1st Slide Set
Operating Systems

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Organizational Information

- **E-Mail:** `christianbaun@fb2.fra-uas.de`

!!! Tell me when problems problems exist at an early stage !!!

- **Homepage:** `http://www.christianbaun.de`

!!! Check the course page regularly !!!

- The homepage contains among others the **lecture notes**
  - **Presentation slides** in English and German language
  - **Exercise sheets** in English and German language
  - **Sample solutions** of the exercise sheers
  - Old **exams** and their **sample solutions**
- Participating in the exercises is not a precondition for exam participation
  - But it is recommended to participate the exercises

The content of the English and German slides is identical, but please use the English slides for the exam preparation to become familiar with the technical terms

The Way a good Course works. . .

Image Source: Google

- Mr. Miyagi says:
  „*Not only the student learns from his master, also the master learns from his student.*“

- **Active participation please!**

Things, which are bad during a Course...

Attending late (regularly!)

$\Longrightarrow$ annoying and disrespectful

Noisy eating in the course

$\Longrightarrow$ annoying

Offensive-smelling food in the course

$\Longrightarrow$ disgusting

Noisy greeting of/by people attending late

$\Longrightarrow$ embarrassing and disrespectful

Teamwork at the laptop in the course

$\Longrightarrow$ annoying for the rows behind

Filming or photographing the course

$\Longrightarrow$ embarrassing and disrespectful

Image sources: Google image search. In detail: Antenne Niedersachsen, Ruhrnachrichten, Celantino, Tagesspiegel, adpic, Fudder

Literature

- **Betriebssysteme kompakt**, *Christian Baun*, Springer Vieweg (2017)
  - My slide sets were the basis for the German-language book
  - You can download it for free via the FRA-UAS library from the intranet
- **Betriebssysteme**, *Carsten Vogt*, Spektrum Verlag (2001)
- **Modern Operating Systems**, *Andrew S. Tanenbaum, Herbert Bos*, Pearson, 4th edition (2014)
- **Operating Systems**, *William Stallings*, Pearson, 9th edition (2017)

The books from Andrew S. Tanenbaum and William Stallings are available in English and German language

Learning Objectives of this Slide Set

- At the end of this slide set You know/understand...
  - to which computer science branches the **operating systems** belong to
  - how the evolution of the hardware influenced the **evolution of the operating systems**
    - Batch processing
    - Singletasking
    - Multitasking
    - Time Sharing
  - **Core functionalities** of operating systems:
    - Memory management
    - File systems
    - System calls to manage access operations to the hardware
    - Process management
    - Interprocess communication
    - Synchronization of processes

Exercise sheet 1 repeats the contents of this slide set which are relevant for these learning objectives

Operating Systems in Computer Science (1/2)

