

Systems and Networking – Unit I

B.Sc. in Applied Computer Science and Artificial Intelligence
2022-2023

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SAPIENZA
UNIVERSITÀ DI ROMA

Who Am I?



Who Am I?



UniPI



Who Am I?



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UniVE

Who Am I?



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Yahoo! Labs

09/28/22

Who Am I?



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Yahoo! Labs

09/28/22

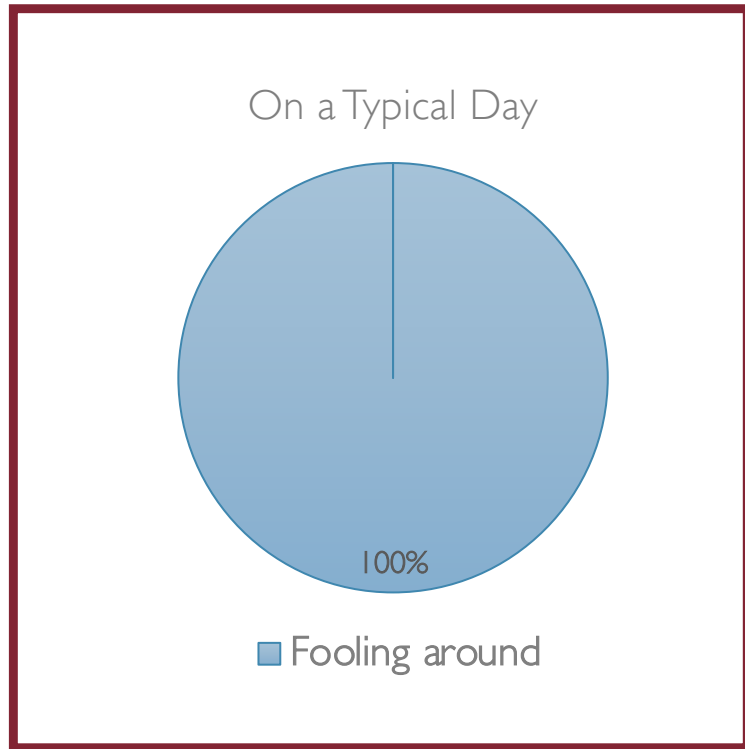


UniPD



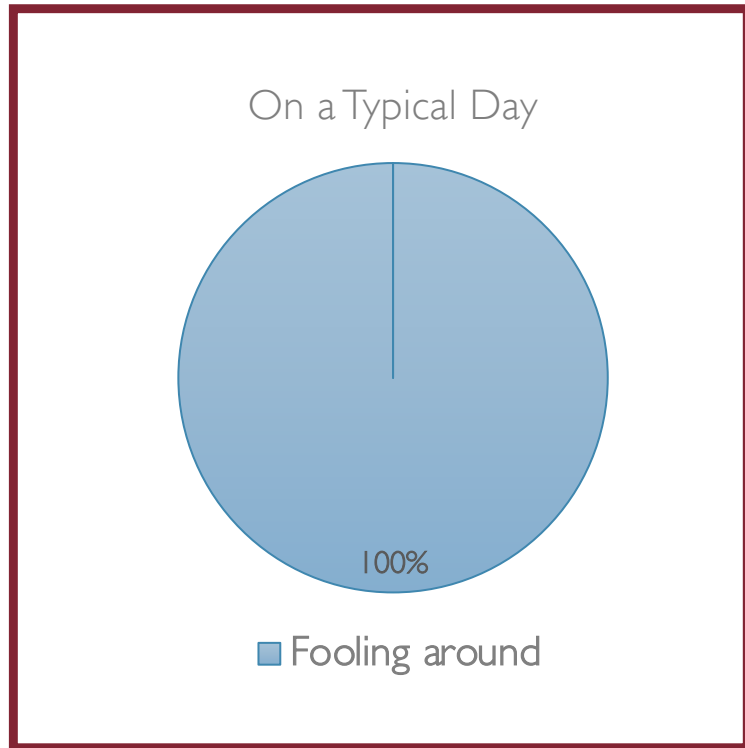
Sapienza

If A Day Of Mine Were A Pie...



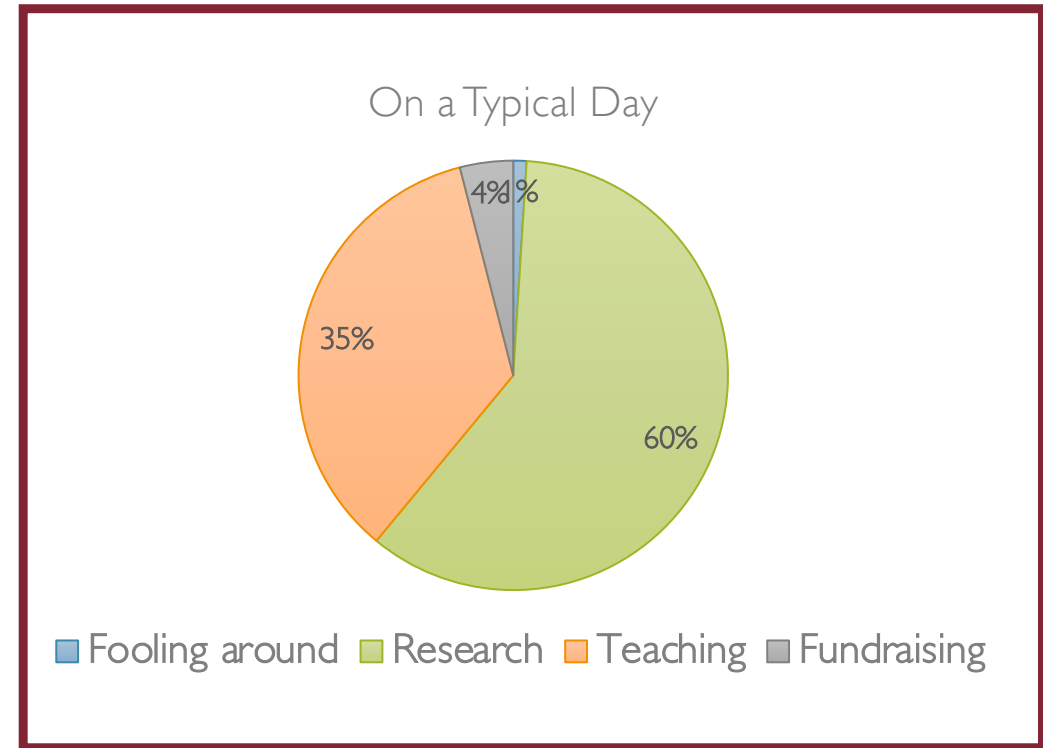
Expectation

If A Day Of Mine Were A Pie...



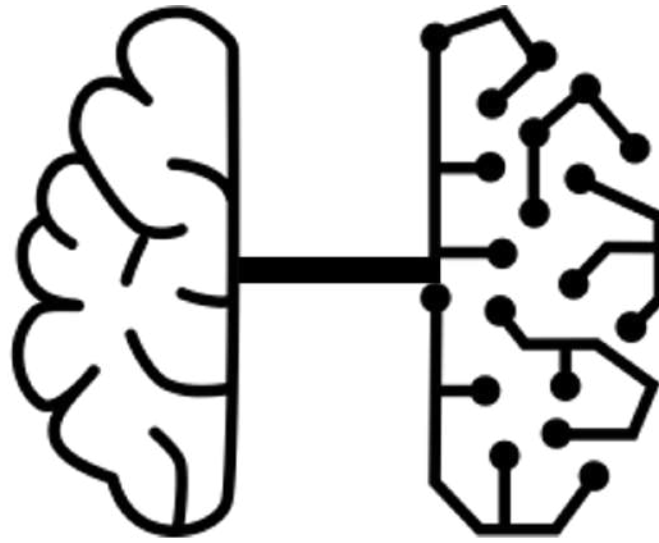
Expectation

VS.



Reality

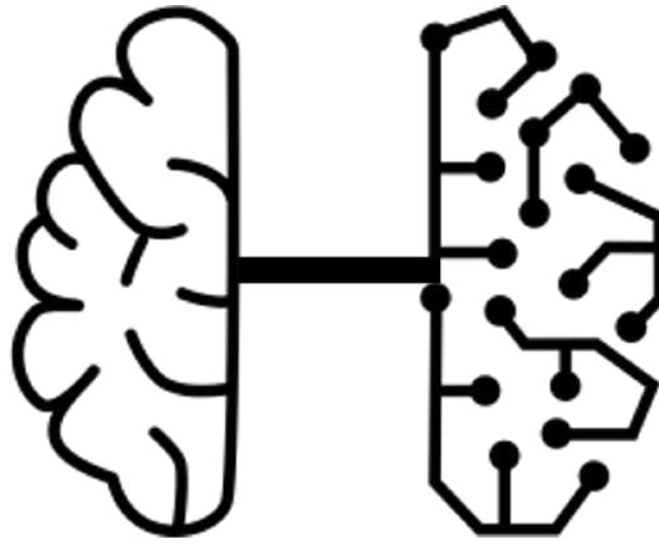
Research On What?



