NATS 1700 Lecture notes 4-6

Credits to Kevin Salt

Lecture 4 – The World of Calculators: from office equipment to pocket gadgets

Overview

17th, 18th, and first half of 19th century the dominating and prevailing calculating aids were:

- Pen and paper methods (algorithms) – These are still taught in schools today
- Abacus (in its variety of forms) – Still used in pre-school to teach numbers and counting
- Mathematical tables

Digital electronic calculators and, in particular the hand-held (or pocket) calculators made mathematical tables and abacus like devices become historical relics of computing.

The birth of the office calculator industry

- Industrial revolution brought new manufacturing methods and ability to produce high quality precision instruments and mechanical devices such as calculators in large quantities.
- First half of 19th century, calculators increasingly offered commercially, but not used widespread
- Second half of 19th century – change came: First in Europe, and later in America, large businesses, institutions, etc. were expanding. These businesses had an ever increasing number of calculation tasks could not be handled cost-effectively without appropriate calculating aids.
- Opportunity for entrepreneurs & inventors determined to sell office gadgets
- Later in the second half of 19th century- mechanical office equipment became an essential infrastructure of modern business.
- End of 19th century calculators were no longer seen as mechanical curiosities, had now become useful devices that enhanced human abilities in many applications

Thomas Arithmometer

- Built by Thomas de Colmar of Alsace around 1820
- One of the first commercially produced adding machines
- Never produced in large quantities – too expensive and too slow for large arithmetic operations in an office (required setting numbers using dials and a hand crank)
- However, they were technically sound and captured the attention of businesses and started office calculator industry first in Europe, then America.

Calculator industry in 19th century America

- While European countries were going through extensive industrialization, America was still mostly involved in Agriculture.
- Civil war of 1861-1865 slowed industrialization in America for a decade
- Introduction of steam power allowed American industry to spread across the nation
- Two main issues with mechanical calculators at the time:
  - Early mechanical calculators were slow to operate, operations *should* be as fast as typing on a typewriter
  - Organizations such as banks required printed records of calculations in order to improve efficiency of office work
- Late 19th and early 20th century America had roughly 3 groups of calculator users:
  - Governmental institutions (treasury) and other large organizations (banks, large manufacturers) – Required large machines capable of reliable operations with large numbers at high speed and capable of printing these results on wide rolls of paper. Continuously improving and very expensive.
  - Medium-sized trade and commerce business (grocers and merchants) – Still expensive (for most people), printing possibility but usually on narrow paper tapes.
  - Small business and individual users (small business and home economics, and other purposes) – Small desktop or handheld calculators. No carry mechanism. Survived until the 1960s. Offered as an inexpensive pocket calculator operated with a stylus.

Dorr E. Felt and William S. Burroughs

- Prominent names in discussions of 19th and early 20th century calculators and their impact on the modernization of the American office.
- Felt's comptometer:
  - Invented around 1886 by Dorr E. Felt
  - First mechanical calculator to feature well-performing typewriter-like keys instead of wheels and leavers
  - Since 1887, Felt & Tarrant Manufacturing (company co-founded by Felt and Robert Tarrant), sold calculators worldwide. Became very successful in the early 1900s and its dominating role in the world-wide business calculator market continued into the 1950s
  - This success as based on novel sales and marketing techniques such as free trials before purchasing, publishing testimonials of satisfied customers, etc.
- Comptometers were became popular and useful but remained expensive
- Companies who could not afford comptometers could rent the equipment or use services who had comptometers

- Being able to operate a comptometer skillfully was a valued in the office, created opportunities for promotion.

- 1888, Felt improved his comptometer by adding a printing device, changed name to "Comptograph".

William S. Burroughs

- Working as a bank clerk, envisioned the idea of mechanizing tedious arithmetic operations

- Designed the Arithmometer in 1885 and co-founded the American Arithmometer Company to manufacture it.