Practical Computer Science

Technical Computer Science

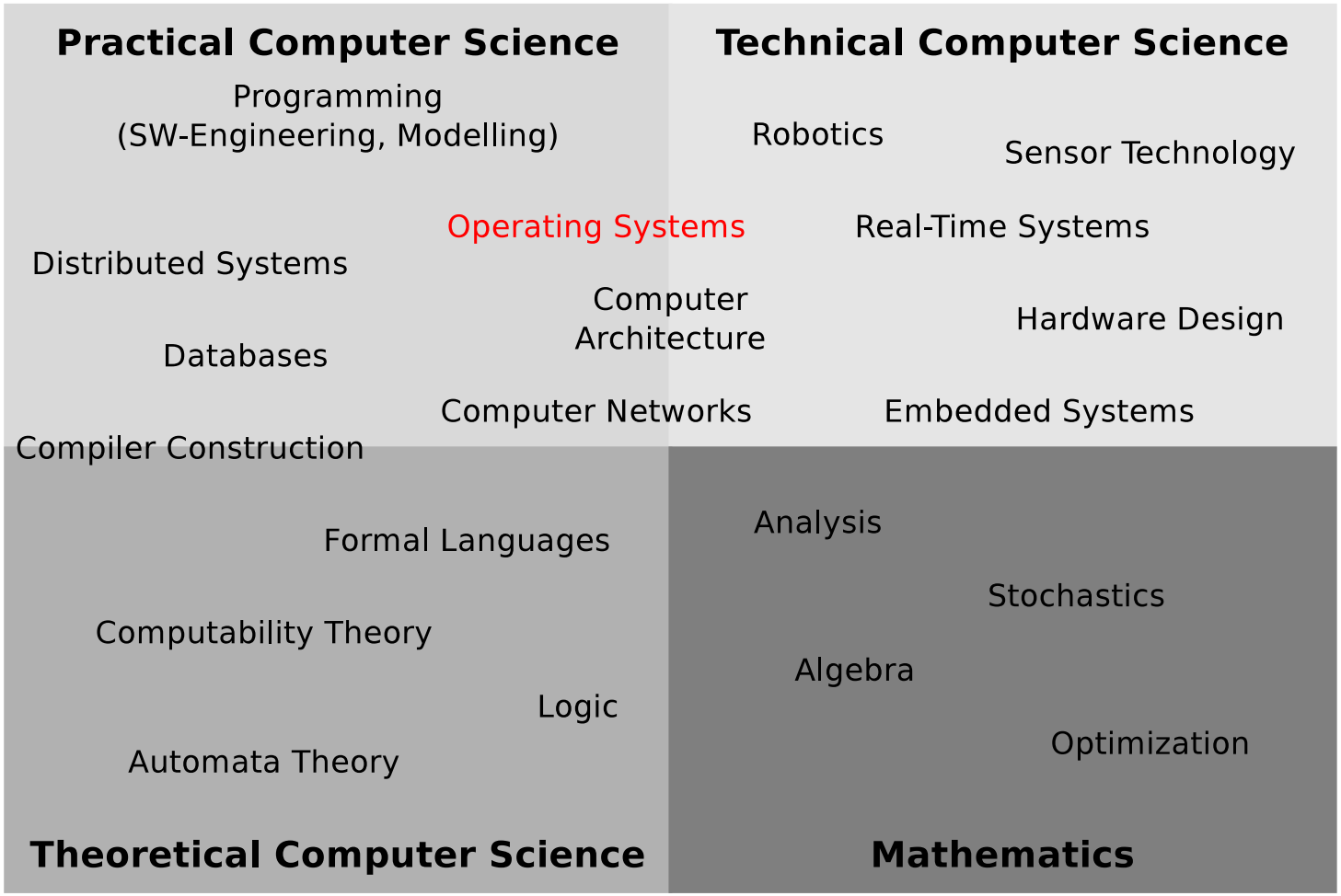
Theoretical Computer Science

Mathematics

Minor Subject

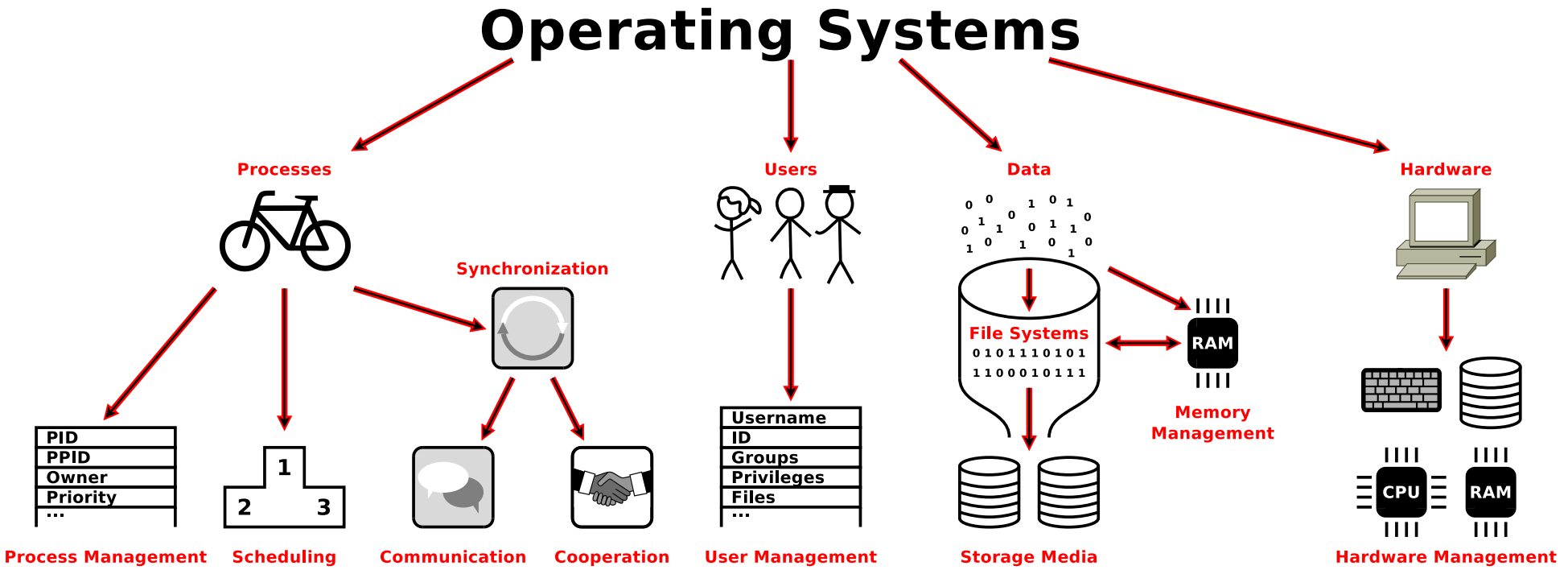
Where would you place the operating systems?

Operating Systems in Computer Science (2/2)



Operating systems belong to practical computer science and technical computer science

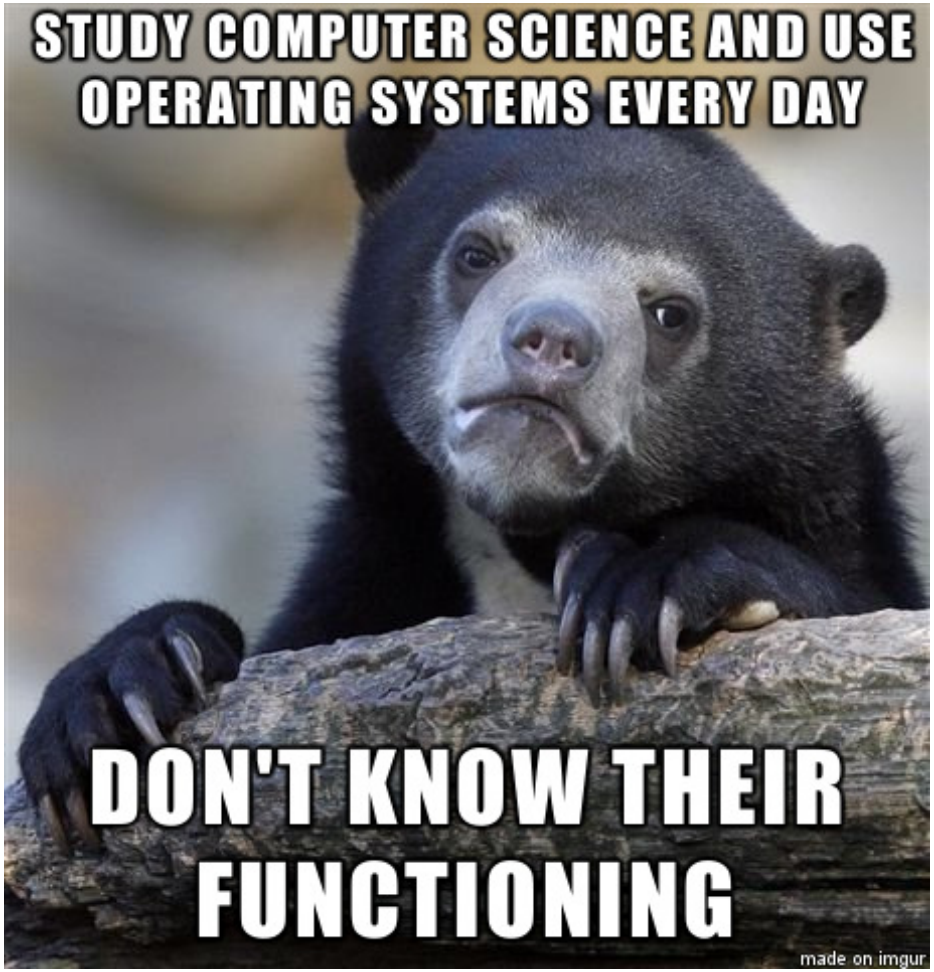
Core Functionalities of Operating Systems