HERCOLE Lab

Research On What?

Human-Explainable

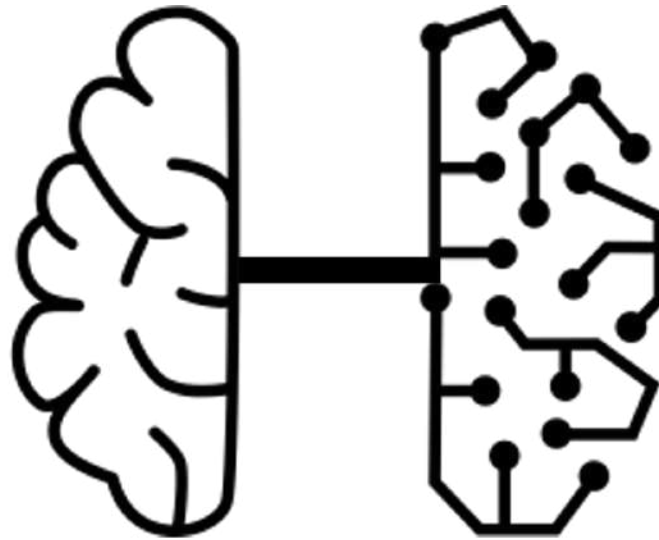


HERCOLE Lab

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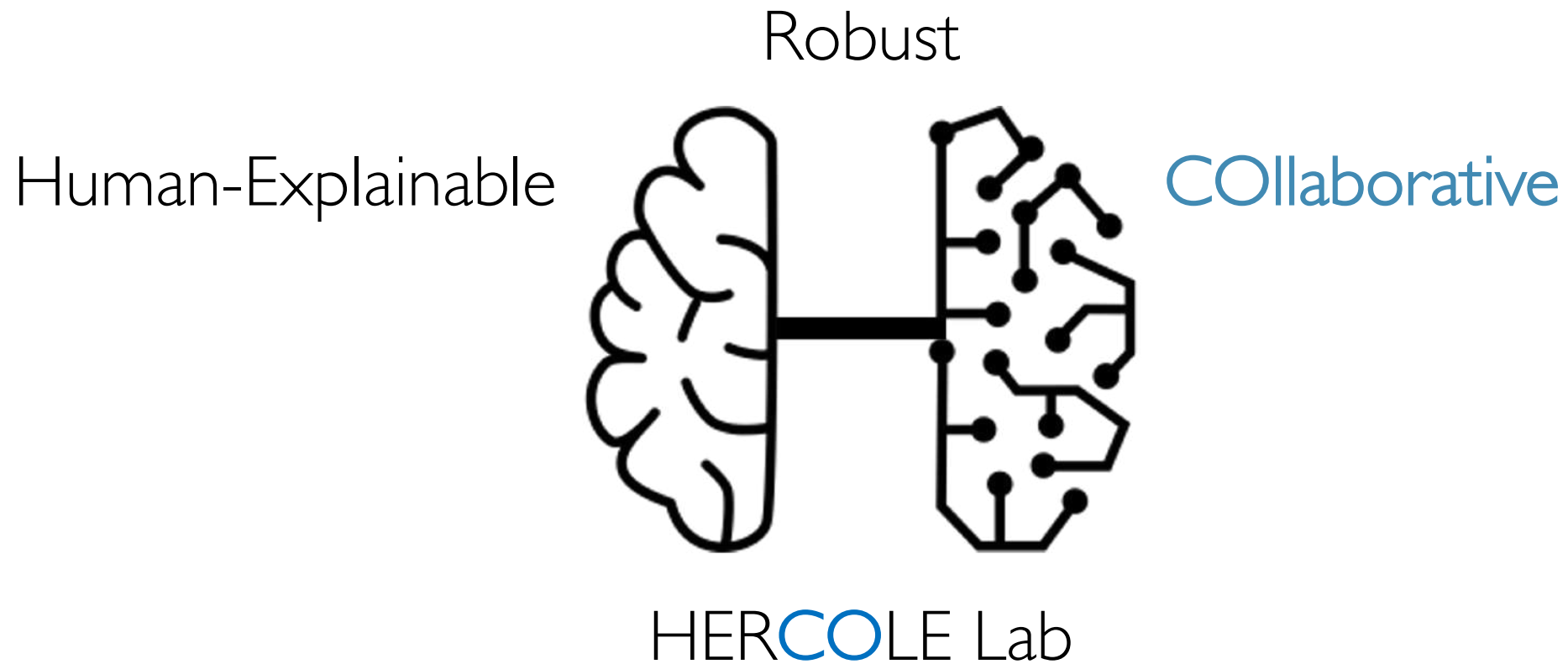
Robust

Human-Explainable

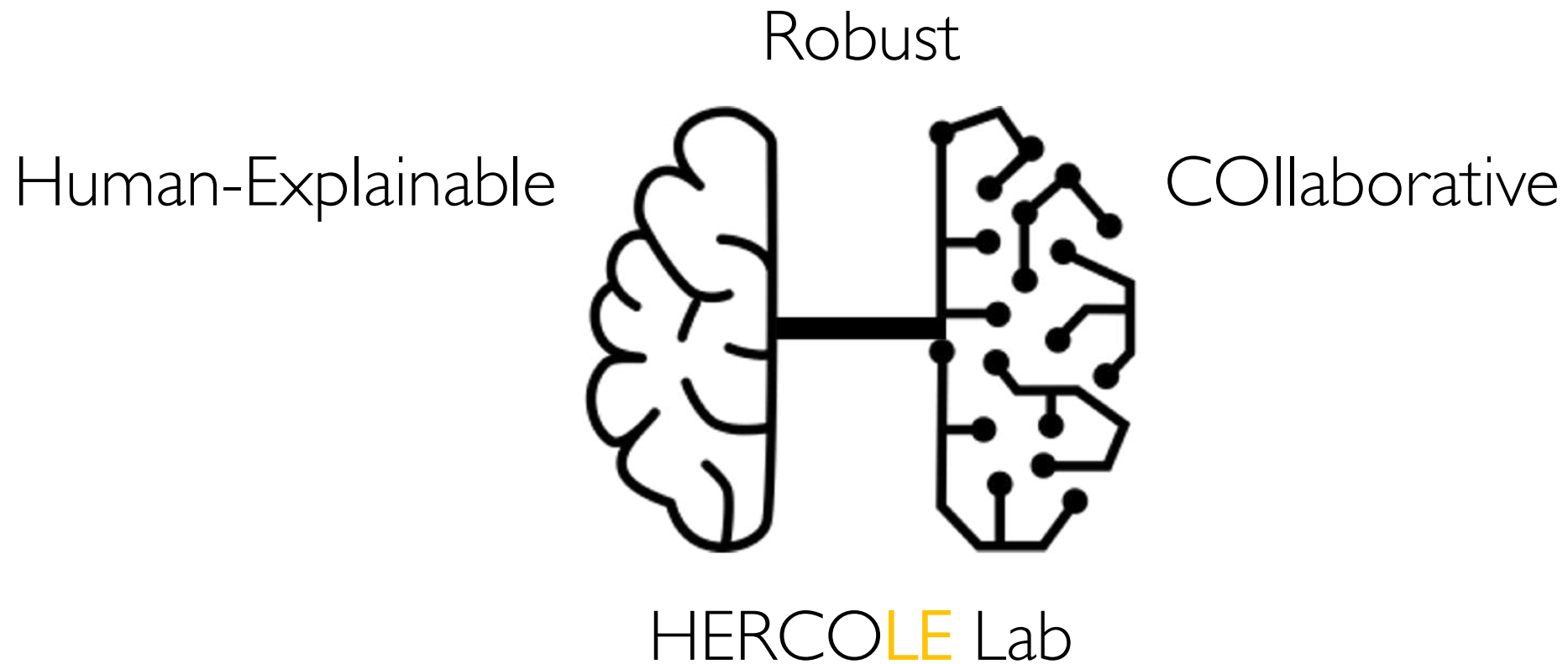


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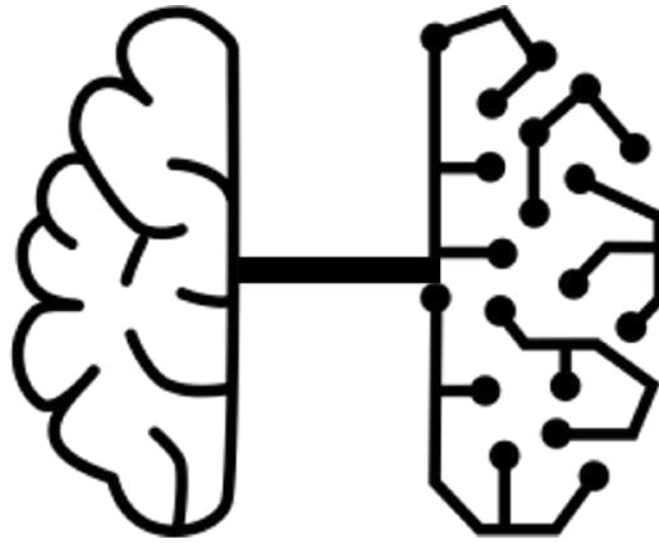
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LEarning

