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OPERATING SYSTEMS

Introduction

Prof. Dr. Oliver Hahm

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AGENDA

- Core Functionalities of Operating Systems
- Generations of Computer Systems and Operating Systems

CORE FUNCTIONALITIES OF OPERATING SYSTEMS

RECAP

What do you already know? Let's go to the survey again:
https://fra-uas.particifyapp.net/p/66824346

- Which operating systems do you know?
- What are the functionalities of an Operating System?

SOME EXAMPLES

GNU/Linux

FreeBSD

Microsoft Windows

BeOS

RIOT

OpenBSD

ORACLE Solaris

AIX

android

QNX

macOS

Zephyr™

DEFINITION: OPERATING SYSTEM

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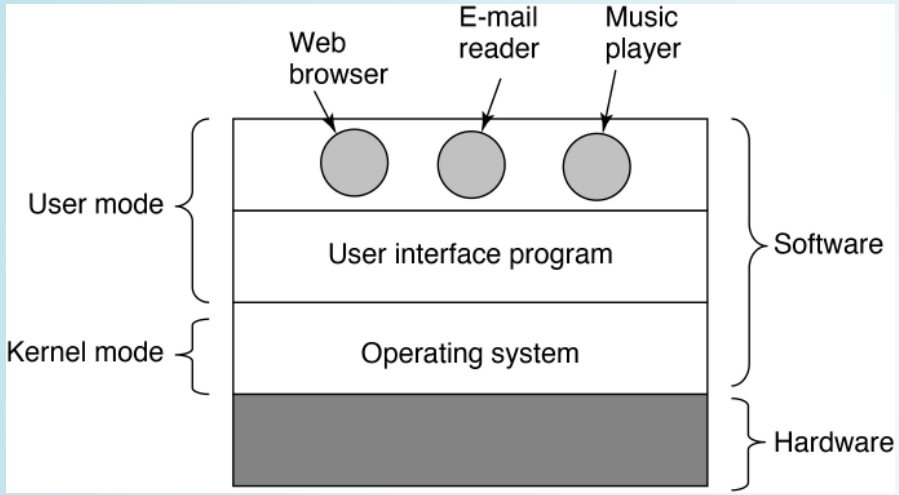
Andrew S. Tanenbaum

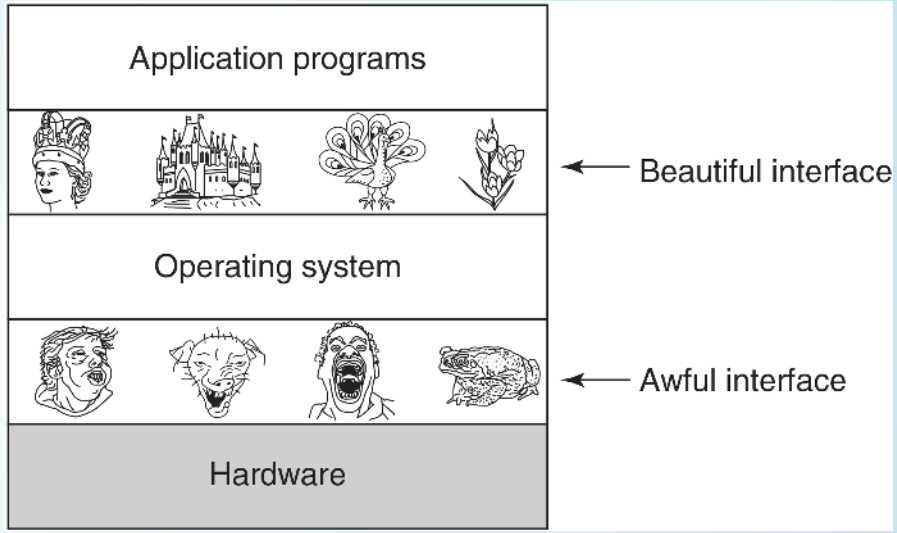
An operating system "[provides] application programmers (and application programs, naturally) a clean abstract set of resources instead of the messy hardware ones and managing these hardware resources."