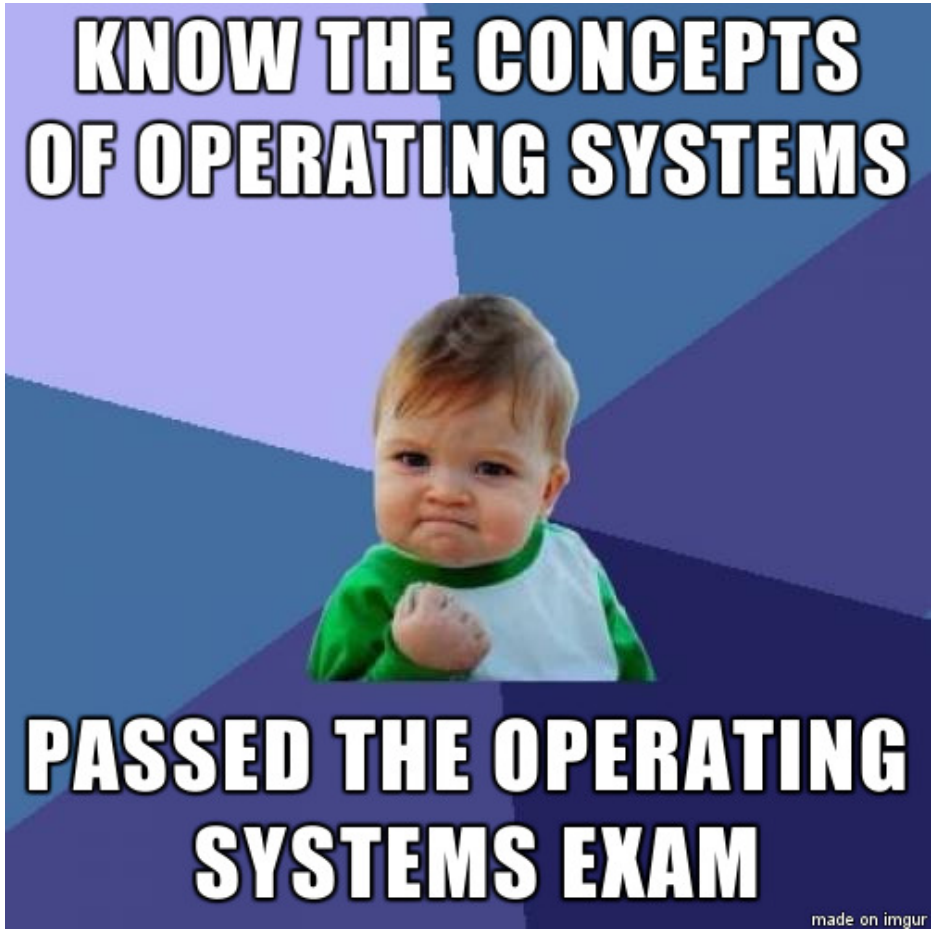


At the end of the semester You...

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

Situation today and Objective for this Semester



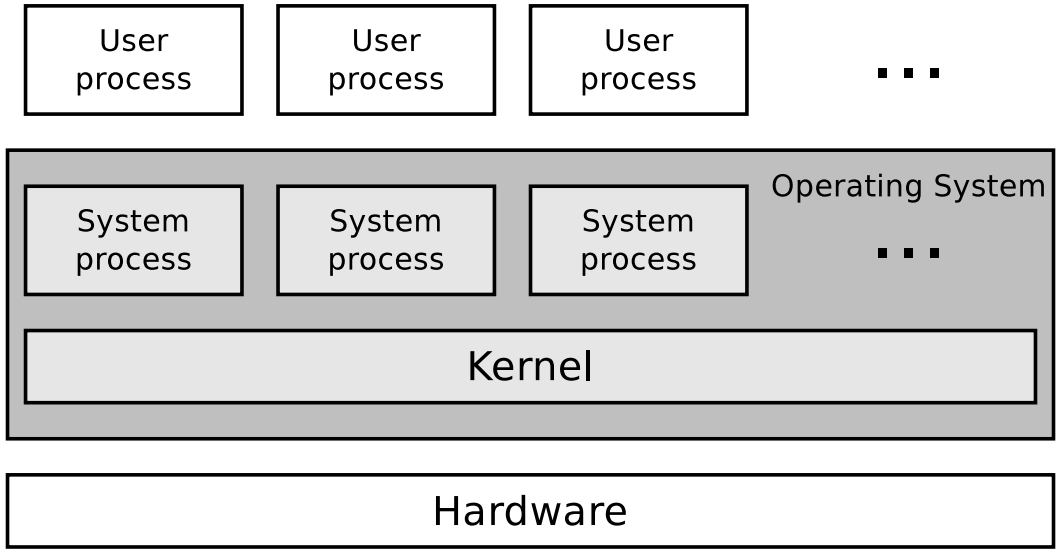


There is much to do until the End of the Semester

- The course includes $>$ 500 slides
  - But you do not need to memorize them all in detail for the exam!
- For each slide set, an exercise sheet exists
  - The exercise sheets repeat the important topics of the course and also help you with your exam preparation

Image source: unknown

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 the available hardware resources

Generations of Computer Systems and Operating Systems

The next slides deal with these questions:. . .