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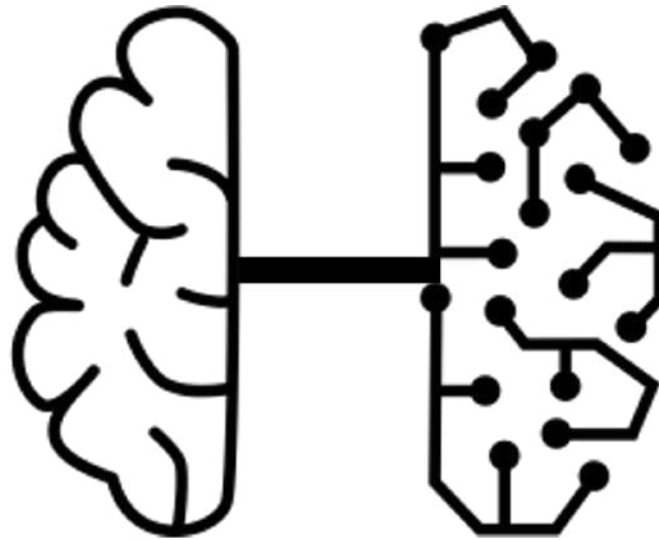
Sounds cool?



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HERCOLE Lab

Check out the lab's

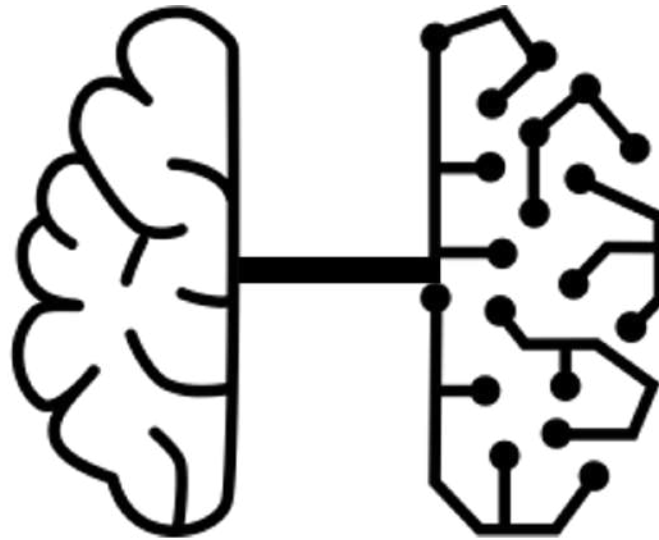
[home page](#)

(still under construction, sic!)



Research On What?

Sounds cool?



HERCOLE Lab

Meanwhile you can
follow us on Twitter
[@HercoleLab](https://twitter.com/HercoleLab)

Useful Information

Class schedule

- **Wednsesday:** 1 p.m. - 4 p.m.
- **Thursday:** 8 a.m. - 10 a.m.

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Contacts

- **email:** tolomei@di.uniroma1.it
- **website:** <https://github.com/gtolomei/systems-and-networking>
- **moodle:** <https://elearning.uniroma1.it/course/view.php?id=15524>

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Office hours

- Arranged via email
- **in-person** or **remotely**
- **Room 106**, 1st floor Building "E" ([map](#))

How to Attend Classes

- To prevent and contain the spreading of COVID-19 infection, it has been created a Google Form (<https://forms.gle/TZYecGadZ6CDFhQj7>)
- Please, fill out the Google Form before, during, or after every class you attend
- This will help keep students and the entire Sapienza community safe!

Class Material

- Released on the class website **and** on moodle
- Suggested books (though not mandatory!):
 - "*Operating System Concepts*" Ninth Edition – Silberschatz, Galvin, Gagne
 - "*Modern Operating Systems*" Fourth Edition – Tanenbaum, Bos
 - "*Operating Systems: Three Easy Pieces*" – Remzi and Andrea Arpaci-Dusseau
[\[available online\]](#)
- Any additional resource available on the Web!

Moodle

- Provides native support for:
 - Sharing news and messages (forum)
 - Uploading class material (e.g., slides, exercises)
 - Exam simulations (e.g., quizzes)
 - ...

Remember to enroll in the course from the [moodle web page](#)!

Exam

- Moodle Quiz:

- 20 multiple-answer questions (max. 60 minutes)
- Marks: +3 (correct answer), 0 (no answer), -1 (wrong answer)
 - score $\leq 14/30 \rightarrow \text{FAIL}$
 - $15/30 \leq \text{score} \leq 17/30 \rightarrow \text{ORAL REQUIRED}$
 - score $\geq 18/30 \rightarrow \text{PASS}$ (oral upon request by the student)

- Oral Session:

- Questions and exercises on the subjects covered during the whole semester

Outline of the Course

- Part I: Introduction

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- Part VI: File System

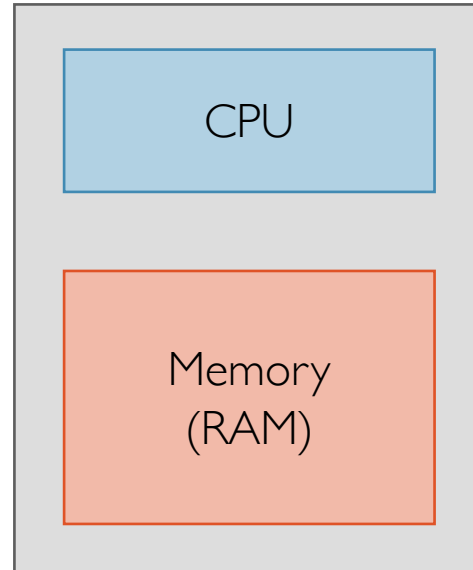
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- Part VII: Advanced Topics