William Stallings

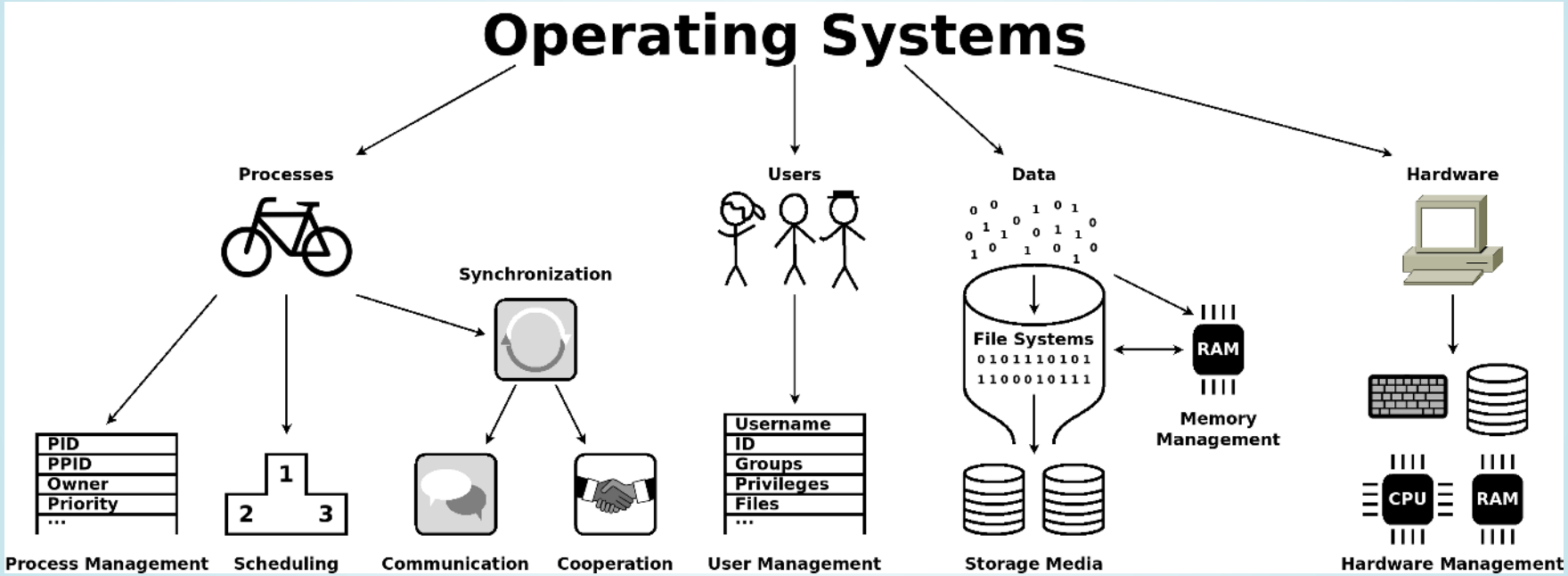
“An OS is a program that controls the execution of application programs, and acts as an interface between applications and the computer hardware. It can be thought of as having three objectives: - Convenience […] - Efficiency […] - Ability to evolve”

ABSTRACTION LAYER FOR THE APPLICATIONS

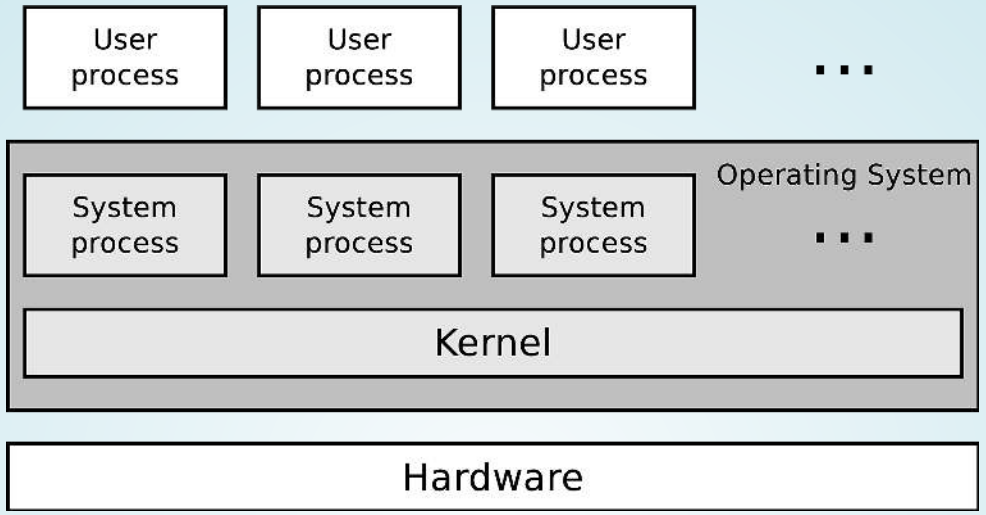




RESOURCE MANAGER



BASIC STRUCTURE OF AN OPERATING SYSTEM



- User processes process the users' jobs
- System processes provide services of the operating system
- The operating system core ($\Longrightarrow$ kernel) contains all components of the operating system, which are not implemented as system processes

Operating Systems are Part of the System Software

System software controls the operation of a computer, assists users and their applications in making use of the hardware and controls the use and allocation of available hardware resources

WHY DO WE NEED AN OPERATING SYSTEM?

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- Abstract hardware interfaces
- Make software portable
- Share resources and allow for separation
- Efficient usage of resources

$\Longrightarrow$ Software development without an OS is painful

YOUR TURN

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Two Challenges

- Name an electronic device without a computer!
- Name a module from your study program that is completely unrelated to Operating Systems!

Which tasks in software development would be much more cumbersome without an Operating System?

GENERATIONS OF COMPUTER SYSTEMS AND OPERATING SYSTEMS

RECAP

Let’s go to the survey again:
https://fra-uas.particifyapp.net/p/66824346

- What are the two main tasks of an operating system?
- Which resources are managed by the OS?
- What is the main component of any OS?

GENERATIONS OF COMPUTER SYSTEMS AND OPERATING SYSTEMS

Generation	Time period	Technological progress
0	until 1940	(Electro-)mechanical calculating machines $\Longrightarrow$ no software!
1	1940 – 1955	Electron tubes, relays, jack panels
2	1955 – 1965	Transistors, batch processing
3	1965 – 1980	Integrated circuits, time sharing
4	1980 – 2000	Very large-scale integration, microprocessors, PCs/Workstations
5	2000 until ?	Distributed systems, *the network is the computer*, virtualization

Quote from the magazine *Popular Mechanics* (1949)

In the future, computers may weigh no more than 1.5 tonnes.

