jobs'.
- The U.S. enters World War II in 1941
  - December 7, 1941 (Japanese attack on Pearl Harbor)
- George Stibitz was recruited to work on the National Defense Research Council (NDRC)



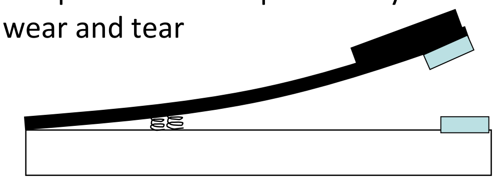
- Doing the calculations by hand was not feasible.

The Relay Interpolator (Model II)

- It was referred to as "The Model II Relay Calculator" or "Model II Relay Interpolator".
- Completed and fully operational Sept 1943.
  - 493 relays in two racks (5' high x 2' wide) – Williams
  - It could produce results for addition and subtraction (via negate and add)
- It not only adequately performed the task for which it was created (AA-gun tracking) it became a general use computer throughout the second world war.
- After the was it was donated to the U.S. Naval Research lab where it was productively used until the Relay Interpolator was shut down in 1961.

The Relay Interpolator: Reliability

- Telephone and computer relays would eventually fail through wear and tear



- Stibitz was concerned that if a relay failed an incorrect result could be produced without any way of knowing about the error.
- Consequently the machine used a bi-quinary system of encoding information stored in the machine.
- Each relay would store 1 bit of information.

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Bi-Quinary Encoding

- Each (decimal) digit would require 7 relays.

Digit	Bi-quinary coding	
0	01 00001	
1	01 00010	
2	01 00100	
3	01 01000	
4	01 10000	(1 = relay set)
5	10 00001	(0 = relay not set)
6	10 00010	
7	10 00100	
8	10 01000	
9	10 10000	

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Table image: "A History of Computing Technology" (Williams)

Bi-Quinary Encoding

- Machines implementing this method of encoding information were extremely reliable.
  - "If a spec of dust got trapped in a relay contact and caused an erroneous result then, as soon as it was found and removed, the machine would take up the calculation from the point at which it had been interrupted without any effort." (Williams)
  - The (later model V) was used continuously for 167 hours (during most of that time it was unattended).

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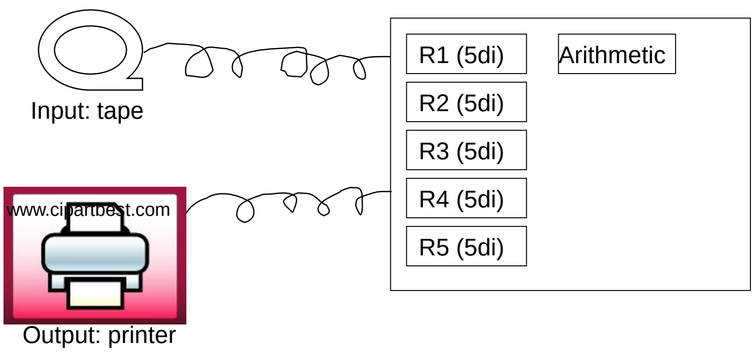
Relay Interpolator: Specifications



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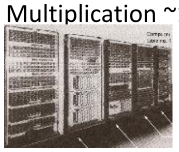
Model III ("The Ballistic Computer")

- The third of Stibitz's relay computers was also designed for the same uses as the Relay Interpolator (Model II).
  - Because of this it was usually known as the Ballistic Computer.
- The machine was being designed (1942) even before the Model II was complete.
- (Specifications from Williams)
  - Over 1,300 relays (5 frames each 5' high x 3' wide)
  - Doubled memory: 5 to 10 registers
  - It could perform addition and subtraction in the same fashion as it's predecessors but also included multiplication and division.
  - Multiplication ~1 second



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Model III ("The Ballistic Computer"): 2

- It was based on the same relay based technology and bi-quinary storage of numbers with some upgrades (slide to come).
- Completed in June 1944 and remained in service until 1958.