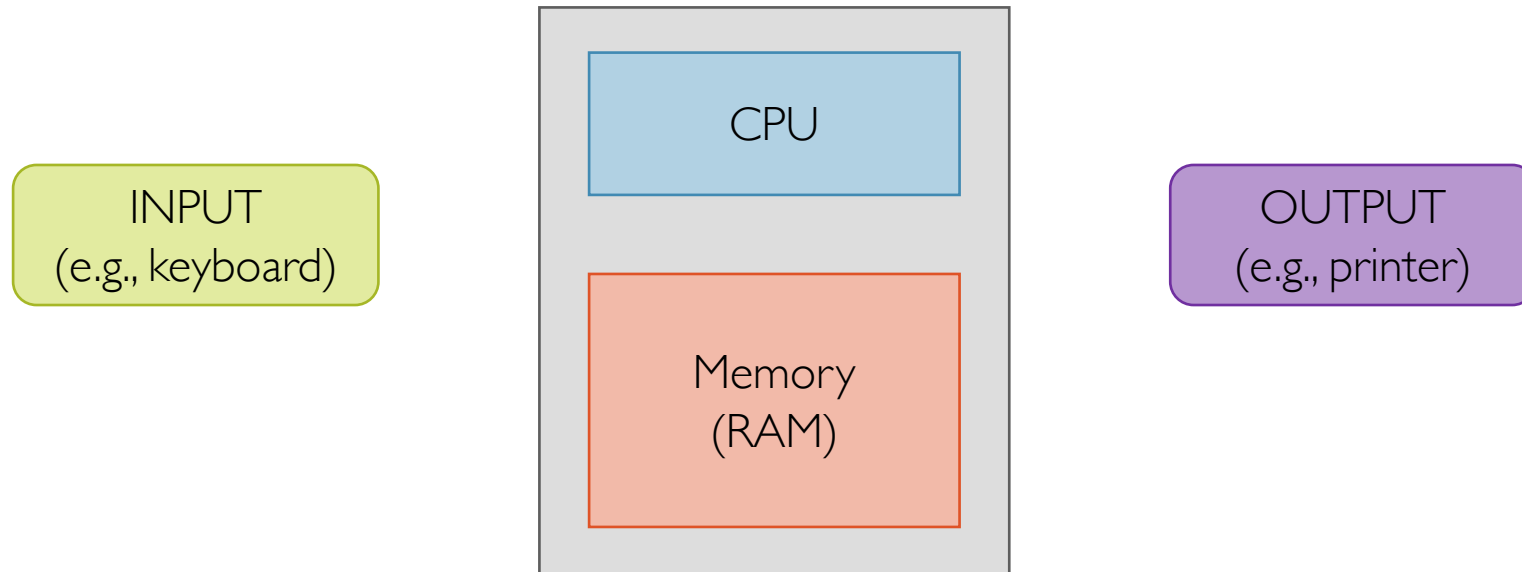
Language and Naming Conventions

- OS → Operating System
 - HW → Hardware
 - SW → Software
 - VM → Virtual Machine
 - ...
 - Other shortcuts/acronyms may appear here and there without notice!
- Please, ask if anything is not clear!

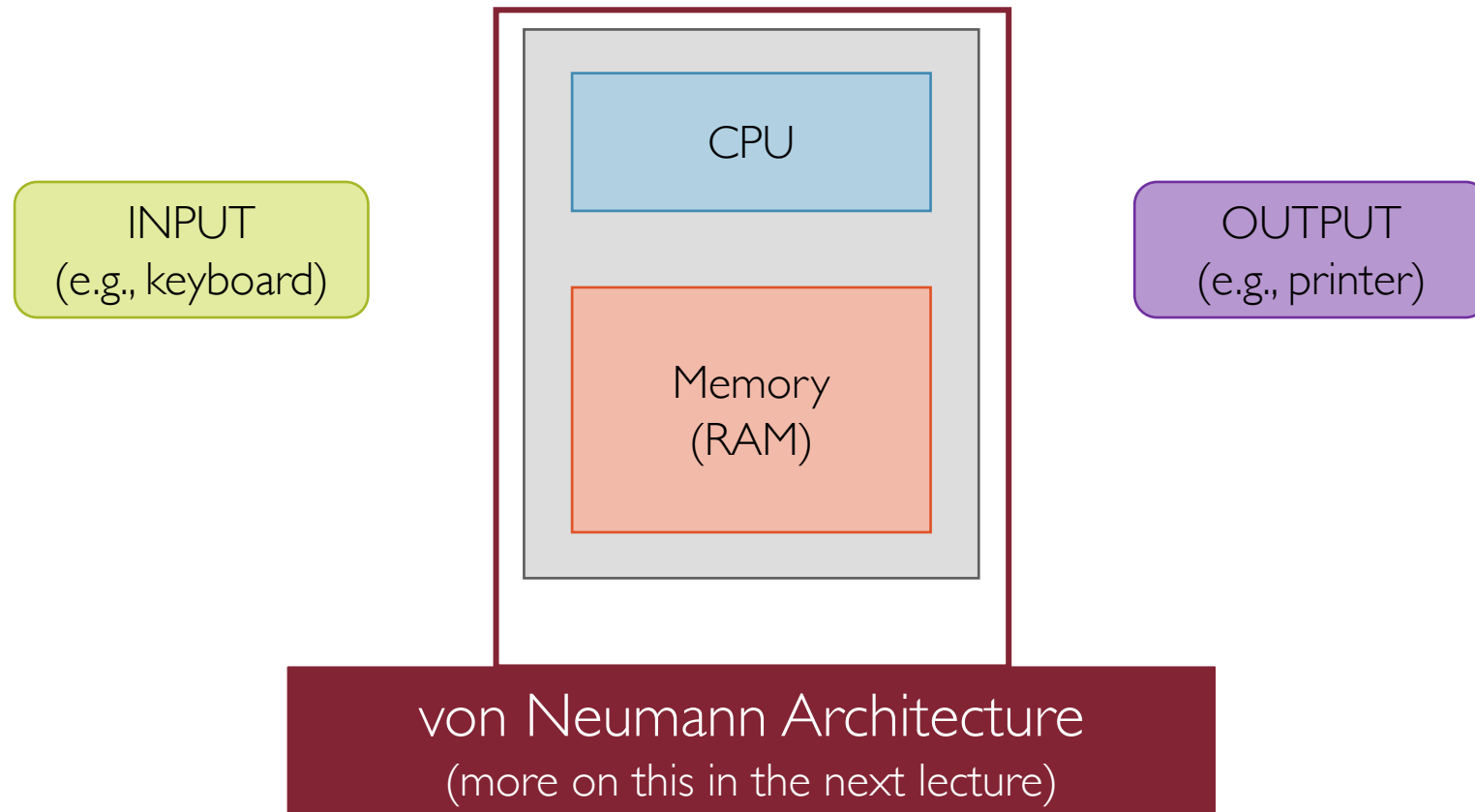
High-Level View of a Computer System



High-Level View of a Computer System



High-Level View of a Computer System



What is an Operating System?

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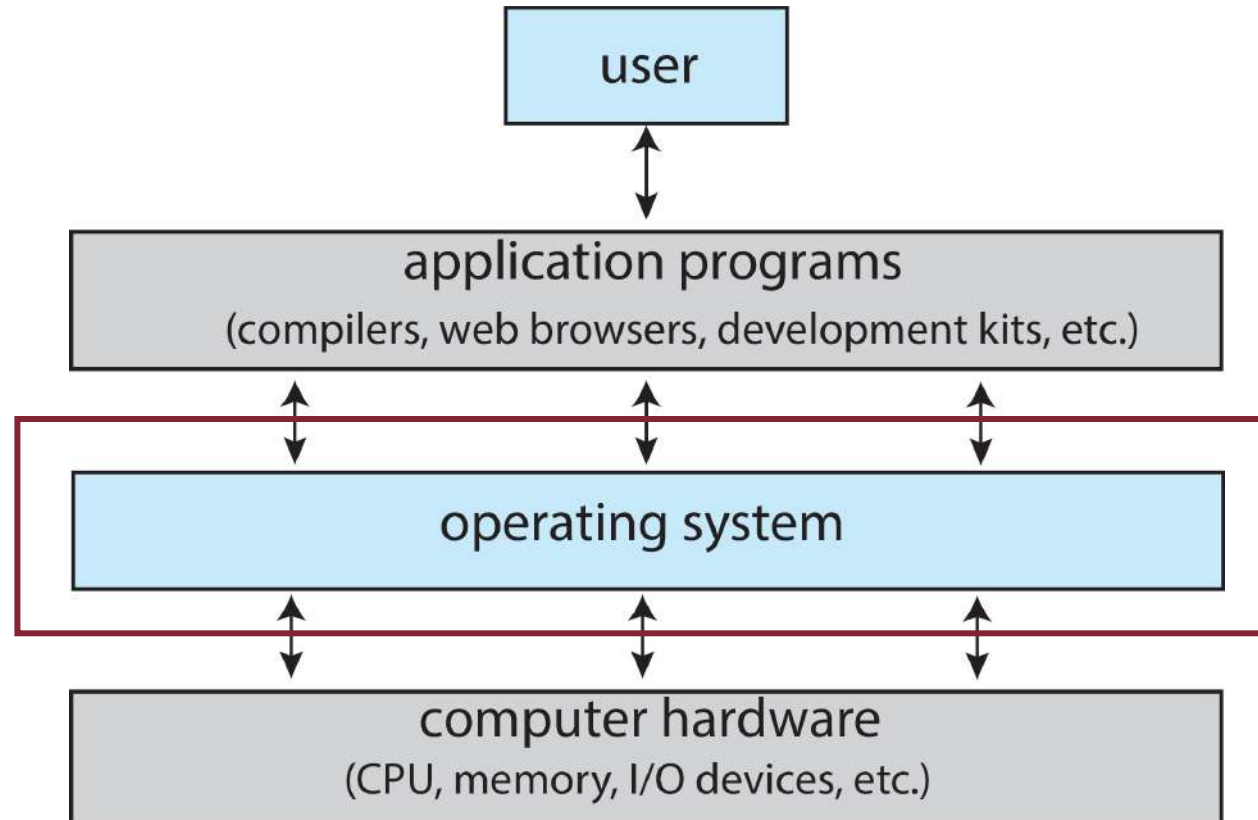
- There exists no universally accepted definition!

