

Systems 3

Principles

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(Handout)

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Timetable

- Lecture: Thursday (15:15) && Friday (11:45)
 - Marcel Waldvogel (marcel.waldvogel@uni.kn)
- Exercise: Thursday (8:15 || 11:45 || 17:00)
 - Klaus Herberth (klaus.herberth@uni.kn)
 - Christian Löhle (christian.loehle@uni.kn)

Exam Admission

- Work in a group of two students
- Your solutions to every exercise need to show serious deliberation
- You are allowed to have two failures (three strikes and out)
- If you get 50% in total you will get a 0,3 exam bonus

Teaching materials

are available via git¹ on the University GitLab². One member of the group forks the repository³ into her personal space and

- **grants access** to the other member (at least ‘Developer’),
- **shares** it with the tutors (at ‘Owner’ or ‘Master’ level).

You can then browse all files in the repository, which includes instructions on how to clone it into a local repository.

¹<https://git-scm.com/>

²<https://git.uni.kn>

³<https://git.uni.kn/disy/lectures/systeme-3-2019>

Chapter Goals

- Operating Systems⁴: What and why?
- What are their functions and how did they evolve?
- First insights into structure and processes.
- Does the CPU⁵ control the OS or vice versa?

⁴OS

⁵Central Processing Unit aka⁶ 'the processor'

⁶ "also known as"

What is an Operating System?

- Where do we find them?
- What do they do there?
- What are common operating systems (OS)?

What does an Operating System do?

Traditional goals

Hardware abstraction

- 1 Simplify application development
- 2 Portability
- 3 ...

Resource management

- 1 Share CPU among multiple processes
- 2 Share network cards among multiple services
- 3 ...

What does an Operating System do?

Today: Communications gateway

Enable communications

- 1 Between processes
- 2 Between systems

Restrict/select communications

- 1 Not everyone should be able to interfere with everything
- 2 Only when a process is ready
- 3 Only what a process expects

Hardware abstraction, resource management, and communications are independent dimensions (more or less).

Gen1 ~1950: Tubes, plugboards, core memory

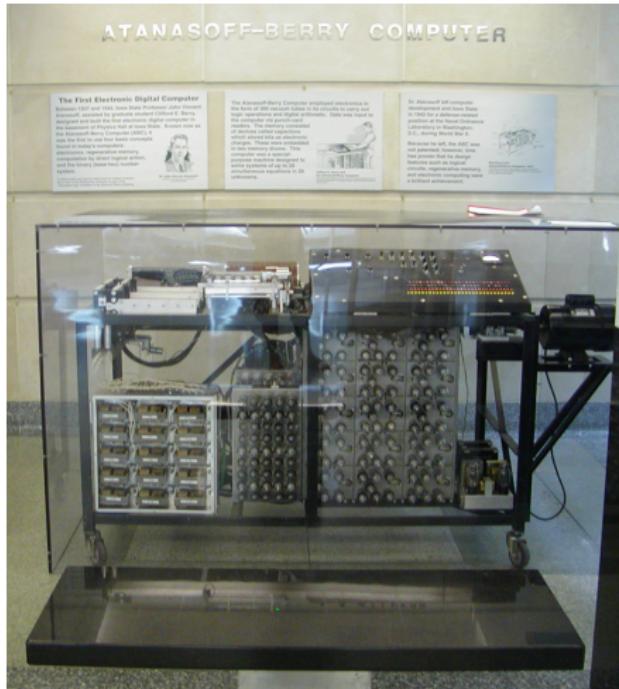
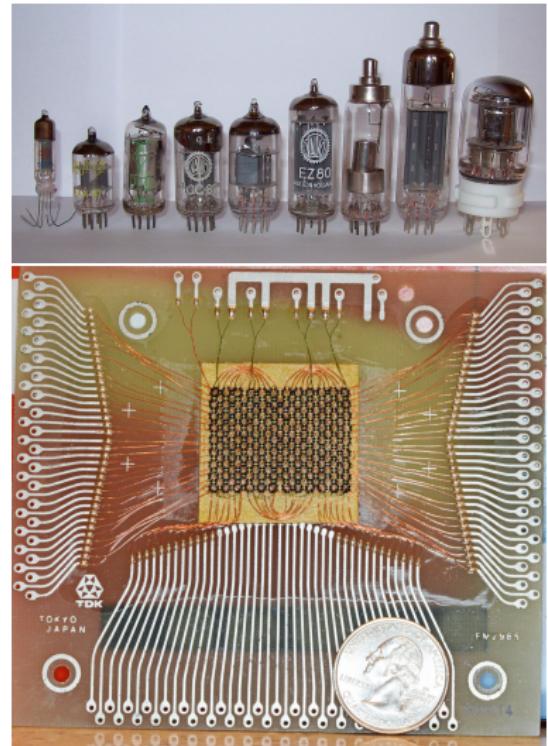
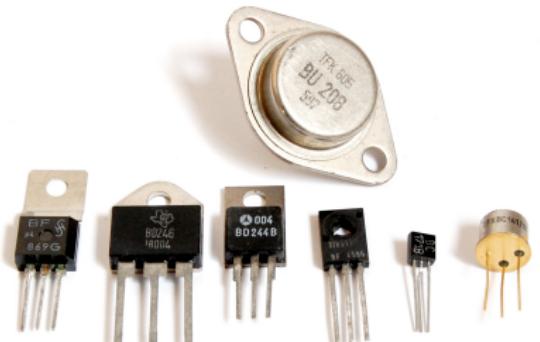