GENERATION ZERO

GENERATION ZERO (UNTIL 1940)

Image Source: Wikipedia (Herbert Klaeren, CC-BY-SA-3.0)

Image Source: Heinz Nixdorf Museum

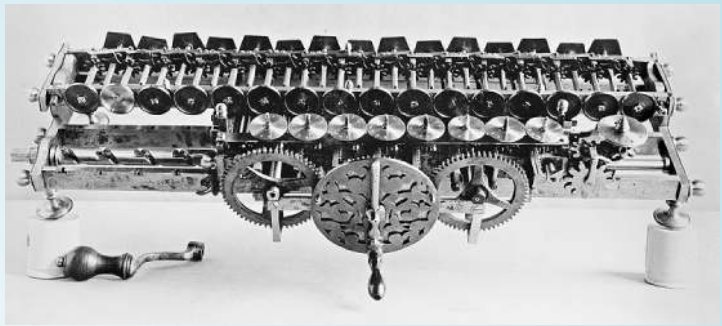

Image Source: Deutsches Museum

- Mechanical/Electromechanical calculating machines
- Examples:
  - Mechanical calculator of Wilhelm Schickard (1623)
    - Offers addition, subtraction and carry mechanism (*Zehnerübertragung*)
  - Mechanical calculator Pascaline of Blaise Pascal (1643)
    - Offers addition, subtraction, $\leq$ 8 digits and carry mechanism
  - Mechanical calculator of Gottfried Wilhelm Leibniz (1673)
    - Offers all 4 basic arithmetic operations, $\leq$ 6 digits and carry mechanism

No software in this generation $\Longrightarrow$ no operating systems

GENERATION ZERO (UNTIL 1940)

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- Another example:
  - Difference Engine No.1 for solving polynomial functions of Charles Babbage (1832)

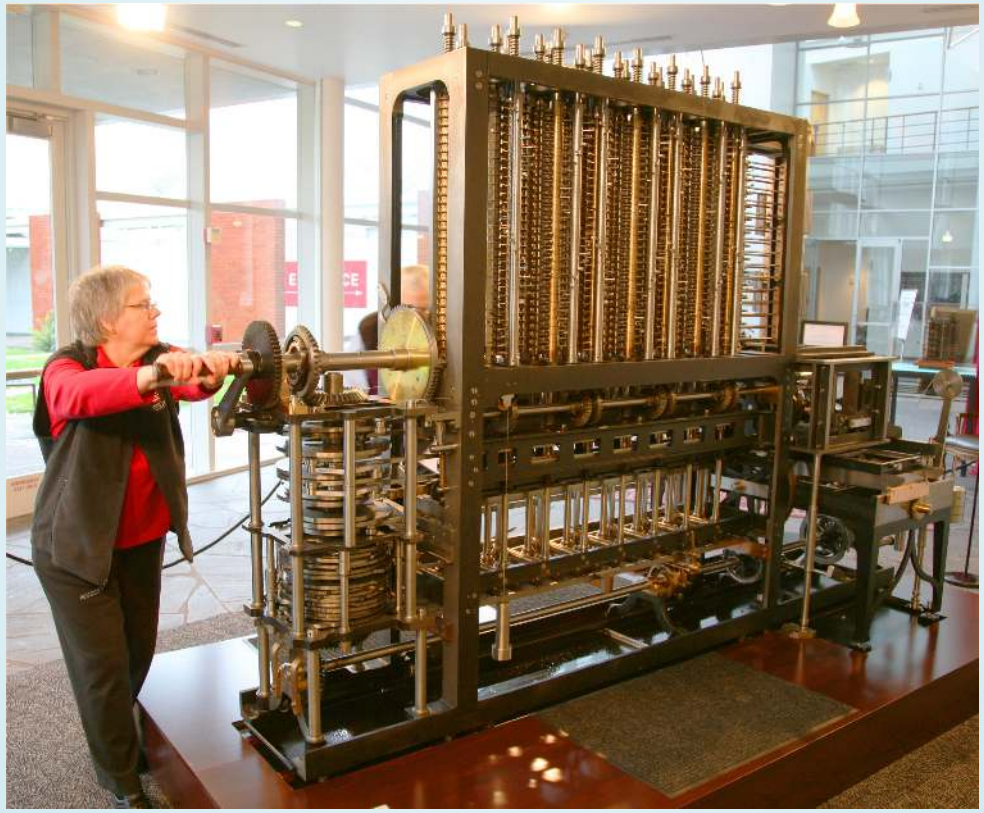

Image Source: flickr.com (Jitze Couperus, CC-BY-2.0)

GENERATION ZERO (UNTIL 1940)

- Another example:
  - Hollerith tabulating machine of Herman Hollerith (1888)
    - Includes: Tabulating machine, punch card sorter, key punch (card punch) and punch card reader
    - 1890: The tabulating machine is used to tabulate the US census
    - 1924: The company of Hollerith is renamed to International Business Machines Corporation (IBM)