- What operating systems exist?
- Since when do operating systems exist?
- How did the evolution of the hardware influence the evolution of the operating systems?

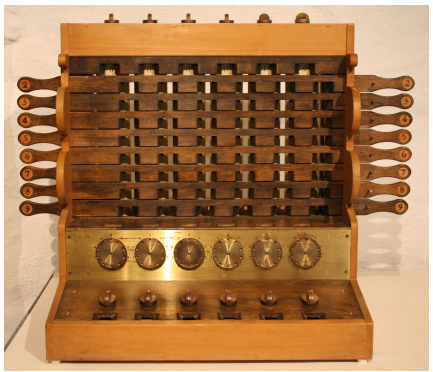
Generation	Time period	Technological progress
0	until 1940	(Electro-)mechanical calculating machines $\Longrightarrow$ no software!
1	1940 – 1955	Electron tubes, relays, jack panels
2	1955 – 1965	Transistors, batch processing
3	1965 – 1980	Integrated circuits, time sharing
4	1980 – 2000	Very large-scale 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 (until 1940)

- 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



Im. Source: Herbert Klaeren

Image Source: Heinz Nixdorf Museum

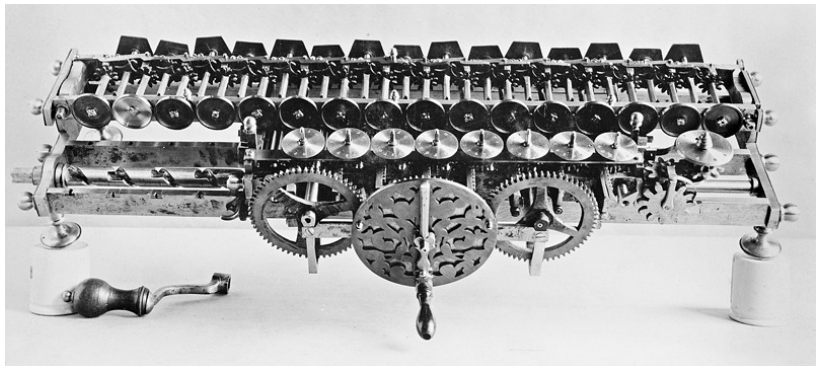


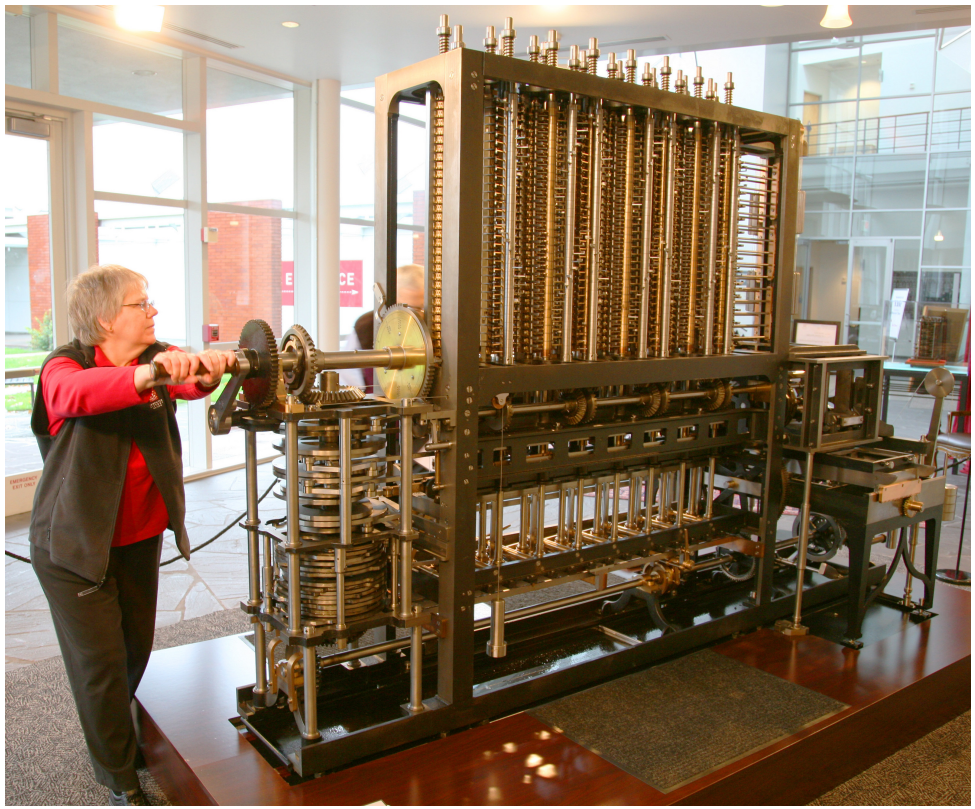
Image Source: Deutsches Museum

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

Generation Zero (until 1940)

Image source: Jitze Couperus

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



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)