- Arithmometer:
  - First Arithmometer was 9 digit adding machine that printed only the final result of calculation
  - First calculator with working printing mechanism
  - Sold several hundred per year by end of 1800s but real success was realized after Burroughs' death at the beginning of the 20th century
  - Awarded gold medal at the 1900 Paris Exposition
  - Companies that could not afford their own could use companies that could provide calculating services such as "Workman Service" (who used "more Burroughs than any other kind")
  - Early 1950s, Burroughs introduced a new generation of electric office accounting machines – Sensimatic- which was able to perform many business functions semi-automatically. Refinements allowed it to store results on magnetic stripes.
  - Late 1950s, moved to computer products. 1960s & 1970s Burroughs was a major American computer company. This move to the computer sector was an indication of things to come for the business calculator market. So called key edit systems to programmable word processors and desktop computers
  - After a century in existence, Burroughs merged with Sperry corporation to form Unisys in 1986.

Calculators for the rest of us

- Ordinary people (not just businesses, government, etc.) were interested in calculators too.

- As it stood Comptometers and Arithmometers were too expensive for everyday people, this created an opportunity for a new market of small, inexpensive mechanical calculating machines.

- Wording was key in marketing these devices, for example: "Simple as a tape measure" and "a price which brings it within the means of all"

- Early American "personal" calculators were inexpensive, but had very basic design and some could not perform the carry operation automatically.

- Some (i.e. the Lighting Portable Adding Machine)still used dial wheels and numbers as seen in Pascal's devices, but sold very well for decades.

The down of "personal" calculators

- Marketed as "portable", "personal", "pocket" and "home" in the early 20th century, since then mechanical calculator names are frequently attached to the word "personal"

- Invention of transistor and later, of an integrated circuit allowed the replacement of mechanical, electro-mechanical and early electronic calculators with sophisticated scientific programmable and business calculators in the 1960s.

- In 1963 the Mathatron was introduced by Mathronix – First digital programmable electronic desktop calculator

- Marketed to "Vanish your problems" *your* problems, not *your company's* problems – marketed for individual use, but incredibly expensive ($5,000 in 1963)

- 1971 –handheld (or pocket) calculators arrive first from Bowmar Instrument and then many other manufacturers in a time when consumer electronics market entered one of the hottest periods in history.

- The idea of a personal calculator, a powerful, inexpensive calculating device for your own unrestricted use always in your pocket or briefcase or desk attracted people to these new gadgets.

- Advent of sophisticated semiconductor device – the microprocessor- created huge opportunities for tech world.

Conclusions

In the late 19th century calculator industry branched into business and personal calculator paths. While the business calculator industry eventually merged with computer industry in the 1970s, the personal calculator industry remains a significant component of consumer electronics industry for this day.

In 5,000 years or so, we have build and modified calculating tools to help us coexist with numbers. From lines and pebbles of a dirt abacus, to the first mechanical calculators and, finally, to our present day microprocessor powered personal calculators, the calculating gadgets have penetrated vast regions of our lives.

***Historical information and excerpts taken from Professor Stachniak's "Lecture 4" as posted on the NATS 1700 course website.**

Lecture 5 – The Dawn of Automatic Computing

Overview

- By the 1930s, mechanical and electromechanical calculators had penetrated all aspects of modern office operations

- Certain branches of science and engineering reached a calculating barrier and required an automated method to handle complex operations in order to make progress. – Needed a calculating machine that could perform large scale, error free calculations by following a program.

- First designs of computers started to appear in Europe and the US in the 1930s, groundbreaking theoretical research on computing was also initiated in this time period

Alan Turing

- Groundbreaking contributions to the science of computing

- Not a computer engineer by training, rather a British mathematician, logician and cryptanalyst

- Best known for his contributions to cryptography during WWII breaking German ciphers

- Discovered one of the most powerful computing devices ever conceived, now called the *Turing Machine*

- Research based on "abstract" computing machines at a time when there were no "real" computers, even still his work is considered to be one of the most significant contributions to computing for this day

The Hilbert Program

- 1928 David Hilbert suggests that entire mathematics could be "mechanized", we could do this on some sort of algorithm following calculating machine and mathematicians would now be tasked with discovering appropriate algorithms

- Turing disagreed, said there are mathematical problems that are unsolvable, could not be solved in an algorithmic way as Hilbert was envisioning

- Turing set to prove his result by creating an abstract computer –Turing Machine (see figure 2 lect 5, pg 4)

- No computers at the time Turing published his work , when computers did start to appear and computer science was born, Turing Machines helped define and understand fundamental notions of computing such as algorithm, a computer, a computation and its complexity.