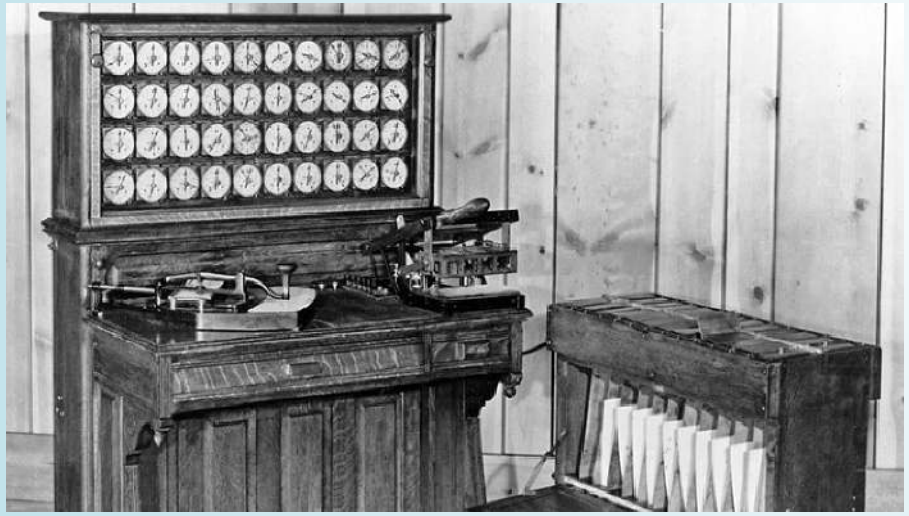

Image source: IBM

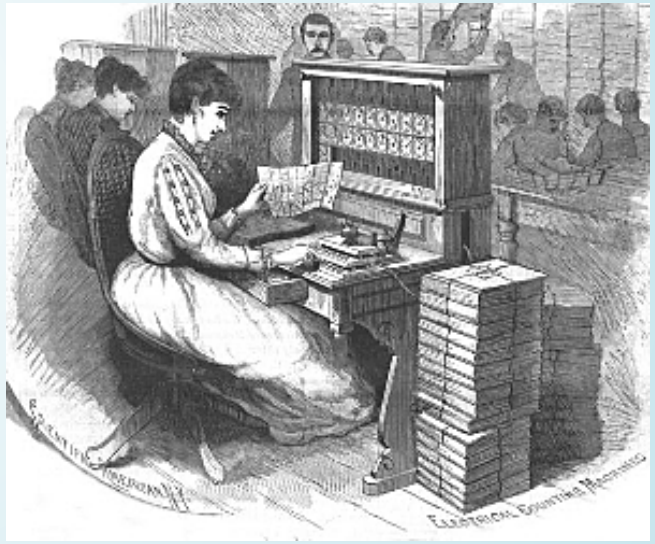

Image source: United States Census Bureau

1ST GENERATION

1ST GENERATION (1940 – 1955)

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- The 1st generation of computer systems was constructed during WW2 $\Longrightarrow$ Konrad Zuse, John von Neumann
- Requirements, universal computer a must satisfy:
  - Stored **program**
  - **Conditional Jump** (GOTO)
  - **Separation** of memory and CPU
- Computers were machines with partially $>$ 10,000 tubes or relays, which worked slow and error prone
- **No operating systems and programming languages in this generation**
- Programs were implemented via circuits in patch bays
  - The user/programmer launches **one** program, which directly accesses the hardware

SOME SYSTEMS OF THE 1ST GENERATION

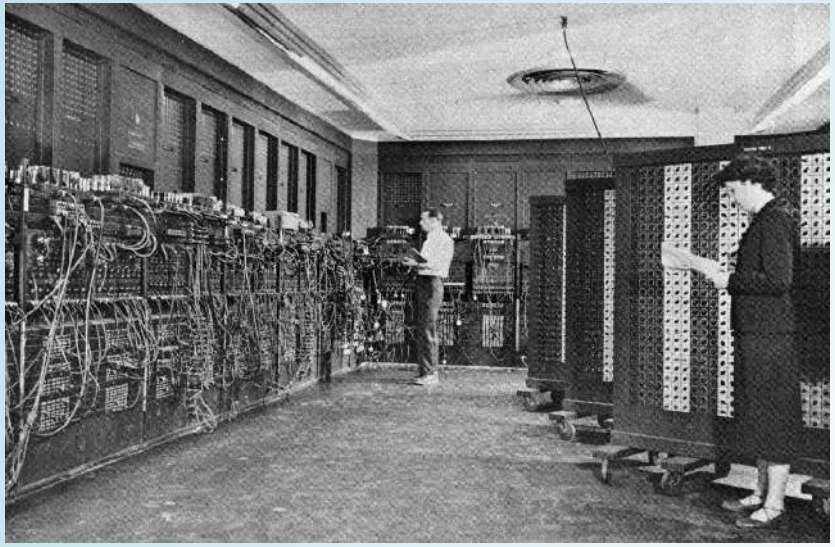
Computer	Development	Storage/CPU separated	Conditional jumps	Program-ming	Internal encoding	Number representations	Technology
Z1 / Z3	1936-1941	yes	no	SW	binary	floating point	mechanical (relays)
ABC	1938-1942	yes	no	HW	binary	fixed-point	electronic
Harvard Mark 1	1939-1944	no	no	SW	decimal	fixed-point	electronic
ENIAC	1943-1945	no	partially	HW	decimal	fixed-point	electronic
Manchester	1946-1948	yes	yes	SW	binary	fixed-point	electronic
EDSAC	1946-1948	yes	yes	SW	binary	fixed-point	electronic

