The Mechanical Monsters: Part III

Physical computational devices from the early part of the 20^{th} century

James Tam

The Harvard Machines Of Howard Aiken

- The Harvard Mark I
- The Harvard Mark II
- The Harvard Mark III
- The Harvard Mark IV

James Tam

The Harvard Machines: Introduction

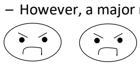
- They were developed under the guidance of Howard Aiken (1900- 1973).
  - He studied at the University of Wisconsin and eventually earned his PhD. at Harvard.
  - He also had a military background.
  - He envisioned a device that could complete many tedious calculations.
  - The current technology wasn't up to the task (by an order of magnitude).
  - Aiken was familiar with Babbage's biography.
    - Borrowed? Learned from?
  - He suggested several ideas to others (so they could fund the development) but he found no takers.
  - Finally with some help: Harlow Shapley (astronomer) and Theodore Brown (Harvard business school Prof.),
    - Aiken managed to get an appointment with Thomas J. Watson (1937).

James Tam

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

The Harvard Machines: Introduction (2)

- Watson agreed to have IBM fund the project
  - But Watson's goal from the project differed from Aiken's.
- The machine (originally named the "IBM Automatic Sequence Controlled Calculator" but soon became known as the Harvard Mark I) was demonstrated to be operational in 1944 and it was donated to Harvard.
  - Because of Aitken's military background it was almost immediately employed in the war effort.
    - Aitken was a navy commander in the reserves was in charge of the navy computational project).
    - Grace Hopper: assigned as Aitken's aide.
  - However, a major rift developed between Aiken and Watson.

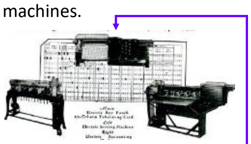


The Harvard Machines: Introduction (3)

- Aiken was well aware of the problems faced by his predecessor designers/developers (e.g., Babbage)
  - He avoided constructing machines that were too 'cutting edge' that employed untested/unproven technologies.
  - The mechanical components used in his machines were slower than the relay-based machines.
  - Pragmatic: "…he was willing to work with anyone's technology so long as they paid the bills" – Williams.
  - When designing the Mark I Aiken originally approached (and was rejected by another company) 'The Monroe Co' – producer of traditional mechanical desktop calculators).
    - The Mark I may have been purely mechanical instead of using electricity to drive the mechanical parts had the original agreement been successful - Williams

Harvard Mark I

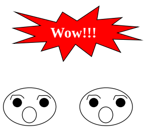
- It was built from parts from standard IBM accounting machines.



Images: http://www-03.ibm.com/

Harvard Mark I (2) - Williams

- It was huge:
  - Size: 51' long x 8' high
  - Wiring required: 500 miles



- It was expensive:
  ~$400,000 - $500,000.

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Harvard Mark I image: "The History of Computing Technology" (Williams)

Harvard Mark I (3)

- Program control came from instructions on punched tape.

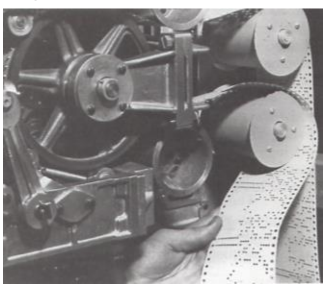

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Image: "The History of Computing Technology" (Williams)

Harvard Mark I: Technical Specifications (Williams)

- The machine was motor powered.
- It contained 72 'registers' each of which could stored 23 decimal digits (plus one more digit for the sign).
  - With a little rewiring the position of the decimal place could be changed (15 – 16th place default).
- Technology
  - Mechanical calculator
- Speed:
  - Additions: 0.3 seconds.
  - Multiplication: <=6 seconds.
  - Slower but more accurate than many of its peer machines.

Z3
- Additions: 0.25 – 0.3 seconds
- Multiply: two numbers every 4 – 5 seconds

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Harvard Mark I: Uses

- As mentioned after the Mark I was completed and set up at Harvard in May 1944 it was immediately enlisted in the war effort.
  - Recall: World War II (1939 – 1945) and Aiken held a Commander rank.
  - It was used entirely for military purposes for the duration of the war.
- After the war the Mark I was employed for research purposes.
- Eventually it was made obsolete by newer machines and dismantled in 1959.
  - Parts on display: Harvard, IBM head quarters (New York), Smithsonian (Washington DC).
- The major impact: a design model rather than the applications it was used for or the results that it produced (Williams).
  - Design model lasted until real memory (RAM) was invented.