- 1966 ACM established the A.M. Turing Award (essentially the Nobel Prize of computing)

Automatic computing in the 1930s, 40s, and 50s: an overview
Review definition of computer see example 1 Page 5 Lecture 5 and questions on page 6 lecture 5

First Computers

- The earliest computers ever designed and built cold be better classified as programmable calculators than computers as they were not designed to be general, but special purpose devices. Designed to perform specific computations only.

Germany

- Z1 designed by Konrad Zuse between 1936 and 1938 was possibly the world's earliest programmable calculating machine.
- Mechanical, but powered by electricity, programs presented to Z1 on a paper tape, could store a few numbers in mechanical memory (metal sticks!)
- Unreliable: operation of device applied excessive mechanical stress on moving parts
- Between 1938-1941 Zuse improved his designs with the an electro-mechanical equivalent of the Z1 in 1941. The new Z3 used electro-magnetic relays.
- Z1 & Z3 destroyed during WWII, Z4 was created in 1950, Z22 (Zuse's first electronic computer using vacuum tubes instead of electro-magnetic relays)

Britain

- Colossus Mark-1 (1943) and Mark-2 (1944) designed by Tommy Flowers in London to help decode intercepted German telegraphs during the war (designed for one purpose only, hence they were "Special purpose")
- First significant application of a programmed calculating machine
- Trained first generation of British computer experts.
- Interconnected hardware modules using vacuum tubes ("electronic")
- Programmed by connecting various hardware modules with wires and switches (not "stored program")
- Read inputs from paper tape (see figure 6, page 10 lecture 5)
- Dismantled by 1960, rediscovered in 1970s and reconstructed in the 1990s.

- Between 1946 and 1948, team of researchers developed a fast, fully electronic mass storage device (memory) – the so called Williams Tube. Built a simple computer called the Small Scale Experimental Machine (SSEM or "The Baby") – First computer with electronic storage, the first stored-program computer.
- June 21, 1948, the team executed the world's first program stored in computer memory (in the same way as modern computers). First to do so.

- This success led to the creation of the Manchester Mark-1 which was converted into a commercial product by Ferranti Ltd. Sold as "Ferranti Mark 1"- First commercially sold computer.

United States

- John Atanasoff saw a need for a new type of calculating device that was fast and had internal memory, late 1930s along with Clifford Berry, began work on the Atanasoff Berry Computer (ABC)
- Completed around 1942, the ABC was designed for a very specific purpose: to solve mathematical problems using the method of Gauss elimination, the so called "difference method"
- First binary electronic computing device, possibly impacted general design ideas behind ENIAC

- Howard Aiken – felt efficient problem solving in science and engineering could not be accomplished with traditional calculators, needed machines that could execute sequences of operations in a pre-programmed manner
- Worked with IBM to build and deliver the machine (the Harvard Mark one or IBM Sequence Controlled Calculator) in 1944
- 8 ft high, 3 ft deep, 51 ft in length, had 760,000 individual components and 530 miles of wires, weighed 5 tonnes. Very slow because of the use of electro-magnetic technology.
- Introduced many to computing, was not shrouded in secrecy like the Z3 or Colossus
- One of the first programmed calculating machines
- Used for military applications during WWII including designing the atomic bomb

- J. Presper Eckert, John W. Mauchly, John G. Brainerd and Herman H. Goldstine were the main architects behind the ENIAC.
- Built during WWII between 1943 – 1945, primary purpose was to speed up calculations required by the Ballistic Research Lab who required fast, reliable calculating machine that must be built quickly
- Could be "programmed" to execute instructions to solve a range of problems, in this way it was a general purpose computer, even though it was designed with specific applications in mind.
- Unveiled to the public in 1946, weighed 30 tonnes, took up a room 170 square meters, used 17,468 vacuum tubes.
- "Programmed" by physically connecting various modules using wires and setting switches. Could store intermediate results of calculations but not programs.
- Proof of principle that large scale, super fast electronic calculating devices could be built (ENIAC could perform additions 1000 times faster than the top calculating speed at that time)
- Generated interest in electronic computers in many countries
- Convincingly demonstrated to the public that construction of such devices should be desirable (speed, scope of problem solving, accuracy, etc.)
- Primarily used for military applications (weapons design e.g. computation of ballistic tables, calculations related to thermonuclear reactions)