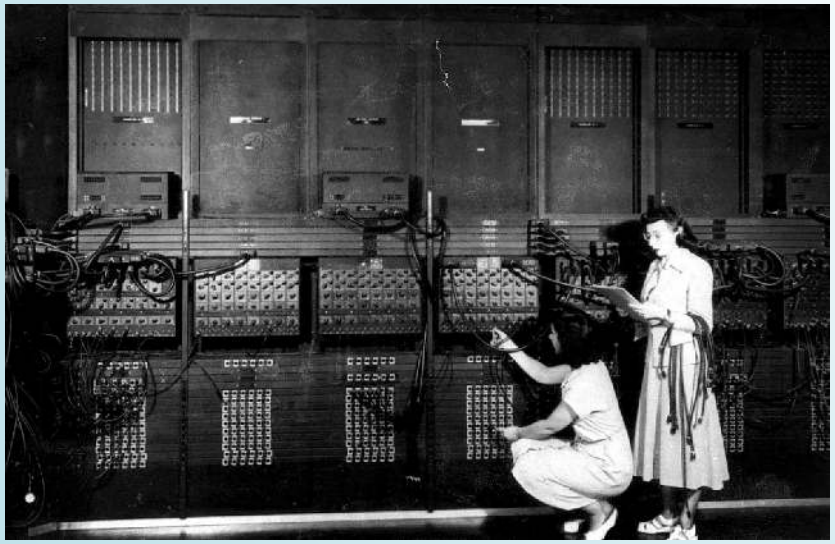
Zuse Z3 (1941)

- The world's first working programmable, digital computer (based on relay technology)
- First computer, which implemented the binary system

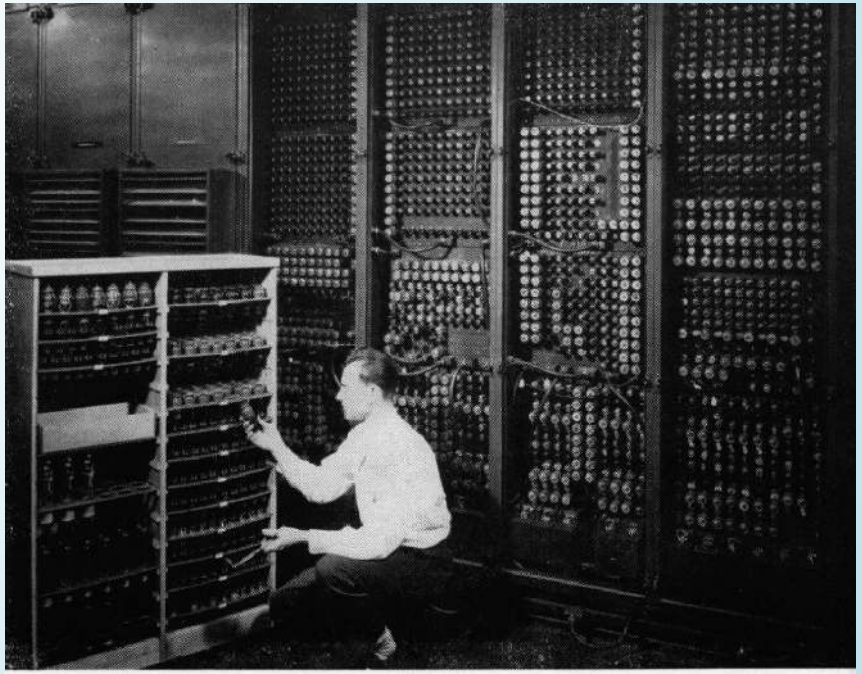
Image Source: Courtesy of Christian Baun, 2008

1ST GENERATION: ENIAC (1944)





- Electronic Numerical Integrator and Computer (ENIAC)
- First electronic general-purpose computer (with electron tubes)



Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

Image Source: US Army (Public Domain)

2ND GENERATION

2ND GENERATION (1955 – 1965)

- Early 1950s: Punch cards replace the patchbays
- Mid-1950s: Introduction of the transistors:
  $\Longrightarrow$ Computer systems become more reliable

Image Source: Flickr (born1945, CC-BY-2.0)

- Programs were written in early programming languages like FORTRAN or COBOL
  - written down by the programmer on form sheets,
  - punched from coders into punch cards
  - and handed over to the operator (**administrator**)
- The operator…
  - coordinates the order (schedule) of programs (jobs)
  - equips the computer with the punch cards
  - loads the compiler from the magnetic tape
  - hands over the printed out computation result

