Early Mechanical Computers

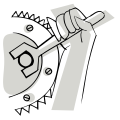
This section covers mechanical (physical rather than electronic) calculating devices

James Tam

What Is A Mechanic?

- Modern usage

- Usage in this section of notes (~1500 – 1800s AD)



Copyrights unknown

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Common Attributes Of Early Mechanical Computers/Computing Devices

- Almost all the mechanical calculators were composed of these basic elements in some form.
  - Set up:
    - Allows the number to be entered
  - Selector:
    - Determines the type of operation (addition, subtraction)
  - Registering mechanism:
    - Indicates the value of a stored number (result)
  - Carry Mechanism:
    - Determines that any carries are handled properly
  - Control mechanism:
    - Ensures that the gears are properly aligned at the end of each operation (avoid false results and jamming)
  - Erasing mechanism:
    - Reset the result register between operations
  - The 6 parts weren't always separate but one part could implement multiple operations
    - These operations were needed in a usable machine (automated or manual)

Optional video: importance of precise design and implementation.

James Tam

Propagating The Carry

- This was a major challenge that was overcome with varying degrees of success (?) in the earliest of the calculating machines (Schickard – Grillet).
  - (It was a non-issue for the 3 commercially produced devices because the problem had been long solved)

James Tam

Wilhelm Schickard (1592 – 1635)

- A well-rounded 'Renaissance man' often compared to da Vinci:
  - Professor of: Hebrew, Oriental languages, Mathematics, Astronomy, Geography.
  - 'Spare time' hobbies: painting, mechanic, engraver.
- Developed the first true adding machine which could handle a carry (Bruno von Freytag Loringhoff).
- Evidence of the machine:
  - Letter to sent to/from Johannes Kepler (mechanical equivalent of his manual calculations).

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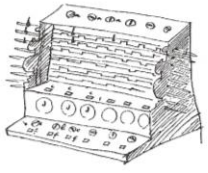
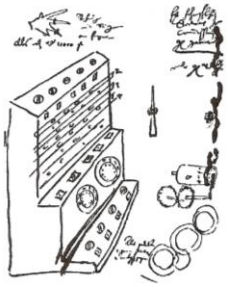
Image : www.computerhistory.org

Wilhelm Schickard (1592 – 1635): 2





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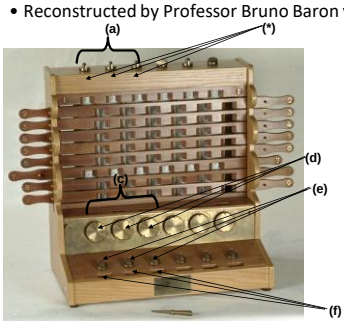
"A History of Computing Technology" (Williams)

Re-Creation Of Schickard's Calculating Machine

- Reconstructed by Professor Bruno Baron von Freytag:



Associations:

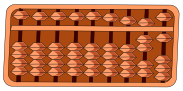
- (a) & (*)
- (c) & (d)
- (e) & (f)

Image: http://www.numericana.com

Schickard Carry Mechanism

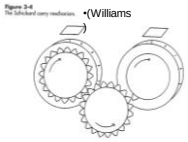
- Result of additions to a previous common passed in next column

00	10
01	11
02	12
03	13
04	14
05	15
06	16
07	17
08	18
09	19
10	20



Previous approaches: manually performed

Solution: Single toothed gear



Schickard's calculator: automated

Fate Of Schickard's Calculators

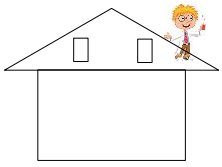
- There were two
  - One was made for Kepler

  - It's unknown what happened to Schickard's copy.
  - It was believed that Schickard's family was wiped out in a plague and the was unceremoniously disposed of

Blaise Pascal (1623 – 1662)

Copyright unknown

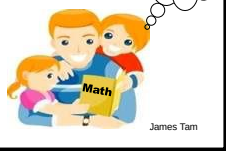
- Born in Southern (Clermont) France
- Because of his many accomplishments some of the stories about his life were (greatly) exaggerated.