- IAS computer was completed 8 years after the ENIAC, but of utmost importance to the understanding of the creation of the modern computer industry
- Created by John von Neumann

- Supporting military efforts in WWII like (Turing in the UK), he realized how significant the computer technology would become to science and the society , which explains his involvement with the EDVAC (ENIAC's successor)

- June 1945, he wrote the "First Draft of a report on the EDVAC" which contained the "basic plan" for a modern computer.

- Incorporating ideas formulated by Turing, Mauchly and Eckert, "von Neumann's architecture" called for a central arithmetic unit, a central control unit, provisions for input/output, and most significantly, a memory for storing program.

- Once an application program is deposited into computer memory, the execution of such a program is accomplished by consulting this memory to determine which instruction of the program should be executed next. Computers that implement this idea of program storage and execution are called stored-program.

- Even today, the design of computer architecture continues to be influenced by the von Neumann architecture.

- IAS was a stored program computer, successfully operated from 1952 until 1960

- **See IAS computer's impact and IAS applications (lecture 5 page 22)**

Early computers elsewhere

USSR

- Architectures of the early American computers such as ENIAC and EDVAC were not kept secret, thus one may only conclude that some of the computer architectures and technologies were reflected in early Russian computers (this is only a hypothesis to be answered by historical research)

- S.A. Lebedev was the most influential early Russian computer designer

- Started work on first electronic computer in the 1930s in Moscow, but was interrupted by the Russian-German war in 1941 and not much is known about Lebedev's early work

- In 1947, after the war, he resumed his work on computers at the Institute of Electrical Engineering of the Ukranian Academy of Science in Kiev

- Lebedev's team completed the MESM computer by 1951

- MESM was not a useful computer, but rather a proof of concept that a useful electronic computer *could* be built in the USSR

- Completed second computer the BESM-1 in 1952 and was used successfully for many applications

- In the first three years of the 1950s a number of other computers were completed in the USSR. They were: the M1 (1951, Isaak Bruk's team at the Power-engineering Institute of the Academy of Science of USSR), the M2 (1952, the same team as for the M1), STRELA (1953, Yuriy Bazilevskiy and Bashir Ramayev, Special Design Bureau-245). The STRELA (which means"arrow") was the first computer in the USSR manufactured in small series

Japan

- Japan started manufacturing its first computers in the second half of the

1950s. Companies such as Fuji Film Company, Nippon Telegram and Telephone Public Corporation as well as universities: Tokyo University, Osaka University, and Keio University designed and built their first hardware. Since the 1960s, Japanese computer industry began to develop at a remarkable rate.

Other European Countries

- In the 1950s, a large number of countries (in addition to US, UK, Germany,

Japan, and USSR) had at least one digital electronic computer to their credit. The (incomplete) list includes: Canada (the UTEC, 1952), France (the Bull Gamma 60, 1956), Czechoslovakia (the SAPO, or Samo˘cinn´y po˘c´ıta˘c, 1956), Sweden (The BARK, or Binr Automatisk Rel¨aKalkylator, 1950; the BESK, or Bin¨ar Elektronisk Sekvens-Kalkulator, 1953), Norway (the NUSSE, or Norsk Universell Siffermaskin, 1953), Denmark (the DASK, or Dansk Automatic Eskvens Kalkulator, 1956), Poland (the XYZ, 1958).

For conclusions and a comprehensive list of early computers, please see Appendix A & B of lecture 5 (pg 27-28)

***Historical information and excerpts taken from Professor Stachniak's "Lecture 5" as posted on the NATS 1700 course website.**

Lecture 6-The Birth of the Computer Industry

Brief Review of Inventors & Their Companies

• In 1949, Konrad Zuse (the creator of the Z1, Z3, and Z4) founded Zuse KG (quite successful);

• In 1946, J. Presper Eckert and John Mauchly (the designers of ENIAC) founded Eckert-Mauchly Computer Corporation (later acquired by Remington Rand) and designed the UNIVAC I (UNIVersal Automatic Computer I) – the first American volume-manufactured computer;

• Howard Aiken (the creator of the Mark 1 programmable calculator) continued his designs of programmable calculators and computers coming up with: Mark 2, 3, and 4;

• the work initiated by Williams and Kilburn at the University of Manchester (The Baby) attracted Ferranti (UK) to computer making and that would be one of the main business lines of the company until its closure in 1993;

• the work on von Neumman's IAS computer attracted the attention of many institutions around the world to computing and seeded their computer industries.