BATCH PROCESSING

BATCH PROCESSING OPERATING SYSTEMS

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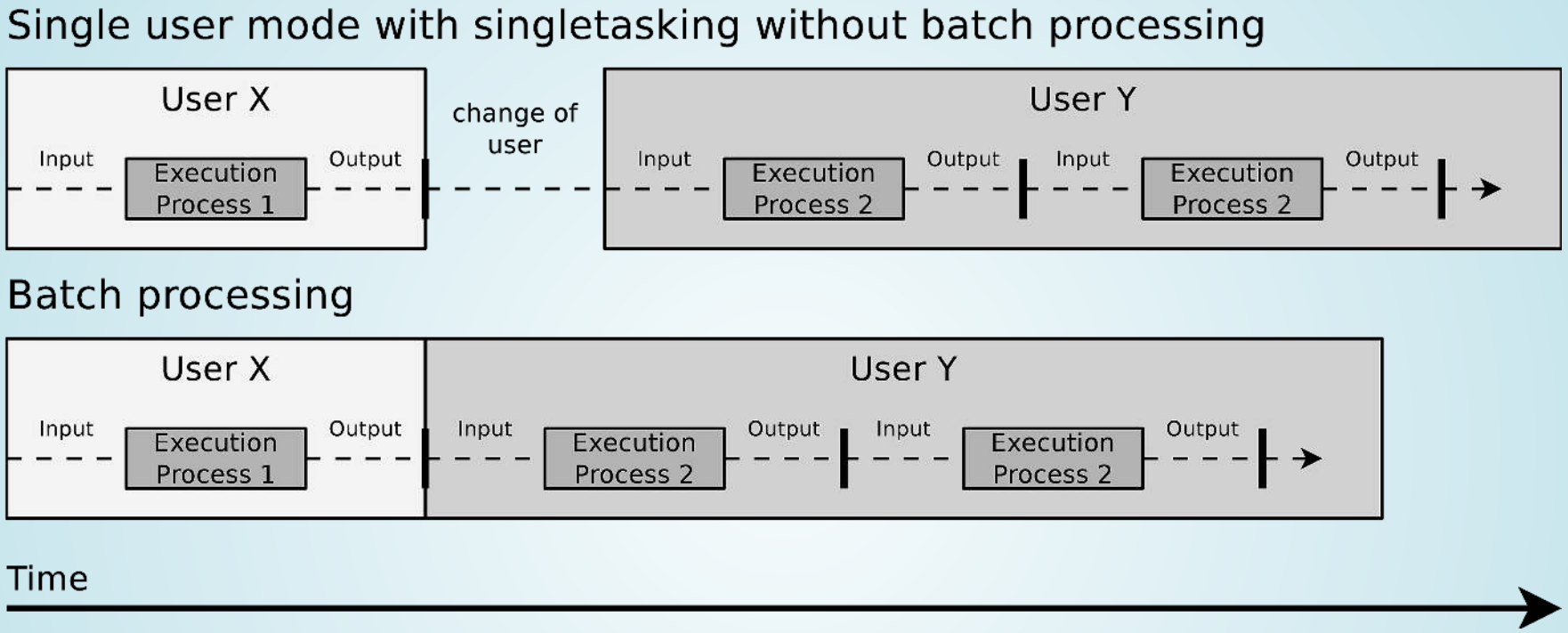
- Operating systems of this generation were all *batch processing operating systems*
- Objective: Maximize CPU utilization

- Each program needs to be provided completely (with all input data!) before the execution may begin
- Batch processing is well suited for the execution of routine tasks

Image Source: IBM (the image shows an IBM 7090 from 1959)
http://www.computer-history.info/Page4.dir/pages/IBM.7090.dir/images/ibm.7090.jpg

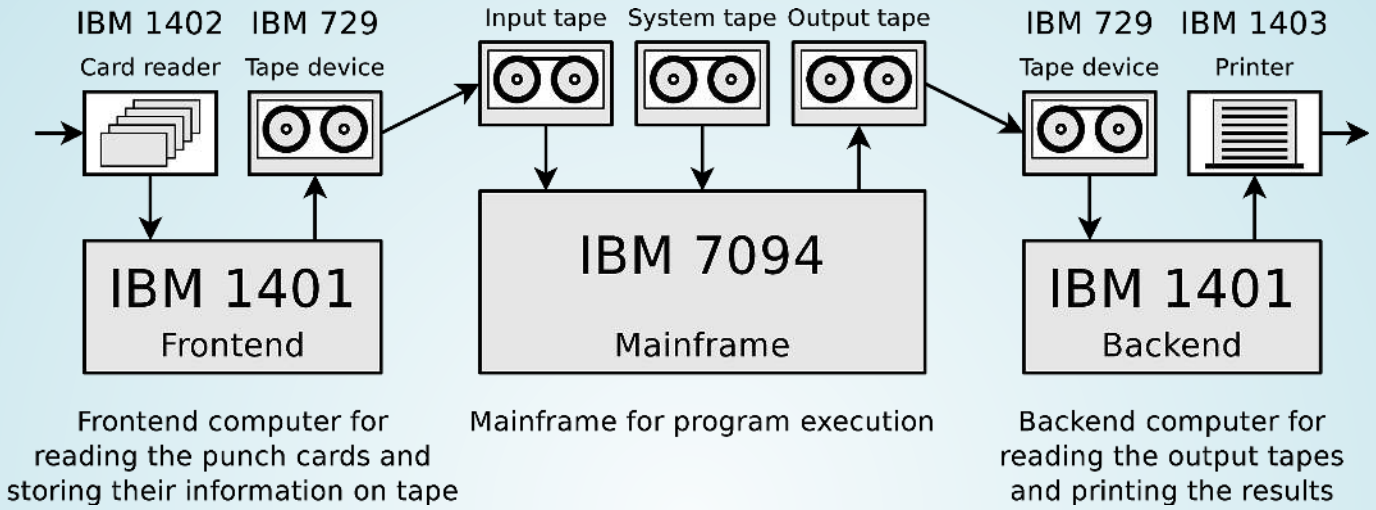
- Today's systems still allow to process program sequences automatically (e.g., non-interactive batch files and shell scripts)

SINGLE USER MODE WITH BATCH PROCESSING



- Batch Processing $\Longrightarrow$ Acceleration via automation
- **Drawback:** The CPU is still not utilized in an optimal way
  - During input/output operations the CPU is idle

SPOOLING



- Frontend/backend computers free the mainframe from slow I/O operation
  - Data can be read from tape much faster than from punch cards and data can be stored on tape much faster than printed out
- Spooling removes I/O workload from the CPU by using additional HW
  - I/O is carried out concurrently with the processing of other jobs

Today, computers have in addition to the CPU, specific I/O processors with DMA capability (*Direct Memory Access*)