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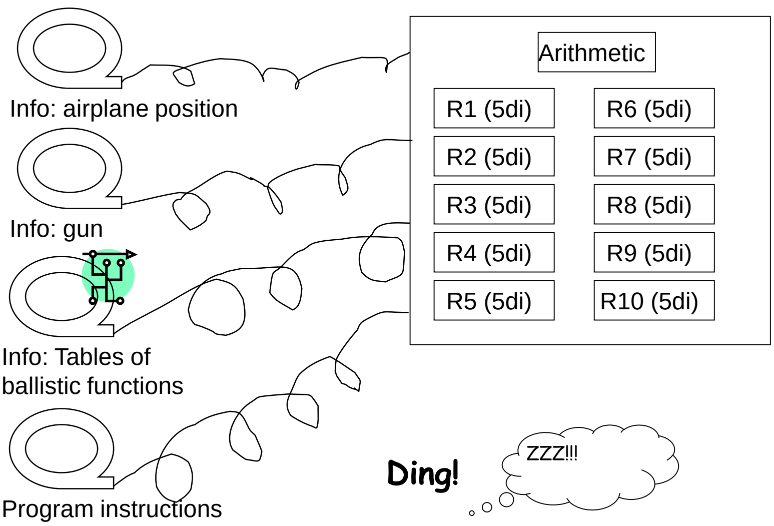
Model III: Specifications



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Reliable: Instructions (24 hours)

Model IV

- The second Ballistic Computer (officially known as “Bell Laboratories Relay Calculator Model IV” or “Error Detector Mark 22” – Navy).
- Completed in March 1945 and like the Model III it was used for ballistics calculations.
  - Model IV: added features to allow for the calculation of negative angles (*otherwise it was a Model III*)

www.ciipartbest.com

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The Model V ("The Two In One")

- The Relay Interpolator and the Ballistic Computers were so successful that the U.S. government decided to back the creation of a much larger relay-based system.
  - Also there were still a backlog of needed calculations to be completed.
- There were two (nearly identical) machines built to fulfill the need
  - Each half could work on a separate problem or both halves could work together.

"A History of Computing Technology" (Williams)

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The Model V ("The Two In One"): 2

- Reliable:
  - As noted data was encoded using the bi-quinary method
  - It could handle the case when an error was detected while an instruction was executed
    - The extra reliability slowed operations
    - Slowest machine (save for the Harvard Mark I) - Williams
- Specifications (Williams)
  - 44 registers
  - 9000 relays
  - 1000 square foot 'footprint')
  - 10 tons
  - 7 digit numbers
- A 'CADET' (Can't Add Doesn't Even Try) architecture for mathematical problems

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Model V: Fate

- After the war, one was used for a while at Fort Bliss and later given to the University of Arizona.
- The other machine was donated to the Texas Technology College in 1958 but the delivery truck ended up in a car accident and that machine was destroyed.
- The wrecked machine was used for spare parts for the machine at the University of Arizona.

Model VI

- After the end of WWII Stibitz left Bell
- But Bell still constructed another version of the Stibitz machines (completed in 1950).
  - It was used for the same purpose as the original Complex Number Calculator.
- It was essentially a Model V.
  - The main difference was that it could store 10 (rather than 7) digit numbers.
  - In the late 1950s it was donated to the Polytechnic Institute (Brooklyn) and later in 1961 donated to the Bihar Institute of Technology (India) where it eventually became a historical display.

Video #4: Bell (AT&T) Computers

- A good source, it's AT&T's official technical YouTube channel:
  - It not only shows the basic design and operation of the Bell lab computer but you can also see relay technology in operation (2:59)
  - Obviously this video is highly recommended!
  - https://www.youtube.com/watch?v=a4bhZYoY3lo

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After This Section (M.M. All Parts) You Should Now Know

- What were the 4 categories/families of mechanical monsters
- In each of the 4 categories:
  - What machines were created and by whom
  - What were some of their important technical specifications and the general appearance of the machine
  - How did the machines work/what technology was employed in their manufacture
  - Why was the significance of the machine/technology (some machines will have more information than others)
  - How were these machines used and what was their eventual fate (with the latter point not a great deal of information may be available for all machines)
  - (For the machines with their own custom encoding) how did the encoding system store information

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After This Section (M.M. All Parts) You Should Now Know (2)

- Who were some of the people behind the development of these machines
  - What were some of the milestones and accomplishments in their lives
  - What were some of their motivations in the design of the mechanical monsters
- Approximately when (and in what order) did milestones in the development of the mechanical monsters occur

Source Material

- “A history of modern computing” Michael R. Williams (IEEE 1997)
- Interational Federation for Information Processing (IFIP 2013) Horst Zuse: pp 287 – 296
- “Giants of Computing” by Gerard: pp 281 – 284 (Springer-Verlag London 2013)