- Success of early computers attracted attention of large corporations which began to think about making their own electronic computers: USA-IBM, Remington Rand, UK-Ferranti, Japan – Fuji, but unclear of demand for computers in the commercial market
- Government Studies on future use of computers produced negative results, Howard Aiken himself had the opinion that: a commercial market would never develop; in the United States there was a need for perhaps five or six such machines but no more
- Despite these results, some companies began manufacturing computers for the commercial market as early as 1951/52 (Ferranti started production of Mark 1, Remington Rand its UNIVAC and IBM its 701 Defence Calculator)
- Early commercial computers made in the 1950s and 1960s are commonly classified as mainframes (large and required specially constructed rooms, even whole floors of buildings to contain and protect them)

-Mainframes were very expensive and were only afforded by rich organizations such as banks

- Programming and operation of mainframes was essentially a "priesthood" in which select computer professionals were granted access to the mysteries of these machines

UNIVAC

- In 1948, Eckert and Mauchly decided to start their own company "The Eckert Mauchly Corporation" and capitalize on the success of the ENIAC with their creation of their next computer: the Universal Automatic Computer or UNIVAC.
- The project was underfunded and was only able to continue when Remington Rand bought the company and provided the necessary funds to have it unveiled in 1951

- Between 1951 and 1954, 19 computers were sold and installed on customer's premises, each bringing about one million dollars to Remington Rand.
- Customers ranged from private corporations such as GE to military defence agencies
- UNIVAC's success significantly contributed to the commercial acceptance of computers
- Demonstrated in the early 1950s there was a substantial commercial demand for electronic computers

The IBM Way

- The success of the UNIVAC made IBM switch it's focus from data processing and tabulating to electronic computers.
- In 1952 IBM announced its first electronic computer: The IBM 701 Defence calculator
- IBM's predecessor – Computing-Tabulating –Recording Company (C-T-R) was formed in 1911 as a result of amalgamation of a number of firms including Tabulating Machine company founded by Herman Hollerith, a statistician at the US census bureau
- Late 19th century, US Census Bureau realized that its traditional counting methods would be inadequate for measuring and researching rapidly the expanding American population
- Census Bureau created a contest to find a more efficient way of tabulating census data.
- The winner of this contest was Herman Hollerith with his Punch Card Tabulating Machine (see Figure 3 lecture 6 page 6)

- **A short IBM timeline**

- 1896: Herman Hollerith founded Herman Hollerith's TabulatingMachine Com-pany to manufacture and use electric tabulating and accounting machines.
- 1911: The formation of C-T-R
- 1914: C-T-R manufactured a range of accounting machines
- 1920: C-T-R introduced printing tabulator
- 1924: C-T-R's name was formally changed to International Business Machines Corporation.
- 1928: IBM adopted the 8-column punch card–the IBM format–setting a defacto industry standard for decades to come
- 1931: IBM introduced the 601 Multiplier calculator
- 1933: the introduction of the IBM Type 285 Numeric Printing Tabulator
- 1944: in collaboration with H. Aiken, IBM build the Automatic Sequence Controlled Calculator (ASCC or Harvard Mark 1)
- 1946: IBM introduced the 603 Electronic Multiplier – the first commercially manufactured electronic calculator
- 1948: IBM introduced SSEC: the Selective Sequence Electronic Calculator (hybrid design with vacuum tubes and electromagnetic relays, input on paper tape.
- In 1952 IBM announced the IBM 701 Defence Calculator, the company's first large electronic computer (vacuum tubes). The 701 was designed primarily for scientific calculation, some were rented for about $16,000 per month.