Photo credits: Wikipedia users Manop, CC BY-SA 3.0; Stefan Riepl (Quark48), CC BY-SA 2.0 de; Bubba73 (Jud McCranie), CC BY-SA 4.0.



Gen2 ~1960: Transistors and batch systems



Batch processing

Programs can be run quickly one after another to reduce turn-around time and increase utilization.

Today used for e.g. HPC/Supercomputing, end-of-day processing.

Photo credits: Wikipedia users [Benedikt.Seidl](#), public domain; [Grkauls](#), public domain.

Gen3 ~1970–1980: ICs and multiprogramming



Multiprogramming

Multiple programs (of different users) can be run seemingly in parallel.
Today used for e.g. personal computers, mobile devices, even IoT.

Photo credits: Wikipedia users Stefan_Kögl, CC BY-SA 3.0; Retro-Computing Society of Rhode Island, CC BY-SA 3.0 (2).

Gen4 1980+: Personal computers



Single-user

Computers were getting cheap enough to be used by single users, instead of using terminals to a central computer. First without networking.

Today many devices are used by mostly a single user, but still run multi-user operating systems. Reasons: Security, compatibility, . . .

Photo credits: Wikipedia users Hydrargyrum, CC BY-SA 3.0; Ruben de Rijcke, CC BY-SA 3.0; Rama, CC BY-SA 2.0 fr.

Gen5 1990+: Mobile devices etc.



Mobile

Faster processors, higher integration, cheaper prices, and lower power consumption made computers more portable and almost ubiquitous (IoT).

Wireless/mobile networking, cloud computing, isolation between processes of the same user (sandboxing), virtualization.

Photo credits: Wikipedia users Snowmanradio, CC BY-SA 3.0; Blake Patterson from Alexandria, VA, USA; Source ([WP:NFCC#4](#)), Fair use.