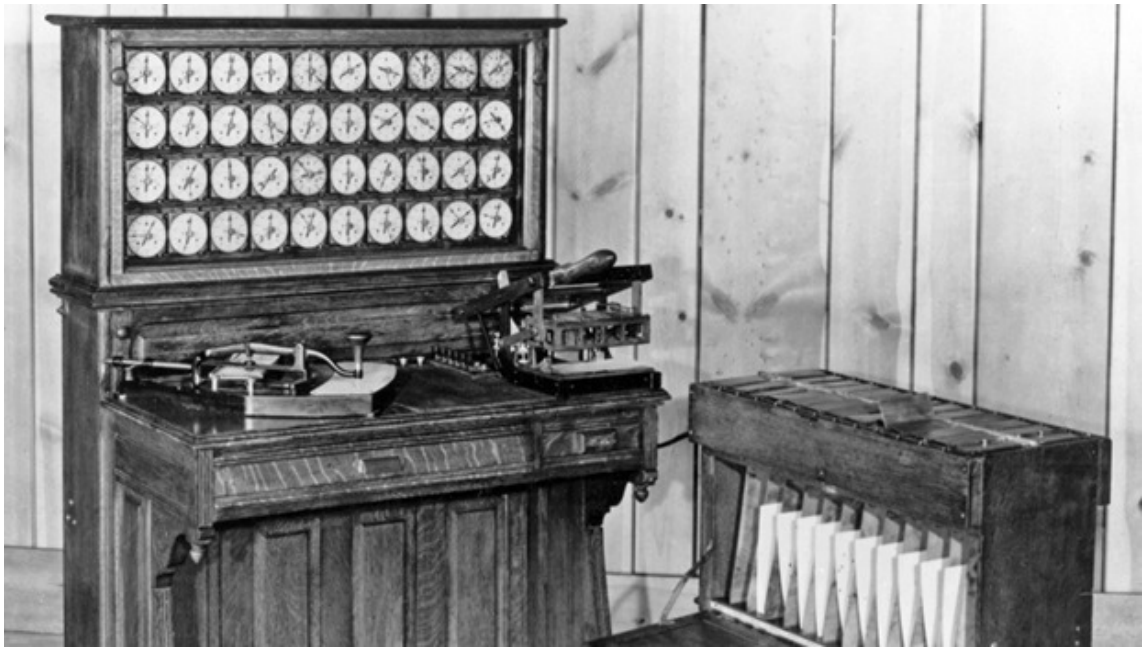


Image source: IBM

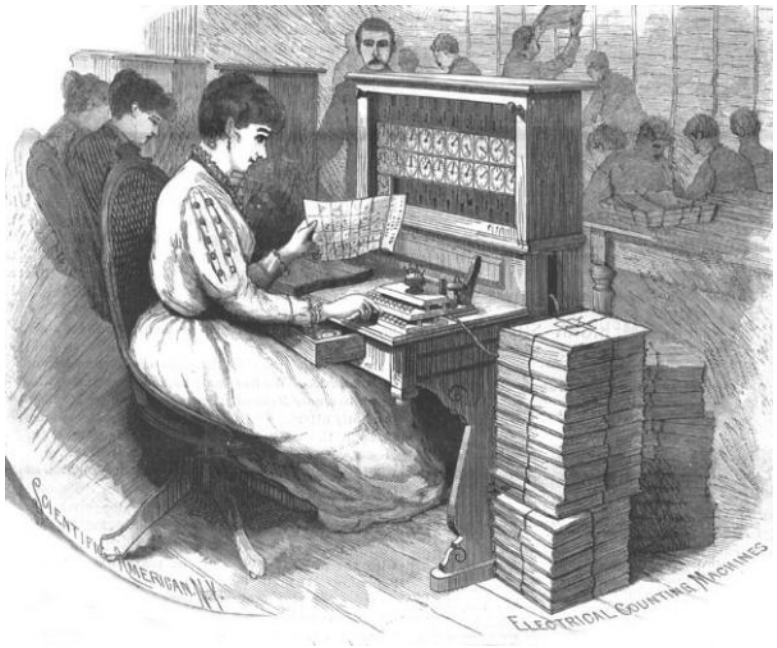


Image source: United States Census Bureau

1st Generation (1940 – 1955)

- The 1st generation of computer systems was constructed during WW2
  $\Longrightarrow$ Konrad Zuse, John von Neumann
- Requirements, a universal computer 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
- Programs were implemented via circuits in patch bays
  - The user/programmer launches **one** program, which directly accesses the hardware

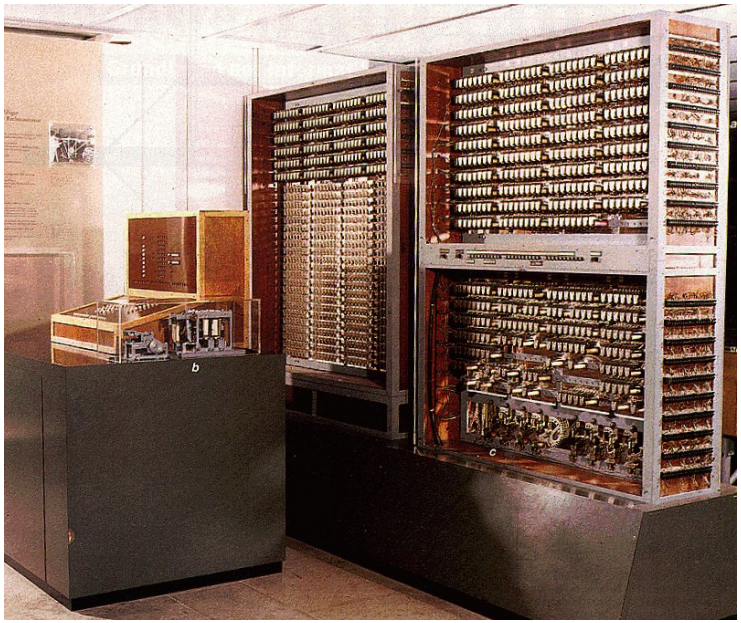
No operating systems and programming languages in this generation

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

Computers that operate according to the decimal system?

Detailed description of the structure: `http://computer-modell-katalog.de/eniac.htm`