These write data directly into the main memory and fetch the results from there

BATCH PROCESSING TODAY

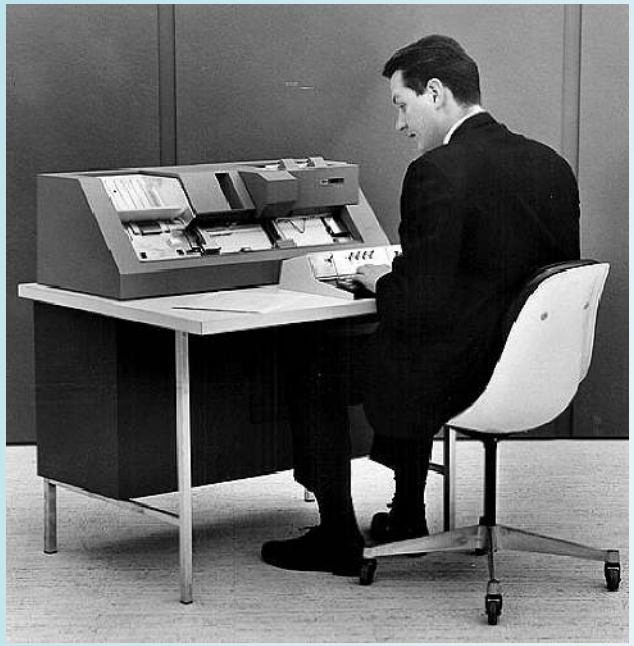


Image source: IBM Archives
https://onfoss.com/a-timeline-of-computer-interface-technology/

- Spooling is still used today
  - e.g., spooling processes for printing
- Batch processing is usually non-interactive
  - A started process is executed without any user interaction until it terminates or an error occurs
- Batch processing operating systems of the 2nd generation only implement singletasking ($\Longrightarrow$ slide set 3)
  - The operating system allows only the execution of one program at once
  - Starting a second program is only possible after the first one has finished

Some Operating Systems of the 2nd Generation
Atlas Supervisor, GM-NAA I/O, UMES, SHARE, IBSYS

„FOR HISTORIC REASONS…"

Why do many E-mail clients
(Mail User Agents (MUAs))
and editors insert line breaks after 80 characters?

2ND GENERATION: PUNCH CARDS

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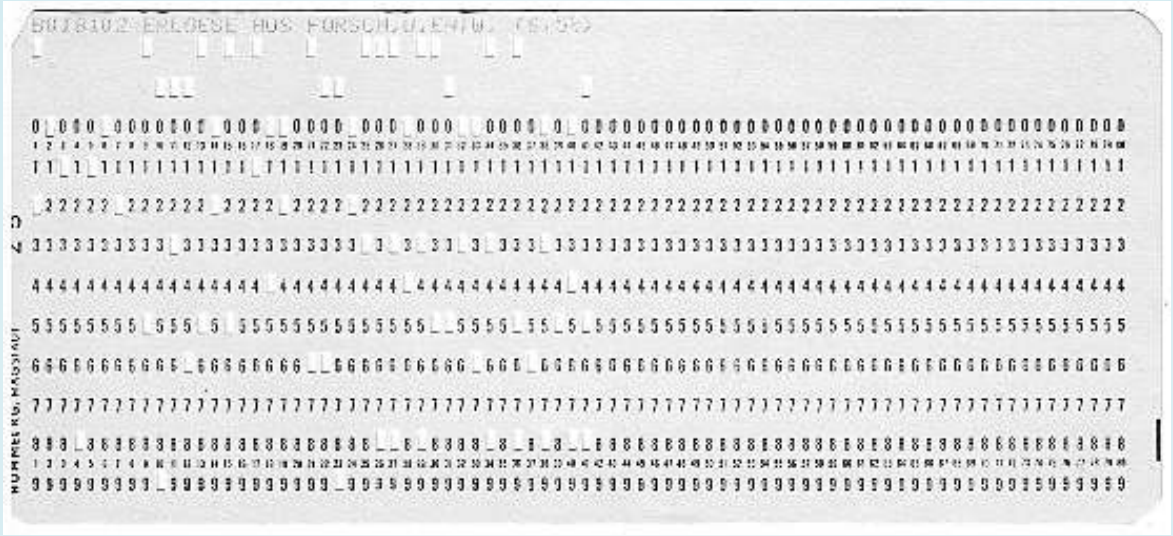
⇒ The standard line size of ≤ 80 characters in E-mails and text files dates back to the punch card



- Each punch card usually represents a single line of text with 80 characters or a corresponding number of binary data
- 12 punch hole positions for the encoding of each character
  - Digits are encoded with a single hole in the corresponding row
  - Letters and special characters are encoded by punching multiple holes in the column

3RD GENERATION

3RD GENERATION (1960 – 1980)

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- Early 1960s: Integrated circuits are available
  $\Longrightarrow$ More powerful, smaller and less expensive computers
- 1960s:
  - Improvement of the batch processing systems to allow the execution of multiple jobs during the same period of time $\Longrightarrow$ multitasking
  - First simple memory management(*fixed partitions*) $\Longrightarrow$ slide set 5
- 1970s: Time-sharing (*interactive mode*)
  - One central unit, multiple terminals
  - Each user gets a user process when logging in
- End of the 1970s: Development of the microprocessor
  $\Longrightarrow$ Development of the home computer / personal computer (PC)
  - 1977: Apple II. First home computer
  - 1981: IBM PC. Top selling computer architecture (Intel 80x86)