What is an Operating System?

- There exists no universally accepted definition!
- However, the following definition is quite appropriate:

Implementation of a **virtual machine** that is (hopefully) easier to program than bare hardware

Computer System Overview



What is Inside an Operating System?

- Again, no single answer to this question!

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- Different systems may have different requirements:
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What is Inside an Operating System?

- Again, no single answer to this question!
- It is a **system design** choice to decide what to include in the OS
- Different systems may have different requirements:
 - general-purpose, real-time, mobile, etc.
- Typically, we distinguish between:
 - **kernel** → the "core" of the OS (always up and running)
 - **system programs** → everything else which is still part of the OS

OS Wears Many Hats

- Referee (Resource Manager)
 - Manages shared physical resources: CPUs, memory, I/O, etc.



OS Wears Many Hats

- Referee (Resource Manager)
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 - To achieve fairness and efficiency



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 - Virtualize any physical resource



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 - To give applications/users the illusion of infinite resources available



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- Glue (HW/SW Interface)
 - Provides a set of common services (APIs) to separate HW from SW



OS Wears Many Hats

- Glue (HW/SW Interface)
 - Provides a set of common services (APIs) to separate HW from SW
 - To allow applications/users to interact with the system without talking directly to the HW



History of Operating Systems

Phase I: Expensive HW, Cheap Humans

- 1 machine : M users
- Hand-programmed systems
- Single-user console systems (mainframes)
- Batch systems
- Multi-programming systems

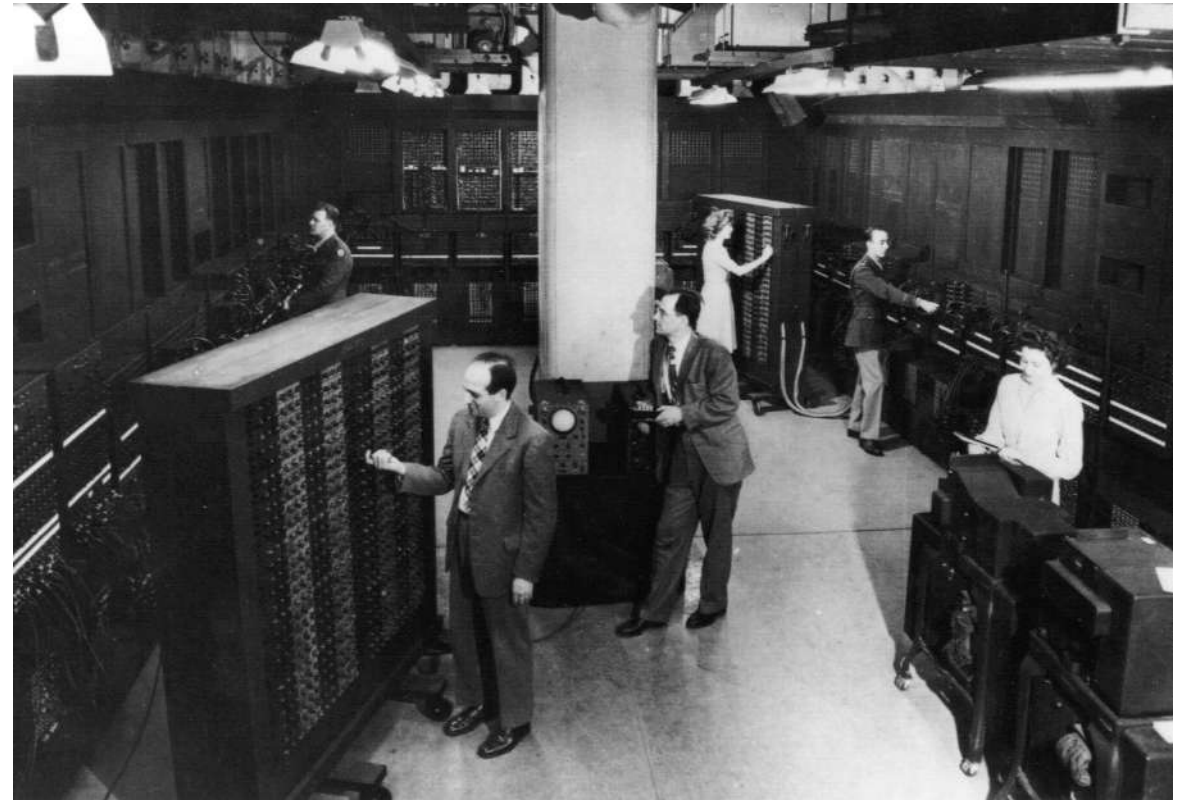
1945-55: Vacuum Tubes and Plugboards

- Used by a restricted and skilled group of people
- All programming was done in machine language directly
- Basically, no OS whatsoever!
- Problem: ?



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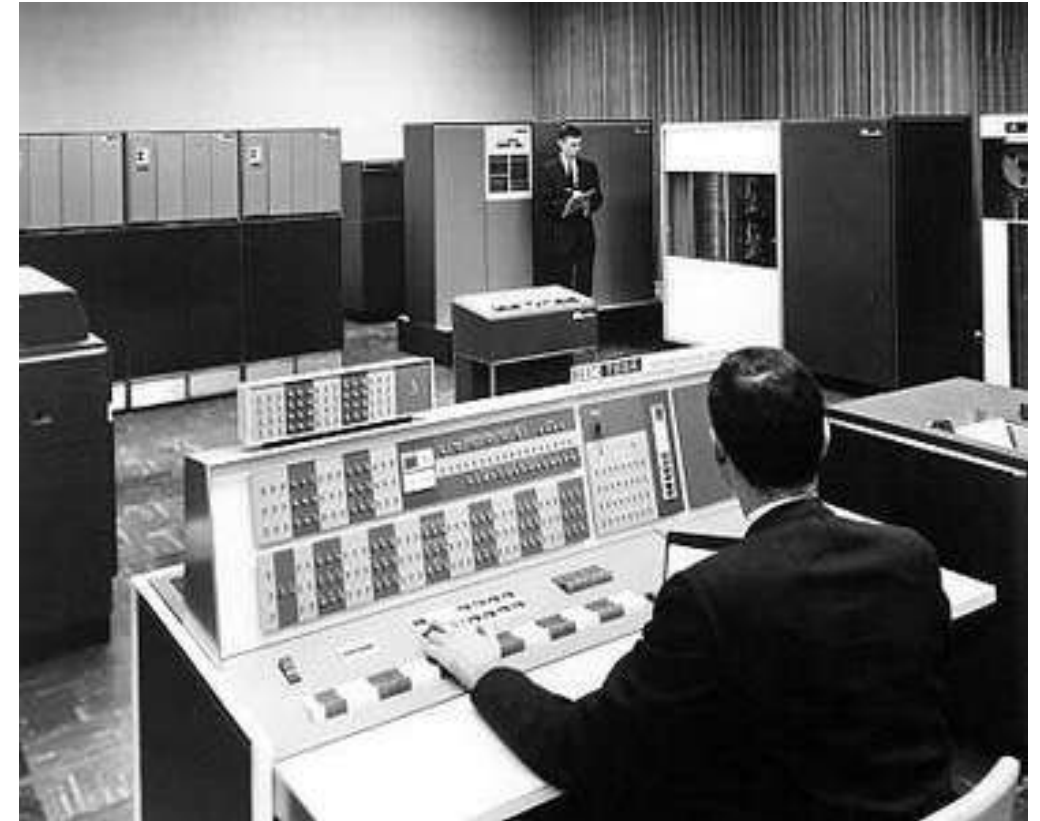
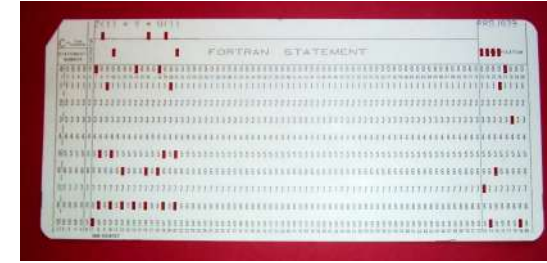


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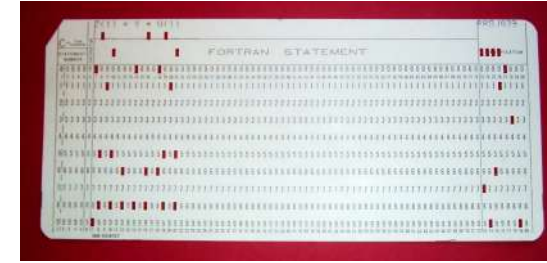
1955-65: Mainframes