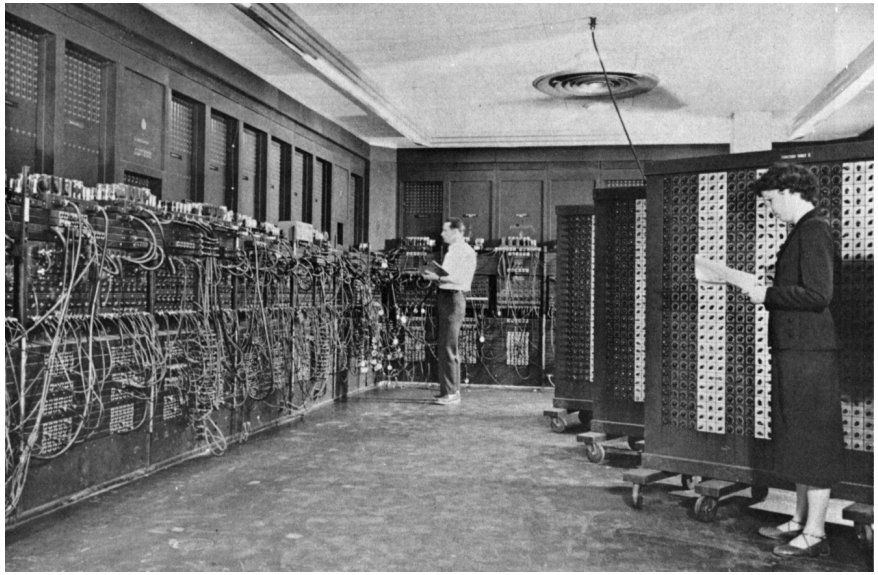


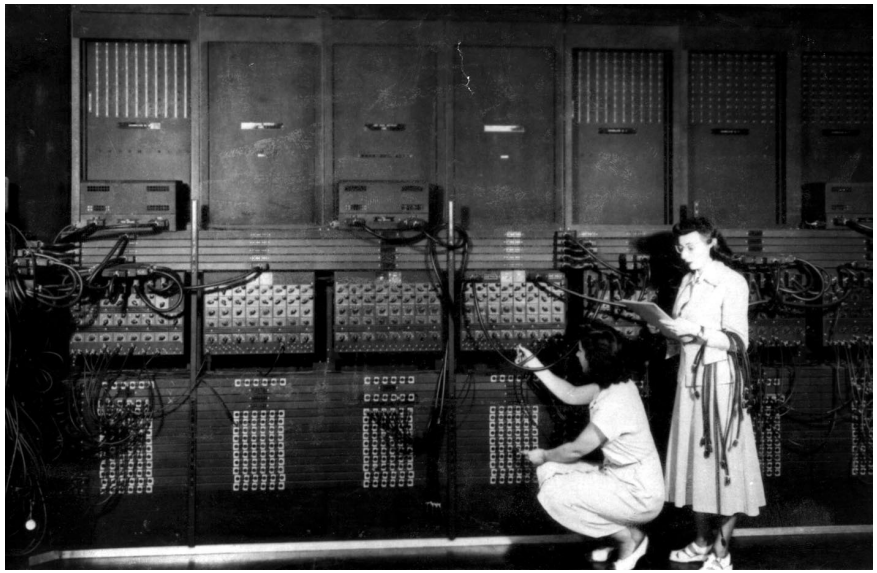
- Image: Zuse Z3 (1941)
- The world's first working programmable, digital computer (based on relay technology)
- First computer, which implemented the binary system

Image Source: Universität Oldenburg

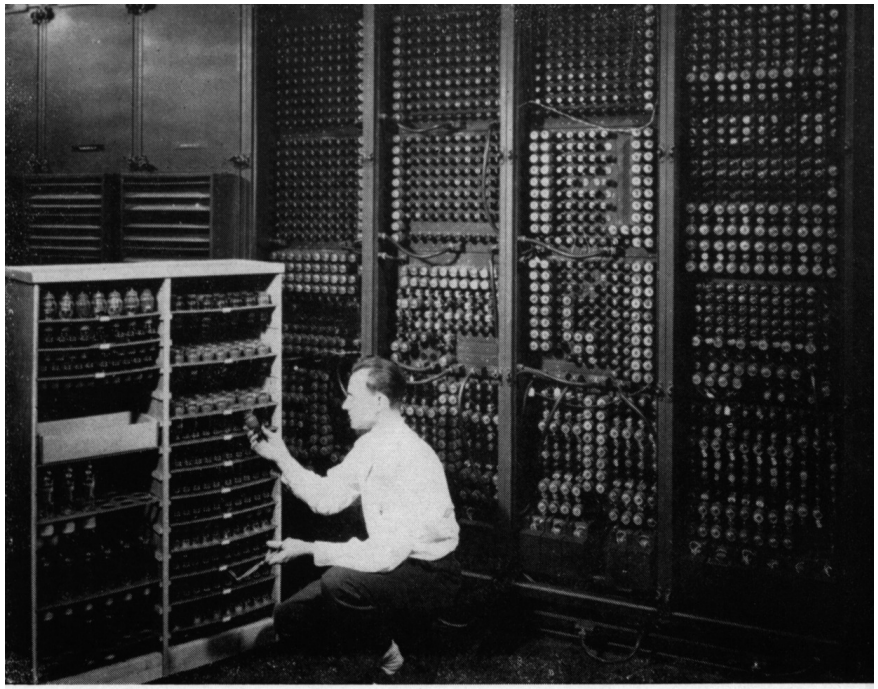
1st Generation: ENIAC (1944)

Image Source: US Army





- 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.

2nd Generation (1955 – 1965)

Image Source: Wikipedia

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

- FORTRAN or COBOL programs were. . .
  - written down by the programmer on form sheets,
  - punched from coders into punch cards
  - and handed over to the operator
- The operator. . .
  - coordinates the order of programs (jobs)
  - equips the computer with the punch cards
  - loads the compiler from the magnetic tape
  - hands over the printed out computation result
    $\Longrightarrow$ Inefficient method
- Later, for efficiency reasons, programs were collected, stored on magnetic tape and then processed in the machine room

2nd Generation: Batch Processing (1/4)

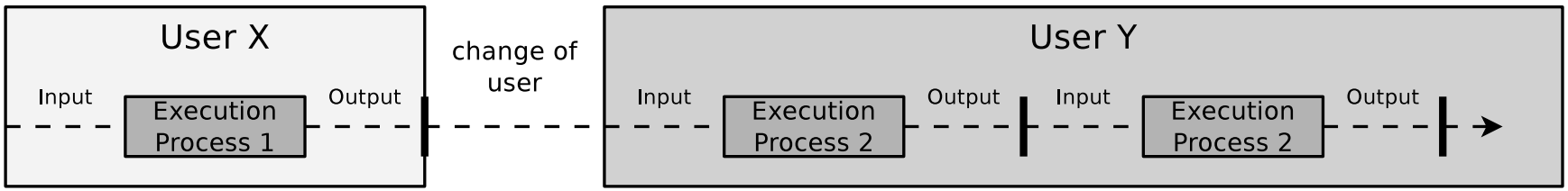
- Operating systems of this generation were all **batch processing operating systems**
- Objective: **Maximize CPU utilization**