Clipart: colourbox.com

Blaise Pascal (2)

- Credited as the next major attempt to produce a calculating machine.
  - Initially he was credited as building the first mechanical calculator but this was disproved by Bruno Baron von Freytag Loringhoff.
- 'Home schooled' in the basics of reading and writing by his father Etienne Pascal.
- After learning the basics: Blaise was left to learn from reading the library of his father.



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Pascal: Motivations

- His family were government tax collectors
- The calculations required were repetitive and rather tedious

- At 19 Pascal designed his first calculating machine (1642)
  - His attempts at finding someone to implement the design was not successful

Copyrights unknown

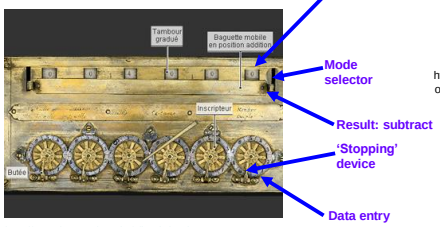
Pascal: Other Vocations

- After his failure at getting others to build his designs he realized that he would have to work as designer and the builder/implementer of the designs
- He trained at other vocations

Copyrights unknown

Pascal's First Machine: Work

- He went through nearly 50 prototypes (all based on the original design).
- In 1645 he publically presented his machine
  - Pascal's calculator (later 'Pascaline')



https://en.wikipedia.org/wiki/Rotary_dia

http://www.laurentdumeix.fr/book-html

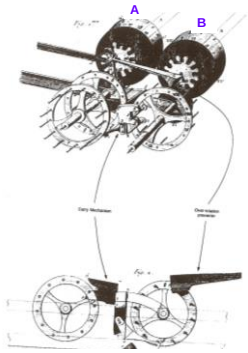
External Extra Videos: Pascaline

- Basic operations, Pascaline video #1: https://www.youtube.com/watch?v=CvKLM_O1Wx0

Pascal's Machine: Carry

- Pascal realized that the gear and tooth mechanism used by Schickard was problematic.
  - (A carry propagated for more than several digits would require force such that the gears could/would be damaged).
- Instead a complex system of falling weights was employed

Pascal's Machine: Carry (2)



Additional details coming up in Pascaline video #2

From: A history of computing technology (Williams)

Pascal's Later Life

- Later in life (1650) Pascal had a life changing dream

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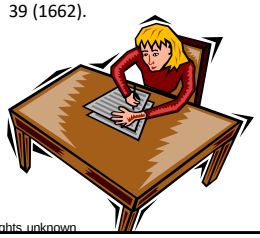
External Extra Videos: Pascaline Video #2

- More advanced operations of Pascaline (e.g. nines complement arithmetic for subtractions, carry mechanism): https://www.youtube.com/watch?v=3h71HAJWnVU

Fate Of Pascal's Machines

- Several machines were produced but sales weren't profitable
- Few survive to today.
  - They were quite delicate
- Pascal suffered from a painful illness which lead to his death at 39 (1662).



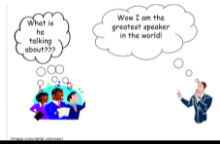
Gottfried Leibniz (1646 – 1716)

"A history of computing technology" (Williams)

- Age 15: admitted to university Leipzig (law)
- Age 20: applied for his doctorate (law)
  - Declined ("Ya bother me kid…")

colourbox.com

- Doctorate awarded at the university of Altdorf



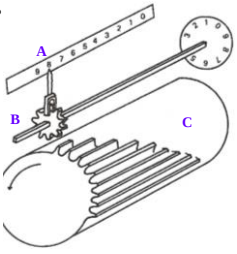
Challenges Faced By Leibniz, Pascal And Others

Leibniz's Final Machine

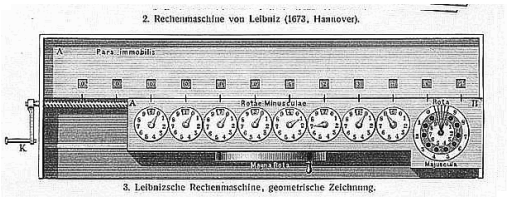
- Luckily Leibniz enlisted the aid of M. Oliver

Leibniz's Calculating Machine

-



Leibniz's Calculating Machine (2)



- *"eine zahl von einer ganzen Reihe Ziphern, sie sey so lang sie wolle (nach proportion der größe der Machine)!!!"* - Leibniz

"A number from a whole series of ciphers, they are as long as they want (according to the proportion of the size of the machine "

James Tam

Image: http://www.rechnerlexikon.de

Leibniz's Calculating Machine (3)

- It used a gear based system (not single tooth gear) for carries.
- Carries were problematic.
- Ripple carry through several digits had to be manually propagated.