James Tam

Video #5: Harvard Mark I

- Background information and technical information:
  - https://www.youtube.com/watch?v=bN7AdQmd8So

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Video #6: Brief Biography Of Howard Aitken

- Video last accessed October 2024:
  - https://www.youtube.com/watch?v=0NG13iZT380

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Grace Hopper (1906 – 1992)

"A History of Computing Technology" (Williams)

- She was a young lieutenant (Jg. Lt.) that was an assistant to Commander (Cmdr.) Aiken.
- She was curious and inquisitive child:

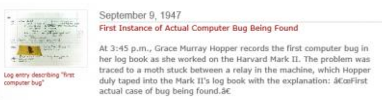
www.colourbox.com

Microsoft.com

www.colourbox.com

Grace Hopper (2)

- She found the world's first 'bug' in a computer program.



September 9, 1947

First Instance of Actual Computer Bug Being Found

At 3:45 p.m., Grace Murray Hopper records the first computer bug in her log book as she worked on the Harvard Mark II. The problem was traced to a moth stuck between a relay in the machine, which Hopper duly taped into the Mark II's log book with the explanation: â€œFirst actual case of bug being found.â€

Log entry describing "first computer bug"

•Screenshot: www.computerhistory.org

Grace Hopper (3)

- She received a degree in Mathematics and Physics from Vassar (New York) and eventually a PhD. from Yale.
  - In 1943 she enlisted in the Naval reserves.
  - Graduated in the top of her class in 1944.
  - She was then assigned to the project at Harvard as a junior grade naval lieutenant (second Lt.)
- She made many contributions to the development of the first compilers and the standardization of the COBOL programming language.
- At the same time she continued to be promoted through the ranks of the Navy:
  - When she attained the rank of Commodore/Rear Admiral Lower Half (1980s) she was oldest serving member. (Williams)

Officer Ranks Of The United States Navy And Grace Hopper

- **Admiral ranks**
  - **Fleet Admiral**
  - **Admiral**
  - **Vice Admiral**
  - **Rear Admiral**
  - **Rear Admiral lower half (formerly: Commodore)**
- **Other officer ranks**
  - **Captain**
  - **Commander**
  - **Lt Commander**
  - **Lieutenant**
  - **2nd Lieutenant**
  - **Ensign**

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(Source:https://www.federalpay.org/military/navy/ranks)

Video #7: Brief Biography Of Grace Hopper

- Original video link not available.

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Video #8: Grace Hopper Interview

- Late Night with David Letterman:
  - A good interview because it's a TV show for everyday audiences
  - It provides you with a good idea of the real world person (JT: a feisty personality with a good sense of humor and the ability to explain technical concepts) behind all the accomplishments.
  - https://www.dailymotion.com/video/x35dsz7
  - (If I can't post the link due to copyright concerns or link is no longer available then try the search phrase: Grace Hopper on David Letterman).
  - This is another highly recommended video.

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Harvard Mark II

- In 1945 the Navy asked Aiken to construct another machine for use at the Naval Proving grounds (Virginia).
- Because (as mentioned) Aiken had a flexible and pragmatic approach to design and because this machine was specifically requested by the Navy he had access to different and better resources.
  - The Mark II was based entirely on relay technology (considerable faster).

Specifications from Williams

•0.01 second for the motion to complete

•1/3 used mechanical locks (rather than magnets to close)

•$15 each (X13,000)

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Harvard Mark II (2)

- Similar to the Bell Model V it could be split into two separate and independent parts.
- Specifications (Williams)
  - 50 data registers
  - 2 tape readers for instructions
  - 4 tape readers for data
- Speed (Williams)
  - Addition: 125 milliseconds (0.125 second)
  - Multiplication: 750 millisecond (0.75 second)

Mark II: "A History of Computing Technology" (Williams)

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Harvard Mark III

- After the war Aiken continued working on developing machines at Harvard.
- His focus was on ease of use over having an ultra high speed machine.
  - Mark I & II: increasing machine speed by a factor of 10 only resulted in a throughput of 2 to 3 times (Williams)
- Consequently the Mark III (and Mark IV) were designed more for accuracy and ease of use than hardware-based increases in speed.
  - (Aiken's boast): "…his Mark III was the slowest all-electronic machine in the world because it took 12.75 milliseconds to do a multiplication" (Williams).

James Tam

Harvard Mark III: Mathematical button board

- A special board designed to increase the ease of use for mathematicians.
- Buttons were labeled in a special mathematical notation would produce the results by automatically calling the appropriate sub-routine.

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Harvard Mark III: Technical specifications (Williams)

- First of the Aiken computers to have a stored program.
  - Stored data on 8 magnetic drums (Total data storage: 4,350 - 16 bit numbers).
  - Instructions were stored on a separate drum.
  - The separation of data and memory was known as the Harvard architecture.
- There was further move away from mechanical parts:
  - The technology was split between electronic (e.g. vacuum tubes) and electro-mechanical components
- Operational speed:
  - Multiplication: 12.75 milliseconds.