- One user at a time interacting with the machine as program runs
- Programs are written on **punched cards**
- Executes one thing at a time: no overlap between computation and I/O
- Primitive OS: program loader
- **Problem: ?**



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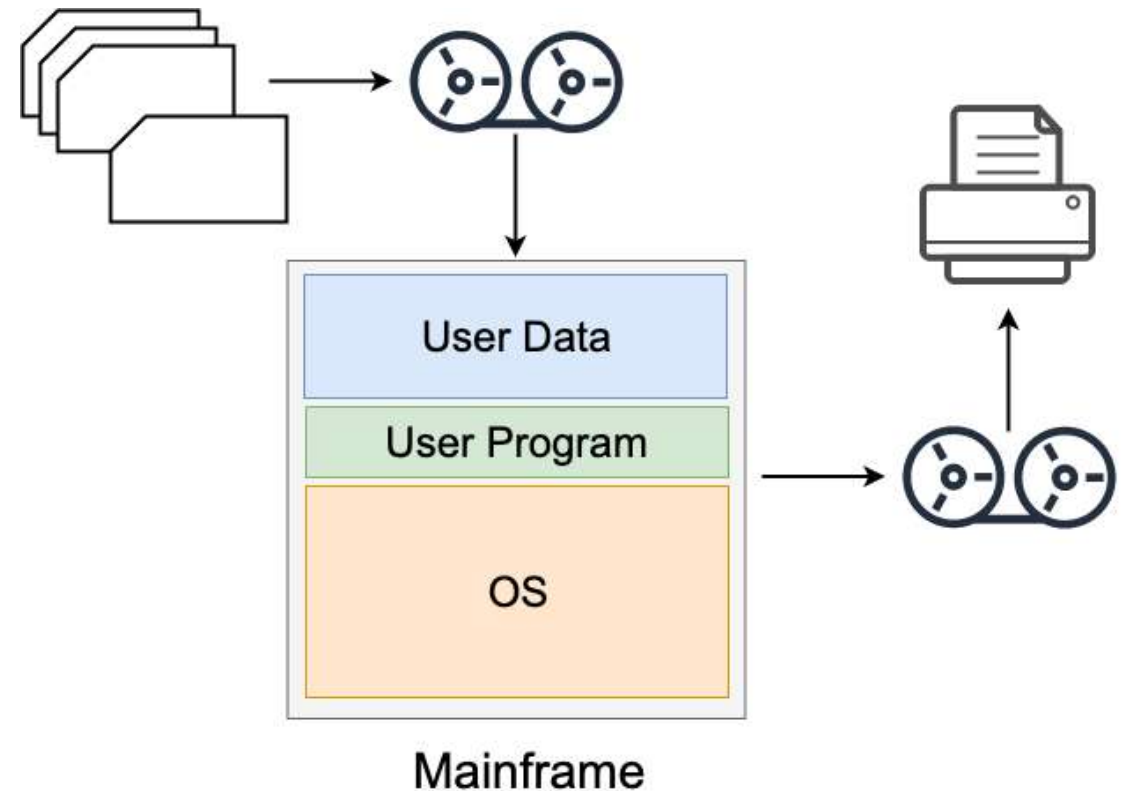


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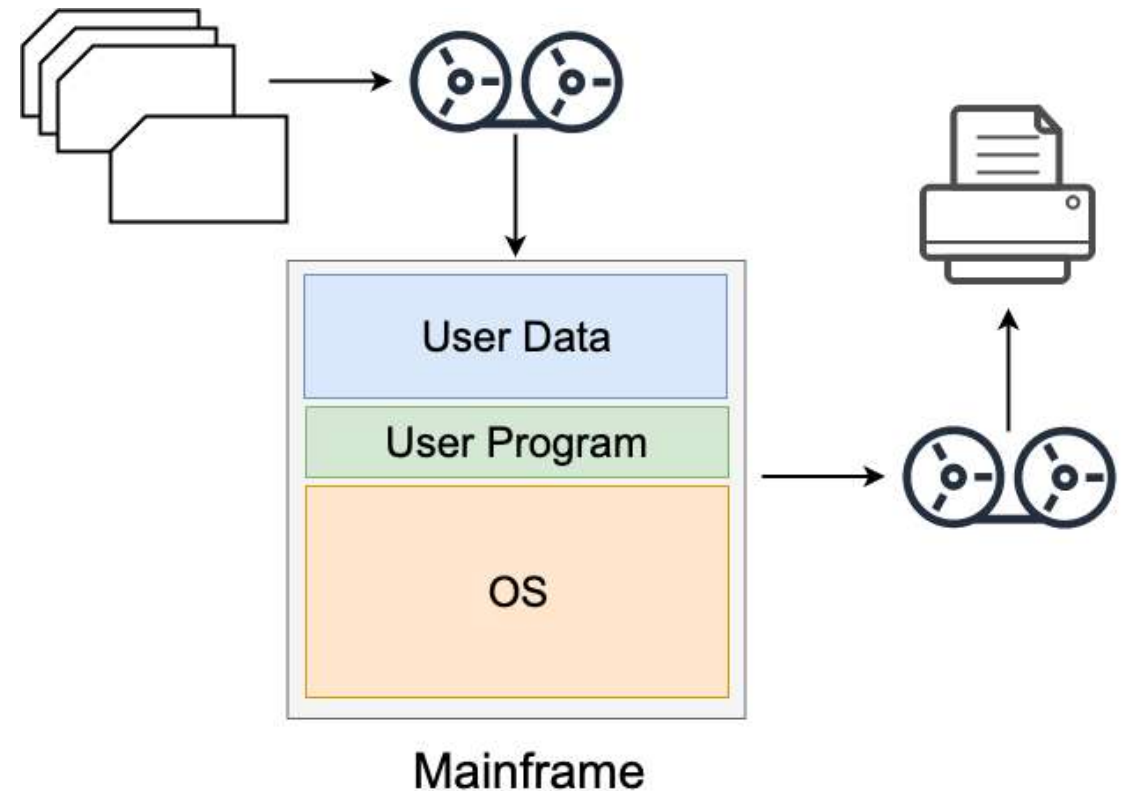
1955-65: Batch Systems

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- Users submit jobs (on cards or tapes)
- Technician still schedules jobs
- OS loads and run jobs
- More efficient use of the machine
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1955-65: Batch Systems

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- **Problem:** still one job at a time!