OS History

1960s

CTSS Time-sharing (processes)

VM/CMS Virtualization (isolation)

Multics Single-level store, hierarchical file system, dynamic linking, IPC, hot-swapping

1970s

Unix ← Multics; modularity (everything is a file, user-level shell, byte stream, text files, pipes), portability, documentation

CP/M (← Unix); OS modularity (BIOS, BDOS, CCP), drive letters, OS for microcomputers/personal computers, Ctrl-Z for EOF

VMS File versions, file databases, multiprocessing/partitioning
Networking, email

OS History (cont'd)

1980s

MS-DOS ← CP/M

MINIX ← Unix; teaching

GNU Unix as free software⁷

Mach Micro-kernel (modularity in the kernel)

GUI Xerox, Apple, Digital Research/Atari, Amiga, Microsoft, X11

Networking Multiple protocols; “OSI”; TCP/IP, WWW

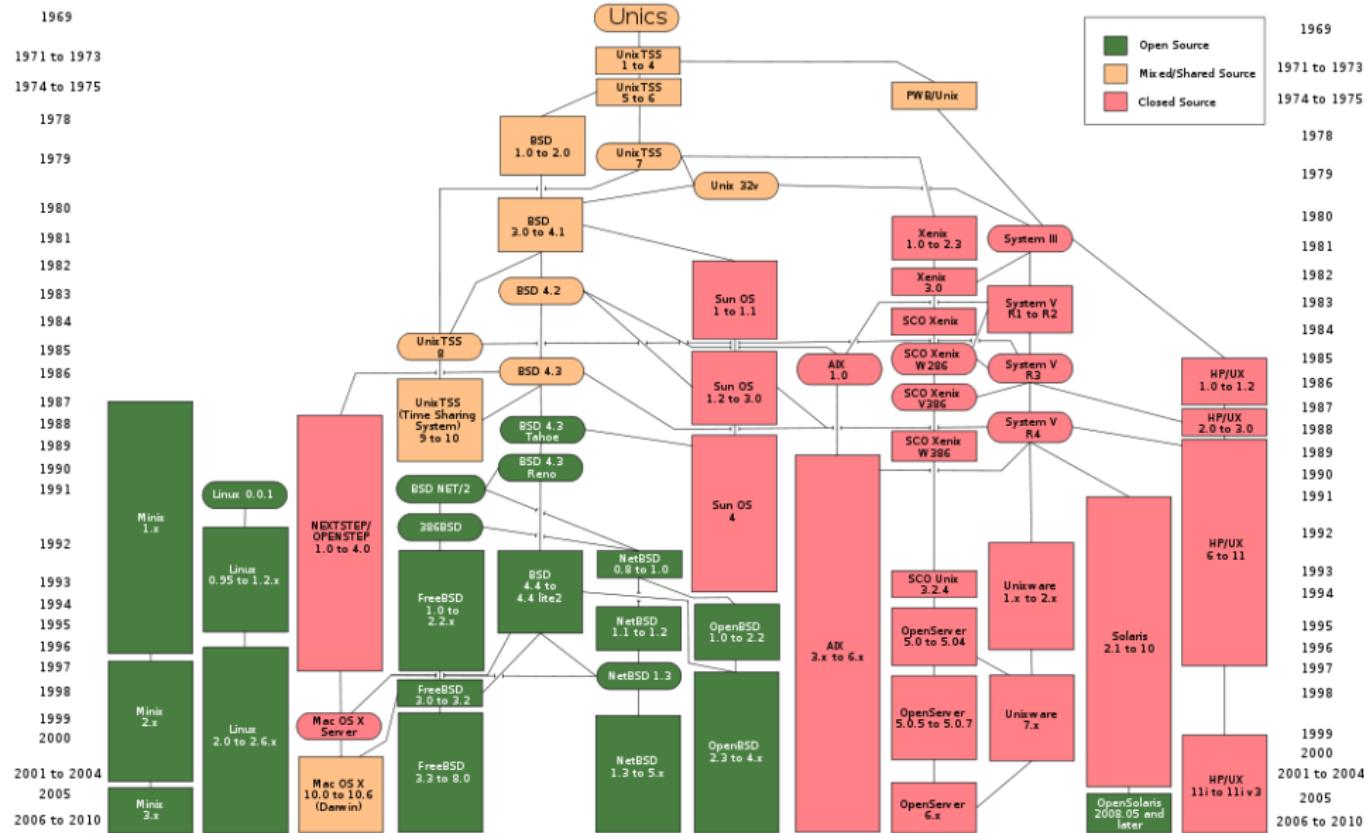
1990s

Linux Free software Unix-compatible kernel⁸

Browser Browser as GUI

⁷user-level software, kernel (**Hurd**) stalled

⁸User-level tools from GNU project, hence, often called *GNU/Linux* in combination