James Tam

Harvard Mark IV

- Completed in 1952.
- Incorporated many of the features of the Mark III except that it employed a different type of memory (magnetic 'core')
- It resided at Harvard but was used extensively by the U.S. Air Force.
- After finishing the Mark IV Aiken retired from designing and constructing new computer equipment.
  - Harvard instructor
  - 1961: Founded his own company (Aiken Industries)

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

The IBM Calculators

1. The Punched Card Systems
2. Large IBM Calculators
3. The Selective Sequence Electronic Calculator (SSEC)

James Tam

Punched Card Systems

- Before producing computers IBM was in the business of calculating machines under different names
  - Hollerith equipment (Europe)
  - IBM (North America)
- Early punched card machines with used to enter/encode data so it could be stored and tabulated.

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

Punched Card Systems (2)

- Advantages of punched cards over electrically driven desk calculators:
  - Speed (slight)
  - Accuracy (reduced human intervention).

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Punched Card Systems: Applications

- Early applications
  - Compiling statistics
  - Accounting/bookkeeping
  - Leslie J. Comrie: the first use of the Hollerith machines for large scale scientific calculation (lunar motion).
- 1929: Columbia university convinced Thomas J. Watson (senior) into founding Columbia University Statistical Bureau.
- 1930: the Statistical Bureau expanded to include work on Astronomical calculations.
- These early machines were based on the same principles as Babbage's Difference Engine.

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Multiplying Punch Card IBM Models

- The IBM 601 (1935) was a punch based system that could also quickly perform multiplications.
  - Relay based and could complete multiplications: ~1 second.
- The 601 rapidly evolved into several models:
  - Each successive model came with increasing abilities or improved technologies.
  - Relay based machines: 602, 602A, 603.
  - Vacuum tube based machines with programmable plug boards: 604, 605.

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Plug Board Programming

- The 604 could be 'programmed' through two plug board control panels.

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

IBM's Market Position

- IBM had little competition in the production of punch card equipment.
- (Remington Rand also produced punch card equipment but their punch card system was less convenient to use so the vast majority of the market went with IBM).

James Tam

Large IBM Calculators


www.columbia.edu

- The first was the Harvard Mark I.
- With this machine's success IBM developed their own series of computers.
  - These other machines were all relay-based.
- IBM Pluggable Sequence Relay Calculator (IBM PSRC)
  - All were relay-based computers which were controlled by a combination of IBM plug boards and punch cards.
  - Arithmetic unit: The 4 standard mathematical operations plus square roots.
  - These machines were faster than the regular desktop punched card machines (e.g., x10 the speed of the IBM 602) ~100 milliseconds

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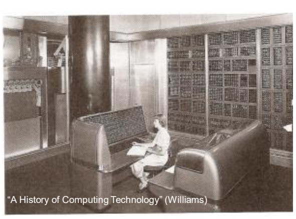
The Selective Sequence Electronic Calculator (SSEC)

- It was one of the really large mechanical monsters produced by IBM.
  - Unveiled in 1948 but completed and running test programs before that.


"A History of Computing Technology" (Williams)

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The Selective Sequence Electronic Calculator (SSEC): 2

- As the SSEC was being designed another machine (ENIAC) had shown that vacuum tubes could be reliably used in a computer.
- However IBM engineers had extensive experience with relay-based technology (the punched card machines…up to and including the IBM 603).
- Final design:
  – Vacuum tubes were used in parts of the machine where speed was essential.
  – Relays were used in all other parts of the machine.
  – 8 high speed registers and the arithmetic unit ~13,000 vacuum tubes
  – 150 slower speed registers ~23,000 relays
  – Employed BCD for efficiency (only 4 vacuum tubes) were required to store a single digit

James Tam

The Selective Sequence Electronic Calculator (SSEC): 3

- The use of vacuum tubes in the arithmetic unit made the SSEC the fastest of the mechanical monsters:
  – Addition: 0.004 seconds (4 milliseconds)
- When IBM developed the first electronic stored program computer (IBM 701) the SSEC was switched off.
  – The IBM 701's capabilities exceed that of the SSEC

James Tam

Option External Video: Overall Summary

- Captures the essence of the 3 projects: Zuse, Bell, Harvard.
  – https://www.youtube.com/watch?v=qundvme1Tik

  – Rough ranges of video that are of the greatest relevance
  – Bell, Zuse: ~2 – ~22
  – Harvard/IBM: ~30 - 43

James Tam

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

James Tam

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

James Tam

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)
- IBM history website (last accessed October 2024):
  - https://www.ibm.com/history/selective-sequence-calculator

James Tam