- IBM continued to manufacture and sell new computer equipment through the 1950s, but their next milestone came on April 7, 1964, with the introduction of the System 360 (the

first large “family” of computers whose software and hardware configuration could be tailored to customers’ needs)
- The IBM system 360 represented a radical departure from the industry standard of offering all clients the same computer with the same configuration
- Gene Amdahl was the main architect of the 360 family of mainframes (later started his own Amdahl Corporation)
- The tremendous success of the 360 placed IBM in a dominant position for a number of decades – By 1965, IBM had over 65.3% of the mainframe market to itself
- Mainframe business in the 1960s described as “IBM and the seven dwarfs” (seven dwarfs being: Burroughs, Sperry Rand, Control Data, Honeywell, General Electric, RCA and NCR)
- 1960s and early 1970s, Canadian academic institutions’ computational needs were served mostly by IBM computers (York’s first mainframe computer was the smallest in the IBM 360 family – the model 30- installed October 1966 with just 22K of memory)
- In May 1968, York replaced its IBM 360 with a rented IBM 360 Model 40 (128k of memory) High rental costs
- A year later, this was replaced with the IBM 360 Model 50 (256k of memory)
- In 1972, both machines were replaced with a state of the art IBM 370 model 155

Giant Brains, computer priesthood and the mortals
- First industrial computers were sold to a very selective group of customers
- 1950s and 1960s the average individual in North America was aware of computers had, at best, a vague knowledge about the purpose and use of such machines
- Mainframes were mostly hidden from the general public and what they were exactly used for was a mystery
- Pop culture spoke of mainframes as “Giant Brains” or “Super Brains” in the 1930s and 1940s
- These “Giant Brains” were served by a sophisticated group of “computer priests” who were programming and operating them (the computer priesthood), we, the public, were mere “mortals” and could only see them in operation in sci fi movies

Computers in Films
- Depicted as “evil” in early Star Trek episodes. Also obey rules of logic and explode when faced with contradiction
- This depiction led to a growing mistrust of powerful technologies
- Some of the futuristic technologies seen in Star Trek have been realized (handheld communication devices) Some became our everyday computing reality: small external storage devices, speech and handwriting recognition and touchscreen interfaces
- Kubrick’s *2001: A Space Odyssey* portrays a self-conscious artificial mind (see script excerpt lecture 6 pg 16-17)

Berkeley and his little idiot
- 1950s and 1960s the computer industry was not interested in computer literacy programs aimed at popularizing computer technologies in society, their clients were big corporations and it was up to them to calm the society being distressed by rumors of Giant Brains eroding thousands of jobs, “watching us”, etc.

- Magazines would publish articles about computers, but failed to demystify them, it would take another decade before a forceful wave of computer hobby movement would assume the role of educator, in the meantime a few dedicated educators did their best to bring the knowledge of computers to the rest of us
- 1949 Edmund C. Berkeley published his book *Giant Brains or Machines That Think*, in which he described early calculators and computers, how they were designed, built and operated, and included a sketch of his own simple computer called Simon.
- First popular science book aimed at educating electrical engineering enthusiasts (and hobbyists) about computing machines
- "Simon" was completed in 1949 and its design was also published in *Radio Electronics* magazine between 1950-1951 for the benefit of electronics enthusiasts
- The magazine called Simon the "World's Smallest Electric Brain", Berkley referred to Simon as "Little Idiot" because it could only operate with 4 numbers: 0, 1, 2 and 3.
- Simon served as an educational aid "to exhibit in simple understandable form the essential principle of any artificial brain"
- Berkley had big dreams for the future of personal computing (see excerpt page 20 lecture 6) these ideas were closer to our present day reality than other "visionaries" of the time
- Berkley's book inspired John Weisbecker
- Weisbecker is best known as the designer of the first microprocessor to be employed in a spacecraft (his RCA 1802 microprocessor was powering computers on board a number of crafts including the Galileo in 1982)
- Weisbecker not only built large computers and microprocessors, but shared the same passion of educating people as Berkley
- Became the designer and promoter of small microprocessor based hobby computers such as the Elf.
- Elf was offered in a kit form to electronics hobbyists

***Historical information and excerpts taken from Professor Stachniak's "Lecture 6" as posted on the NATS 1700 course website.**