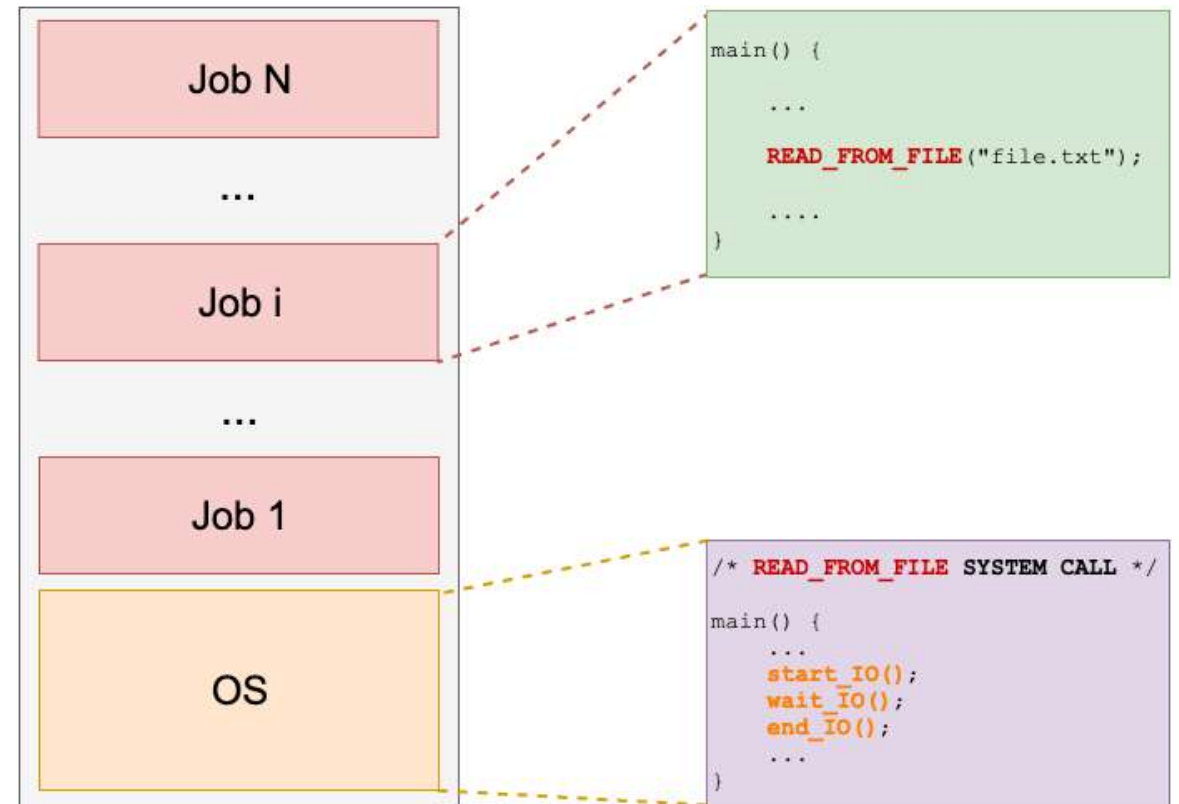


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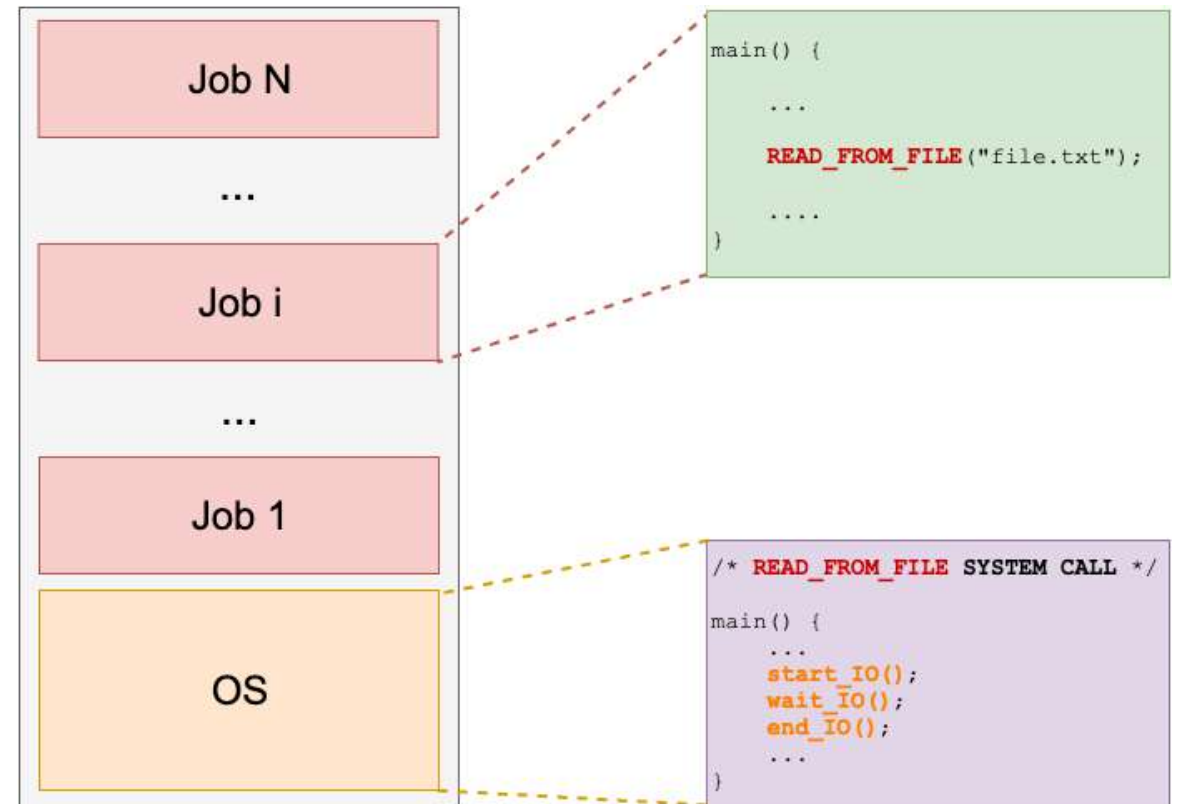
1955-65: Multiprogramming Systems

- Keep several jobs loaded in memory
- Multiplex CPU between jobs
- OS responsibilities:
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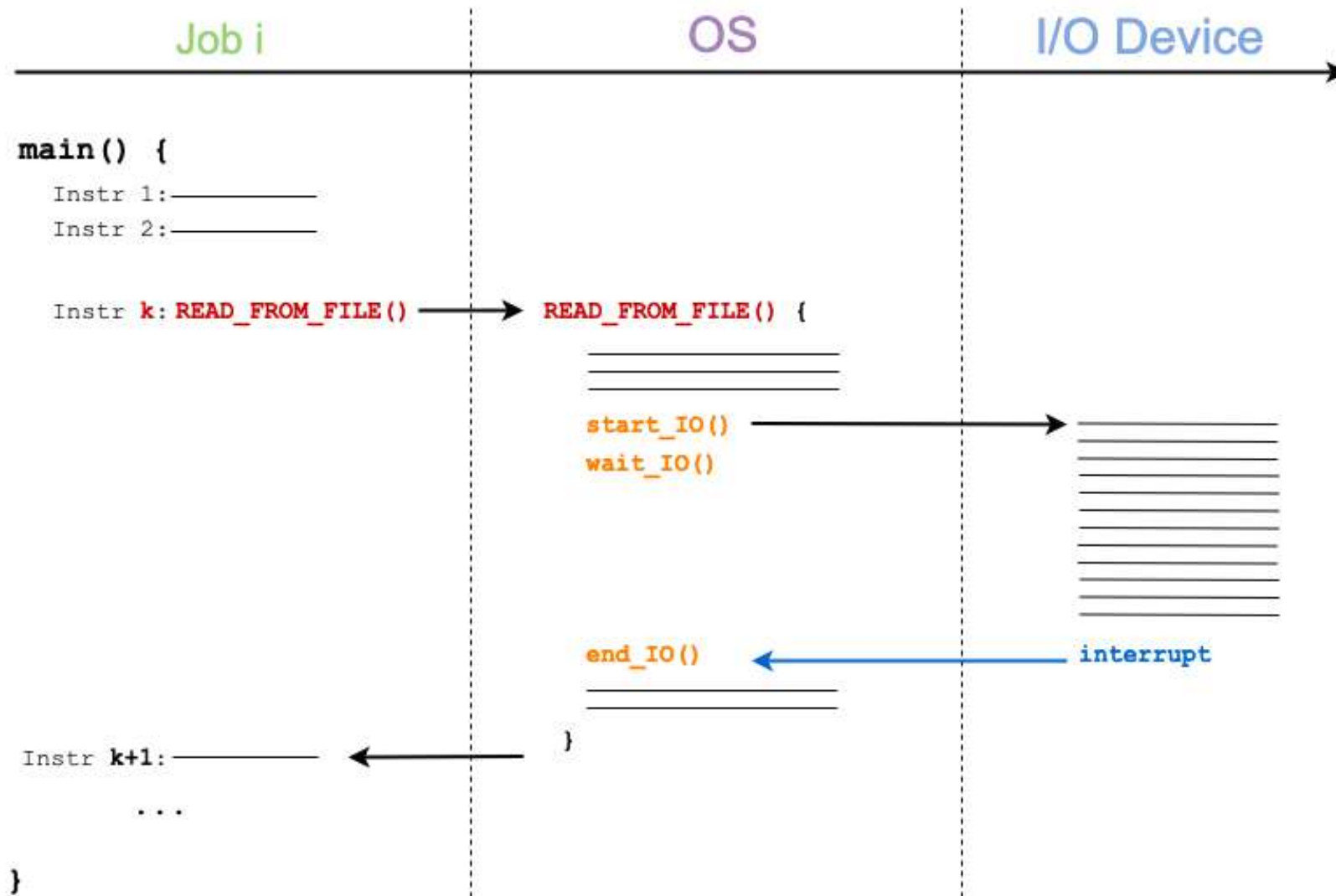