James Tam

External Extra Videos: Leibniz Stepped-Drum

- https://www.youtube.com/watch?v=klLB5k3LkwU

James Tam

Leibniz: End Years

- "..he (Leibniz) holds the position, perhaps more than any other post-Renaissance figure, of a man of almost universal genius.
- People like him are often very difficult to get along with, and there was an almost audible sigh of relief from his contemporaries when he finally died."
  - Williams (History of Computing Technology)

Image copyrights unknown

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External Extra Videos: Leibniz Vs. Newton

- Leibniz-Newton feud (video mostly just for fun, caution: minor gore near the end)
- https://www.youtube.com/watch?v=KQyIU10pD-A

James Tam

Who Invented The First True Adding Machine?

- Pope Sylvester II (946 – 1003)?

•www.d.umn.edu
  - No it was most certainly an abacus that was referred to
  - (Delicate machining wasn't possible).
- William Schickard (first: but may have been incomplete Williams and others, did the carry work?)
- Blaise Pascal (either second or the first complete)

James Tam

Operations Available: Schickard, Leibniz And The Pascal Machines

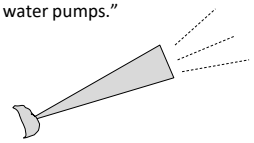
- Addition (Schickard, Pascal, Leibniz)
- Addition and subtraction (Pascal & Leibniz)
- Multiplication and division (Leibniz)
  - Repeated additions and subtractions

James Tam

Samuel Morland (1625 – 1695)

Image: "A history of computing technology" (Williams)

- Due to the political strife in England he attended university at an older than average age.
- He received a BA from university (usual profession was in the clergy) but instead he took up Mathematics.
- Also he was a capable mechanic and invented several devices, "…ranging from calculating machinery to barometers, speaking trumpets and water pumps."



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Morland's Adding/Subtracting Machine

- Carry handling (Williams):
  - Schickard: carries propagated multiple times could damage the machine
  - Pascal: the carry mechanism was delicate and sometime unreliable.
- Morland's machine implemented a partial (manual) carry

'Pocket' calculator 4" x 3" x 0.25"

James Tam

Re-creation from: http://collectionsonline.nmsi.ac.uk

Morland's Adding/Subtracting Machine

- (Auto carry Morland machine)
  - "As far as the author is aware, no instruments of this design were actually constructed or if they were, none survived to modern times" (Williams)
- Morland also designed another machine for multiplication, division, square and cube roots
  - Based on Napier's bones (circular)

James Tam

External Extra Videos: Morland Machine

- https://www.youtube.com/watch?v=XJ7cscFVNF0

James Tam

René Grillet

- "Very little is known about René Grillet or his accomplishments…" (Williams)
  - Birth? Death?
  - One source: He was appointed clockmaker to very prestigious position to a royal!
  - Second source: His working machine was exhibited in county fairs for a silver (Williams)
- In 1678 he published information about his calculating machine.
- Unfortunately the article was short on details ("marketing brochure")

It does it all!

Here's how you can get one…

James Tam

René Grillet (2)

- Some additional details came from a manuscript from Charles Babbage (discovered by Michael R. Williams).
  - As compared to Morland's machine:
  - Morland's machine had the more useful mechanism Napier's bones (multiplication) while Grillet's had the larger capacity adding mechanism.

Commercially Produced Machines

- These machines that achieved (varying degrees of) commercial success and were based on the older designs:
  - The Thomas Arithmometer
  - Baldwin-Odhner Machines
  - Key-Driven Machines: Comptometers

The Thomas Arithmometer (1820s ~1914)

- M. Charles Xavier Thomas de Colmar applied modern engineering and design practices to the Leibniz mechanism.