- Each program contains 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**
- Today's systems still allow to process program sequences automatically (e.g. batch files and shell scripts)

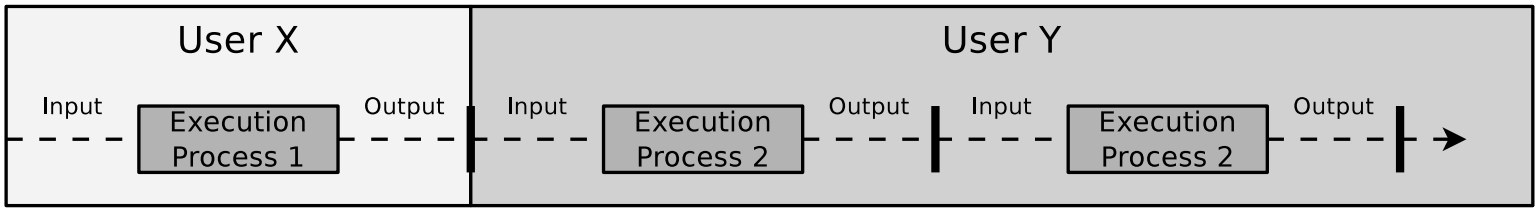
Image Source: IBM (the image shows an IBM 7090 from 1959)
`http://www.computer-history.info/Page4.dir/pages/IBM.7090.dir/images/ibm.7090.jpg`

2nd Generation: Batch Processing (2/4)

Single user mode with singletasking without batch processing



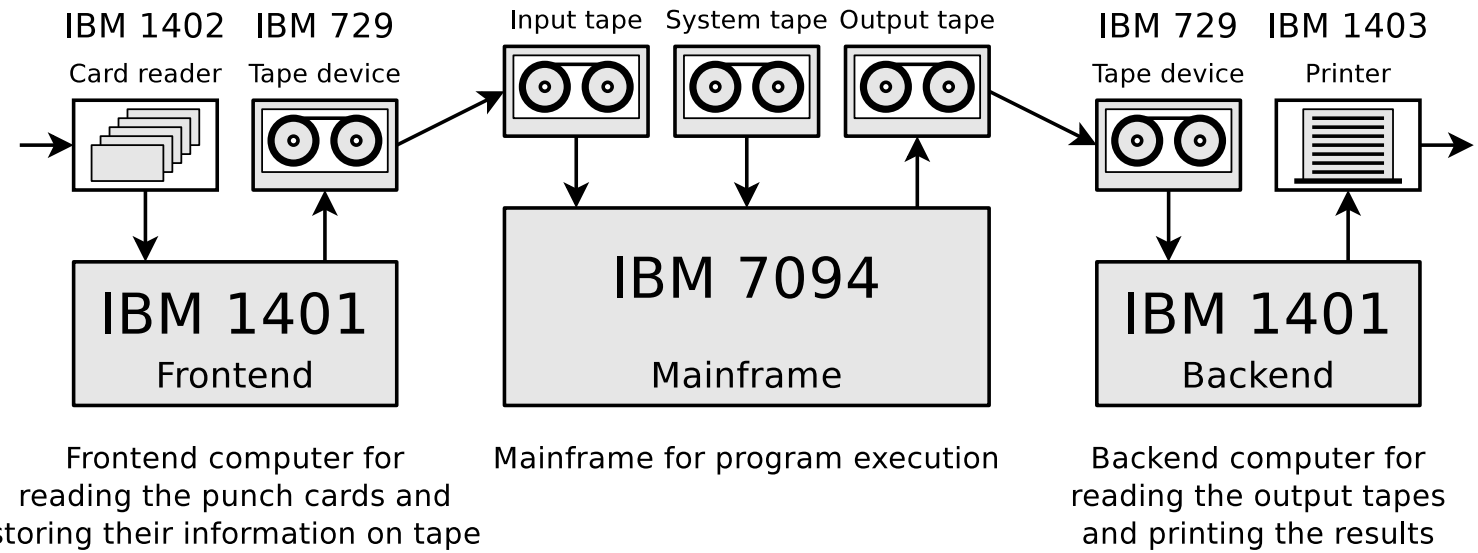
Batch processing



Time

- 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

2nd Generation: Batch Processing (3/4)



- 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

2nd Generation: Batch Processing (4/4)

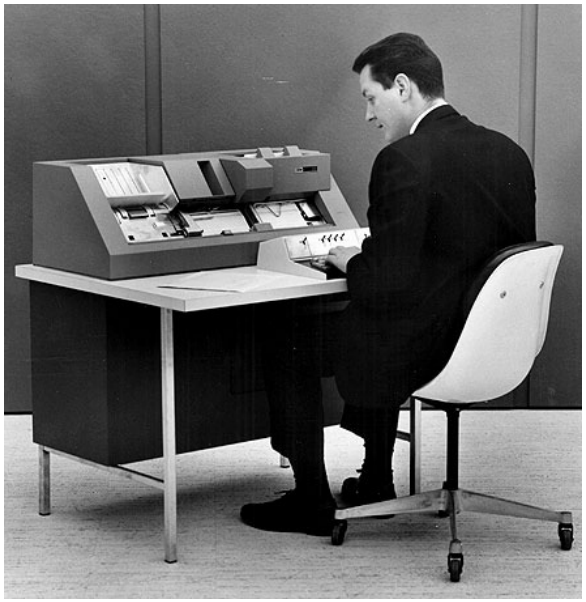


Image source: IBM

- 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 is not obsolete today!