Market shares

Mobile

- Android (76%) ← Linux
- iOS (22%) ← Unix

Tablet

- iOS (73%) ← Unix
- Android (27%) ← Linux

Desktop

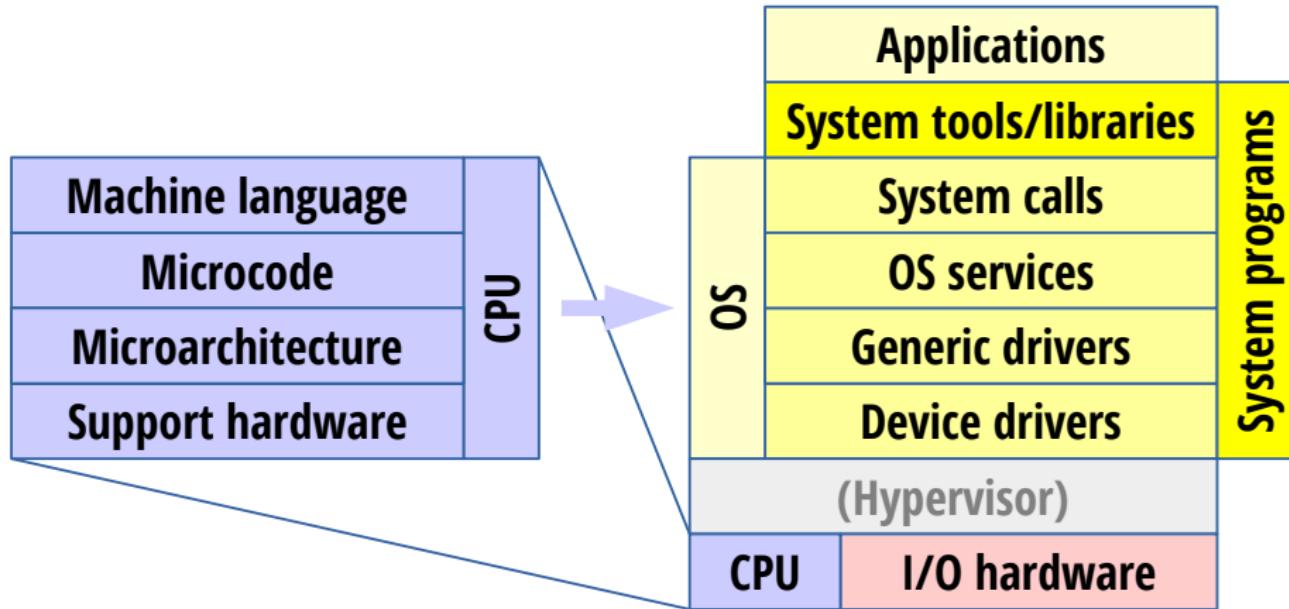
- Windows (80%) ← MS-DOS, VMS
- OS X (15%) ← Unix
- Linux (2%) ← Unix

Server

- Cloud: Linux 90%
- Home router: Linux ~100%
- HPC: Linux ~100%
- Web servers: Linux 70...97%
- IoT: Linux 72%
- Business: Windows-mostly(?)

Source: Clients StatCounter, September 2019; servers MakeUseOf, March 2018, James Playfair on Quora, IT Pro Today/Eclipse Foundation

The Modern Computer System



- 1 A main program that initializes the system and the first process(es)
- 2 A set of service procedures that carry out the process' system calls
- 3 A set of utility procedures that help the service procedures

The Process

Properties

- Environment for user programs
- Unit for the OS to manage running programs (=processes)
- Created by other processes

Most programs are written to run in processes. It becomes our little world with which we interact with the OS using system calls. The OS remains a black box with a defined API.