Some Operating Systems of the 3rd Generation

BESYS, CTSS, OS/360, CP/CMS, Multics, Unics (later Unix), DEC DOS-11, DEC RT-11, Version 6/7 Unix, DEC CP/M, Cray Operating System, DEC VMS

SOME SYSTEMS OF THE 3RD GENERATION

Computer	Development	Special features
CDC 6600	1964	First supercomputer
IBM System/360	1964	8-bit character size. Flexible architecture
PDP-8	1965	First commercial minicomputer from DEC
ILLIAC IV	1969	First multiprocessor computer
CRAY 1	1976	Supercomputer

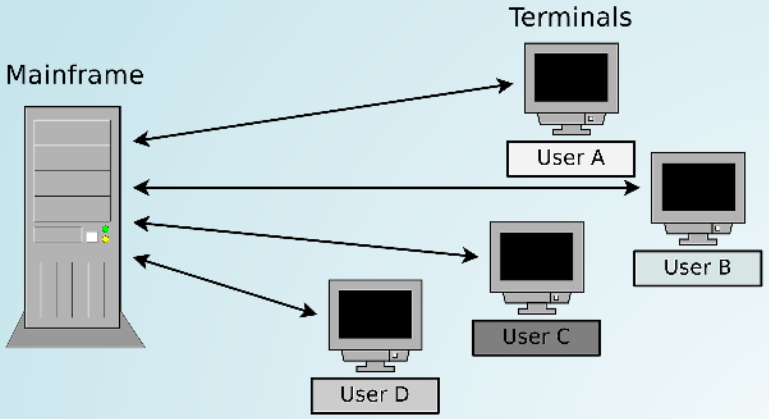
Image Source: Clemens Pfeiffer (CC-BY-2.5)

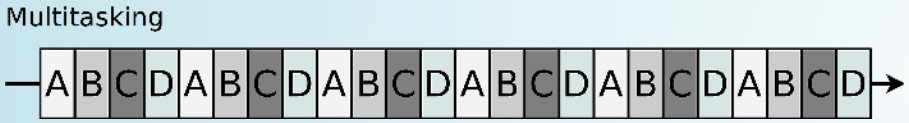
This generation includes also...

- first decentralized computer network (ARPANET)
- computer networks to connect terminals with mainframe computers via time slices serial lines (e.g., IBM Systems Network Architecture)
- proprietary interconnection networks (e.g., DECnet)

TIME-SHARING

MULTI-USER OS





- Multiple users work with a single computer in a **simultaneous and competitive** way by sharing the available computing time of the CPU
  - **Objective:** Fair distribution of the computing time
- The computing time is distributed via
  - The distribution can carried out according to different strategies
- can work interactively and simultaneously with a computer via terminals () (() next slide set)
- The programs of the individual users are independent of each other
- The pseudo-parallel program or process execution is called (() next slide set)
  - Minimizing the response time

NEW REQUIREMENTS

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- Because of time-sharing, new concepts were required:
  - Memory protection: The memory is split and running programs are separated from each other
    - This way, a *bug* or crash of a single program does not affect the stability of other programs and the total system
  - File system, which allow quasi-simultaneous file access
  - Swapping: Process of storing and removing data to/from main memory from/into background memory (HDDs/SSDs)
  - Scheduling: Automatic creation of an execution plan (*schedule*), which is used to allocate time limited resources to users or their processes

4TH GENERATION

4TH GENERATION (1980 – 2000)

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- This generation provides highly integrated circuits (ICs) and an exponentially growing integration density of electronic components
  - CPUs become more powerful and cheaper
  - The main memory capacity rises
- High computing power can be installed on every workplace
  - Workstations become standard in the in the professional sector
  - Popularity of home computers and personal computers (PC) rises
    - Main objective of operating systems: Intuitive user interfaces for users who do not want to know anything about the underlying hardware

Some Operating Systems of the 4th Generation

QDOS, Xenix, MS-DOS, PC-DOS, QNX, GNU project, SunOS, MacOS, AmigaOS, Atari TOS, Windows, IBM AIX, GEOS, SGI IRIX, MINIX, OS/2, NeXTSTEP, SCO UNIX, Linux, BeOS, Haiku, Google Fuchsia

- Computer networks with open standards became popular
  - Ethernet, Token Ring, WLAN ($\Longrightarrow$ computer networks course)

5.GENERATION

5TH GENERATION (2000 – ????)

- Some key words from the 5th generation:
  - *The network is the computer*
  - Distributed systems $\Longrightarrow$ Cluster-, Cloud-, Grid-, P2P-Computing
  - Resources are requested and rent when needed $\Longrightarrow$ on demand
  - Multicore processors and parallel applications
  - Virtualization $\Longrightarrow$ **VMware, XEN, KVM, Docker...**
  - Free Software (OpenSource) $\Longrightarrow$ **Linux (Android), BSD**,...
  - Communication everywhere $\Longrightarrow$ mobile systems
  - Internet of Things $\Longrightarrow$ **RIOT, Zephyr, AWS FreeRTOS**,...
- Keywords for later generations:
  - Quantum computers (maybe 6th or 7th generation)

SUMMARY

At the end of the semester you…

- know and understand the **functioning** of the **core functionalities** of operating systems
- understand the **functioning** of the most important hardware components
- have basic skills in working with **Linux**
- have basic skills in **shell scripting**