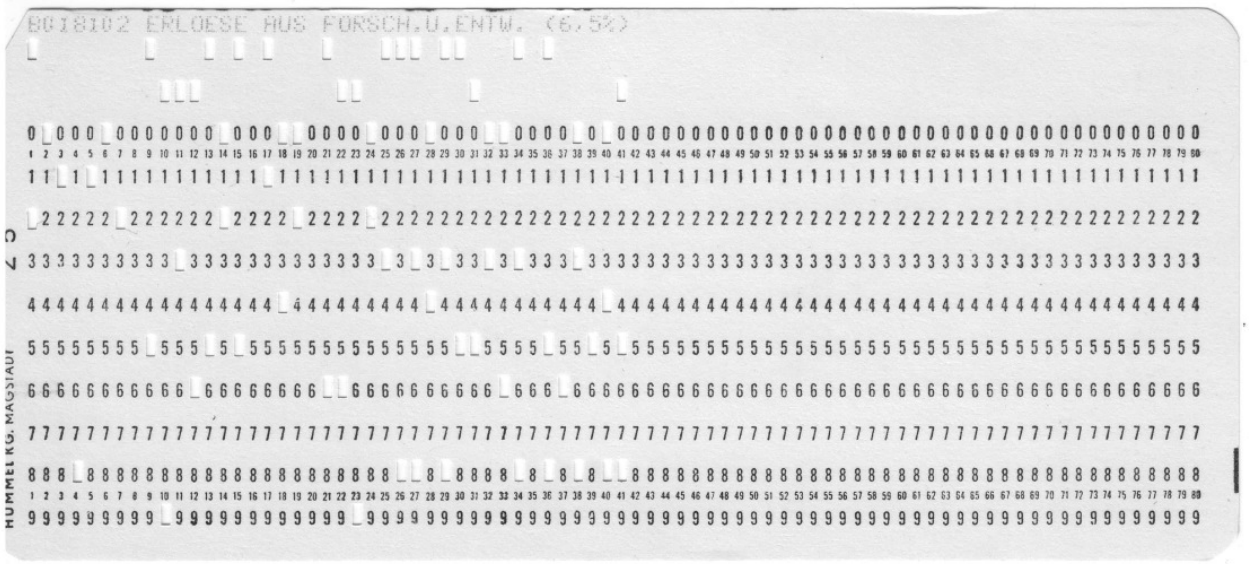
compute-intensive programs in distributed systems are usually non-interactive batch programs
$\Longrightarrow$ Distributed computing and so-called number crunching

- Batch processing operating systems of the 2nd generation only implement **singletasking** ($\Longrightarrow$ slide set 2)
  - 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

2nd Generation: Punch Cards



- Each punch card usually represents a single line of text with 80 characters or a corresponding number of binary data
  - The standard line size of $\leq$ 80 characters in E-mails and text files dates back to the punch card
- 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 (1960 – 1980)

- 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*)
- 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

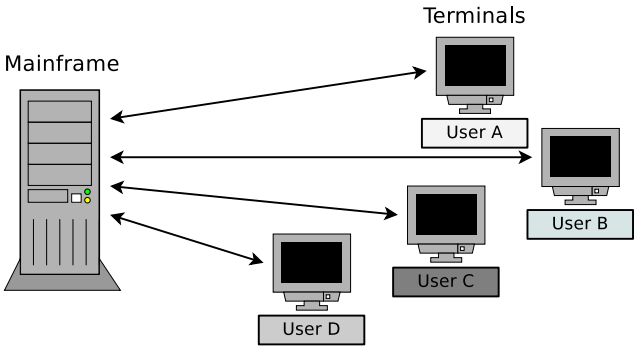
Some systems of the 3rd Generation

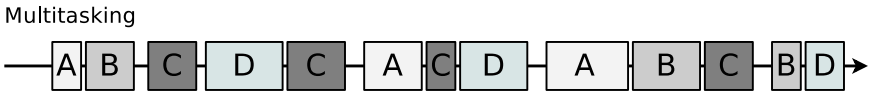
Image Source: tecchannel

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

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

3rd Generation: Time-sharing (1/2)





- **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 **time slices**
  - The distribution can carried out according to different strategies
- **Multiple users** can work **interactively** and **simultaneously** with a computer via terminals $\Longrightarrow$ **Multi-user operation** ($\Longrightarrow$ slide set 2)
- The programs of the individual users are independent of each other
- The quasi-parallel program or process execution is called **multitasking** ($\Longrightarrow$ slide set 2)
  - Objective: Minimizing the response time

3rd Generation: Time-sharing (2/2)

- 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

    $\Longrightarrow$ slide set 5
  - **File systems**, which allow quasi-simultaneous file access

    $\Longrightarrow$ slide set 6
  - **Swapping**: Process of storing and removing data to/from main memory from/into background memory (HDDs/SSDs)

    $\Longrightarrow$ slide set 7
  - **Scheduling**: Automatic creation of an execution plan (*schedule*), which is used to allocate time limited resources to users or their processes

    $\Longrightarrow$ slide set 8

4th Generation (1980 – 2000)

- This generation provides highly integrated circuits 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 become popular
  - Ethernet, Token Ring, WLAN

5th Generation (2000 – ????)

- Some key words from the 5th generation:
  - *The network is the computer*
  - Distributed systems $\Longrightarrow$ Cluster-, Cloud-, Grid-, P2P-Computing
  - Multicore processors and parallel applications
  - Virtualization $\Longrightarrow$ **VMware, XEN, KVM,...**
  - Free Software (OpenSource) $\Longrightarrow$ **Linux (Android), BSD**,...
  - Communication everywhere $\Longrightarrow$ mobile systems
  - New ways of working $\Longrightarrow$ e-Science, e-Learning, e-Business,...
  - Services $\Longrightarrow$ web services (REST, SOAP)
  - Resources are requested and rent when needed $\Longrightarrow$ on demand
  - Personal Computing vs. Parental Computing (e.g. iOS)
  - Artificial Intelligence (AI)
- Keywords for later generations:
  - Quantum computers (probably 6th, 7th or 8th generation)