Process vs. program

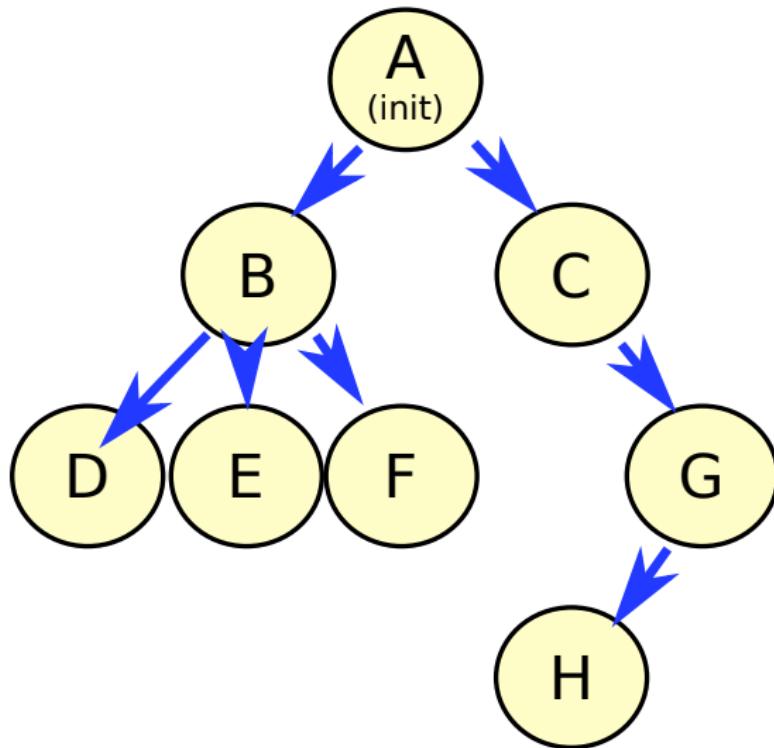
Program The (static) code to be executed.

Process The environment for running a program (processor state, OS state (open files etc.), ...)

Multiple processes may run the same program at the same time.

On Unix, a single process may run multiple programs in turn.

Process Tree



System Calls

OS is a black box

- How to get into this box?

Entry options

- Function call opcode? (**Defeats isolation!**)
- Special opcode for system calls! (**Gatekeeper**)

Goals for separation

- Isolation
- Security
- Abstraction

→ How can we call into an isolated environment **with elevated rights?**

System Calls

Example system calls

Files open(), close(), read(), write()

Processes fork(), exec(), exit(), getpid(), getppid()

Networking socket(), bind(), listen(), accept(), ← Files

Memory brk(), sbrk(), mmap(), munmap(). **Not** malloc(), free()!

IPC pipe(), shmat()

Resources setrlimit()

Users getuid(), setuid(), getgid(), setgid()

Schedule

Week	Thursday	Friday
0	Principles	C Basics
1	Pointers	—
2	I/O	Memory
3	Memory in C	Memory Expansion
4	Process Model	Process Synchronization
5	Threads	Scheduling
6	Big Programs	Filesystem
7	OS Structure	OS Design
8	Vulnerabilities	Cryptography
9	Libraries	Virtualization
10	Meltdown	Security
11	Networking	Linux Boot Process
12	OS Summary	PC Summary
13	Review	Q&A
14	Exam	—

Literature

- Andrew S. Tanenbaum, Albert S. Woodhull. *Operating systems: design and implementation*. Uni-KN kid 346/t16a + lbs 843/t16b
- Brian W. Kernighan, Dennis M. Ritchie. *The C Programming Language*. Uni-KN kid 248 k27.
- Peter van der Linden. *Expert C Programming — Deep C Secrets*. Uni-KN kid 248 v16.