Image: www.cis.cornell.edu

The Thomas Arithmometer (1820s ~1914): 2

- Thomas created an industry in which mechanical devices were used to aid in calculation (Williams).
- However the device was fairly large:
  - Big foot print
  - Not very portable

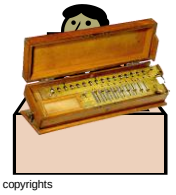


Image copyrights unknown

External Extra Videos: The Thomas Arithmometer

- Besides showing how the Arithomometer works it shows how Leibniz's stepped drum design is employed inside the device
- https://www.youtube.com/watch?v=h8DVTAeyXK4

Baldwin-Odhner Machines (1885 - ~1965)

- It consisted of two different sets of machines
  - US: Frank S. Baldwin (Baldwin machines: America)
  - Russia: W.T. Odhner (Odhner machines: Europe)
- They used a variable toothed gear (# of protruding 'teeth')

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

Baldwin-Odhner Machines (1885): 2

- It was a 4 function calculator that could now sit on a corner of a desk

Baldwin-Odhner

www.vintagecalculators.com

Leibniz

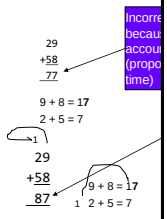
www.teachingcollegemath.com

James Tam

Baldwin-Odhner Machines (1885): 3

- Even with the improvements of the other machines (Arithmometer and the Baldwin-Odhner Machines), the UI (User Interface) was still too awkward and time consuming for general office tasks (e.g., adding up long columns of numbers).

Example balance sheet		
Assets		**Liabilities**
Inventory $100k		Short term funds $125M
Machinery $50M		Bonds $25M
Furniture $15k		Deferred taxes $15k



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Baldwin-Odhner Machines (1885): 4

- Example of data entry with an Odhner machine (non-key driven)

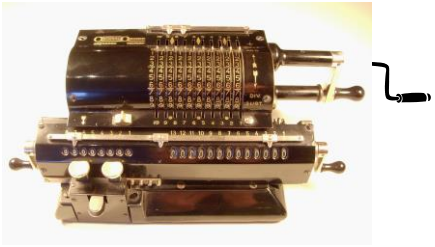


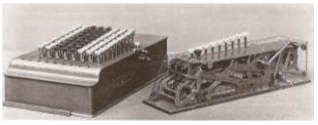
Image: https://ca.wikipedia.org (last accessed Jan 2016)

James Tam

Key-Driven Machines

- Mr. Dorr E. Felt was the person who made a functional key driven machine "Comptometers":
  - Prototype completed N.Y.D.: 1885:
  - First fully working model completed: Autumn 1886

"Macaroni box"



Production model

James Tam

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

Key-Driven Machines (2)

- "Felt was able to speed up the addition operation by an order of magnitude above the times available with other mechanical calculators" – A History of Computing Technology (Williams) p. 151

James Tam

External Extra Videos: Comptometer Video #1

- External operations & explanation of the input and display mechanism: https://www.youtube.com/watch?v=l41k4q755yE

James Tam

External Extra Videos: Comptometer Video #2

- Internal mechanisms: https://www.youtube.com/watch?v=h8DVTAeyXK4

James Tam

After This Section You Should Now Know

- Who were some of the people behind the early mechanical computers and when they lived
- The appearance and general operation of these mechanical machines
- What was the one major challenge faced in the design of all the early calculating machines (Schickard – Grillet)
- William Schickard's calculator
  - How were Napier's bones employed
  - How did carries get propagated from one digit to another
  - What was the limit on the carry and how was it deal with
  - The eventual fate of Schickard's calculators
- Who invented the first true adding machine

James Tam

After This Section You Should Now Know (2)

- Events from Pascal's early child hood background, the events that lead up to the design and eventual development of his Pascaline and the end of his life
- The Pascaline
  - How the Pascaline is operated in order to perform an operation and what operations were possible
  - How a carry is propagated between digits
- The eventual fate of Pascal and his machines
- How the stepped drum was implemented in Leibniz's calculating machine
- How the partial carry approach for Morland's adding (subtracting) machine worked

James Tam

After This Section You Should Now Know (3)

- The approximate date in which Grillet published work on his calculating machine
- What were the three commercially produced mechanical calculators and roughly when were they available
- The impact of the Thomas Arithmometer
- How the variable toothed gear mechanism in the Baldwin-Odhner Machines worked and the benefit of this design
- What was the advantage of the key-driven machines
- The history behind the development of the first key driven machine

James Tam