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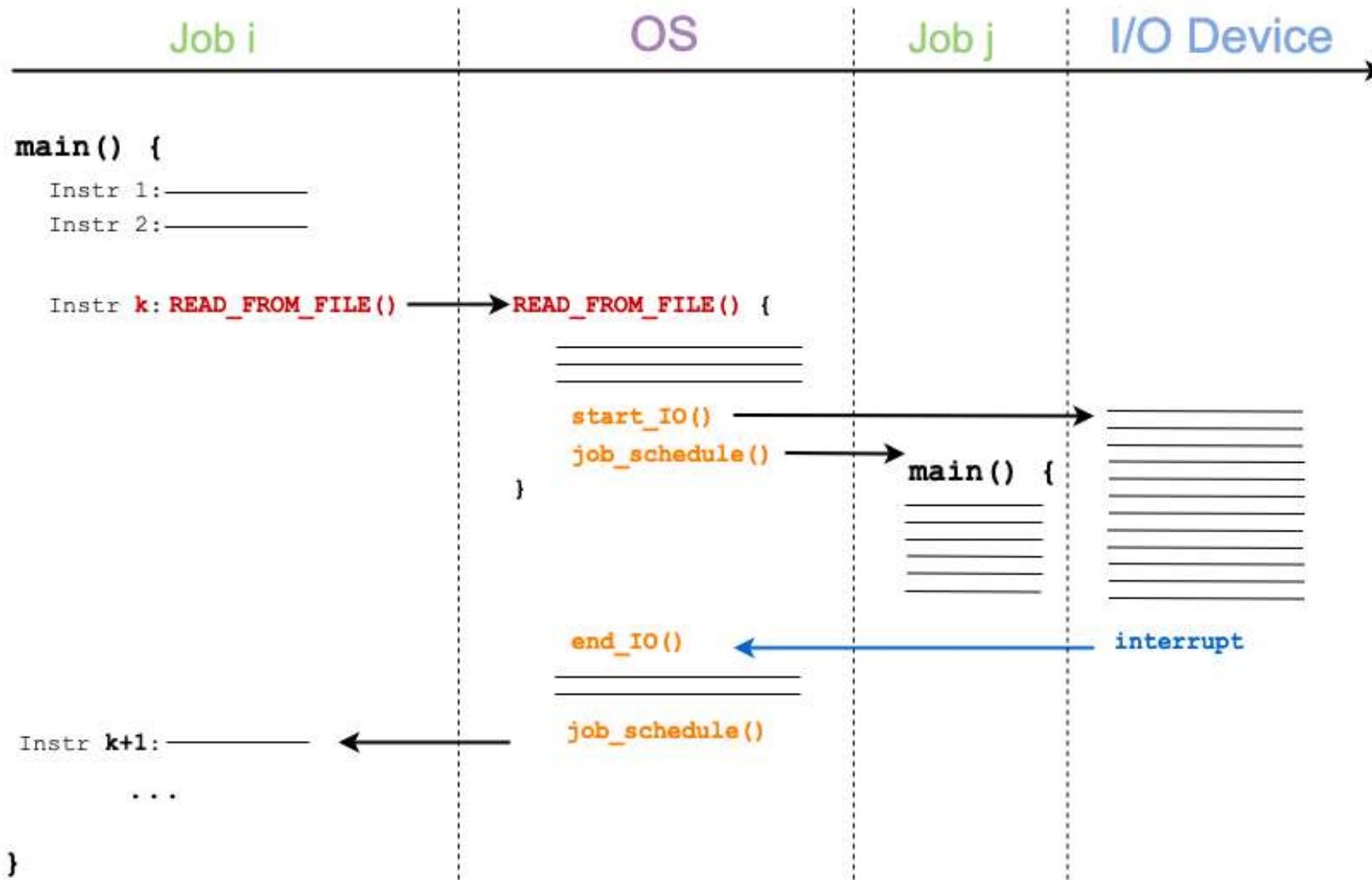
- Keep several jobs loaded in memory
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- **Problem:** CPU is left **idle** while **blocking** I/O operations take place



Blocking System I/O



Non-Blocking System I/O



Phase 2: Cheap HW, Expensive Humans

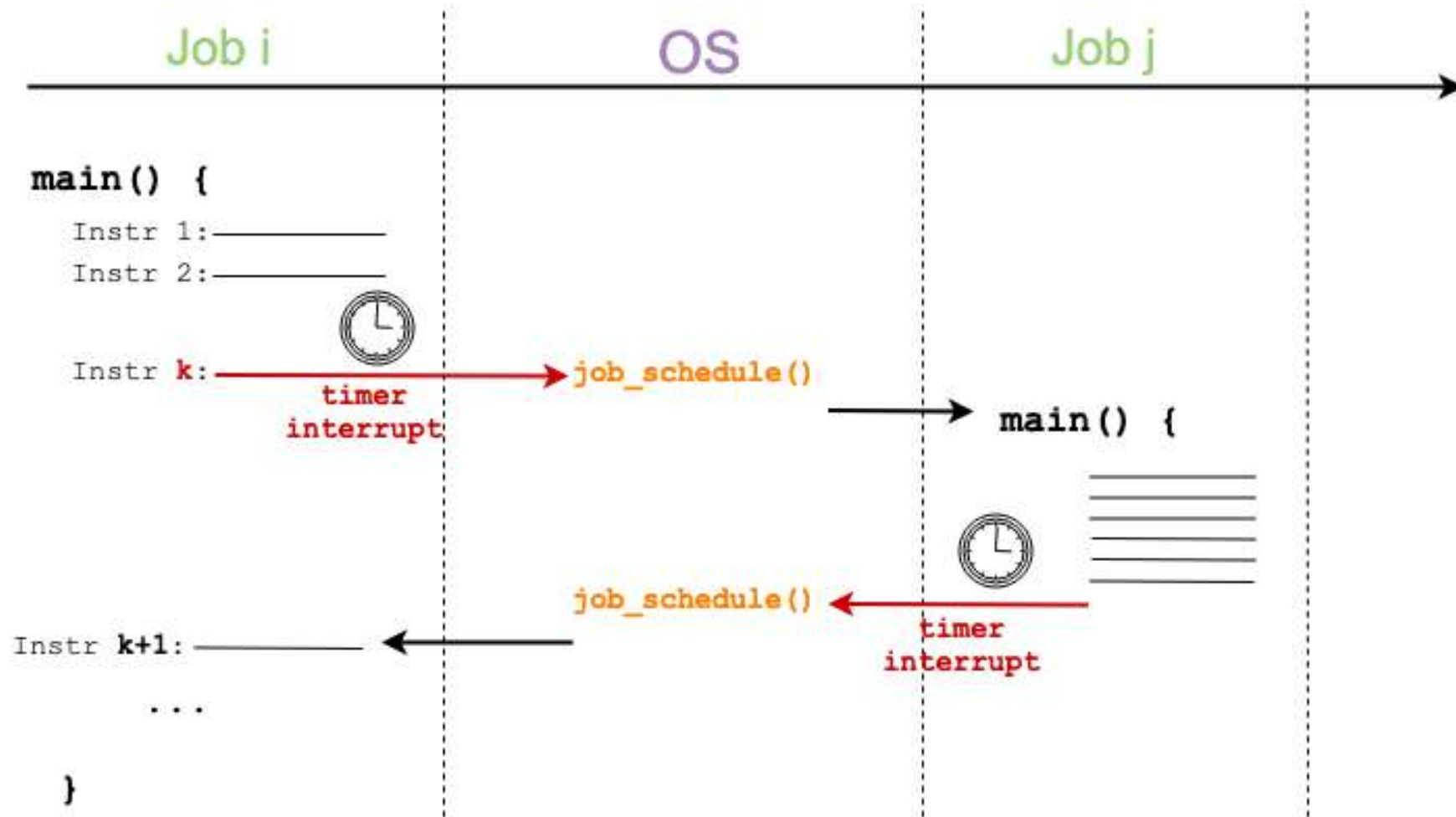
- 1 machine : M users (still)
- Time-sharing systems

1970-:Time-sharing

- Many users connected to the same CPU via cheap consoles
- Timer interrupt used to multiplex CPU between jobs
- Illusion of parallelism (pseudo-parallelism)
- Ken Thompson and Dennis Ritchie → **UNIX OS**



Pseudo-parallelism



Phase 3: Very Cheap HW, Very Expensive Humans

- Personal Computing → 1 machine : 1 user

Phase 3: Very Cheap HW, Very Expensive Humans

- Personal Computing → 1 machine : 1 user
- Distributed/Ubiquitous Computing → M machines : 1 user

1980's: Personal Computers

- Initially, simple OSs:
 - No multiprogramming, concurrency, memory protection, etc.
- Later on:
 - Networking, file sharing, Graphical User Interfaces (GUIs)
- IBM PCs (1981) and Apple Macintosh (1984)

1990's-: Personal Computers (and more)

- PCs are now equipped with a fully fledged OS:
 - Windows NT (1991)
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 - **Telecommunications:** smartphones
 - **Home appliances:** smart TVs

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- Several new (computing) environments where an OS is needed:
 - **Transportations:** airplanes, cars, etc.
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 - **Home appliances:** smart TVs
- Plus, the Web has made everything distributed!

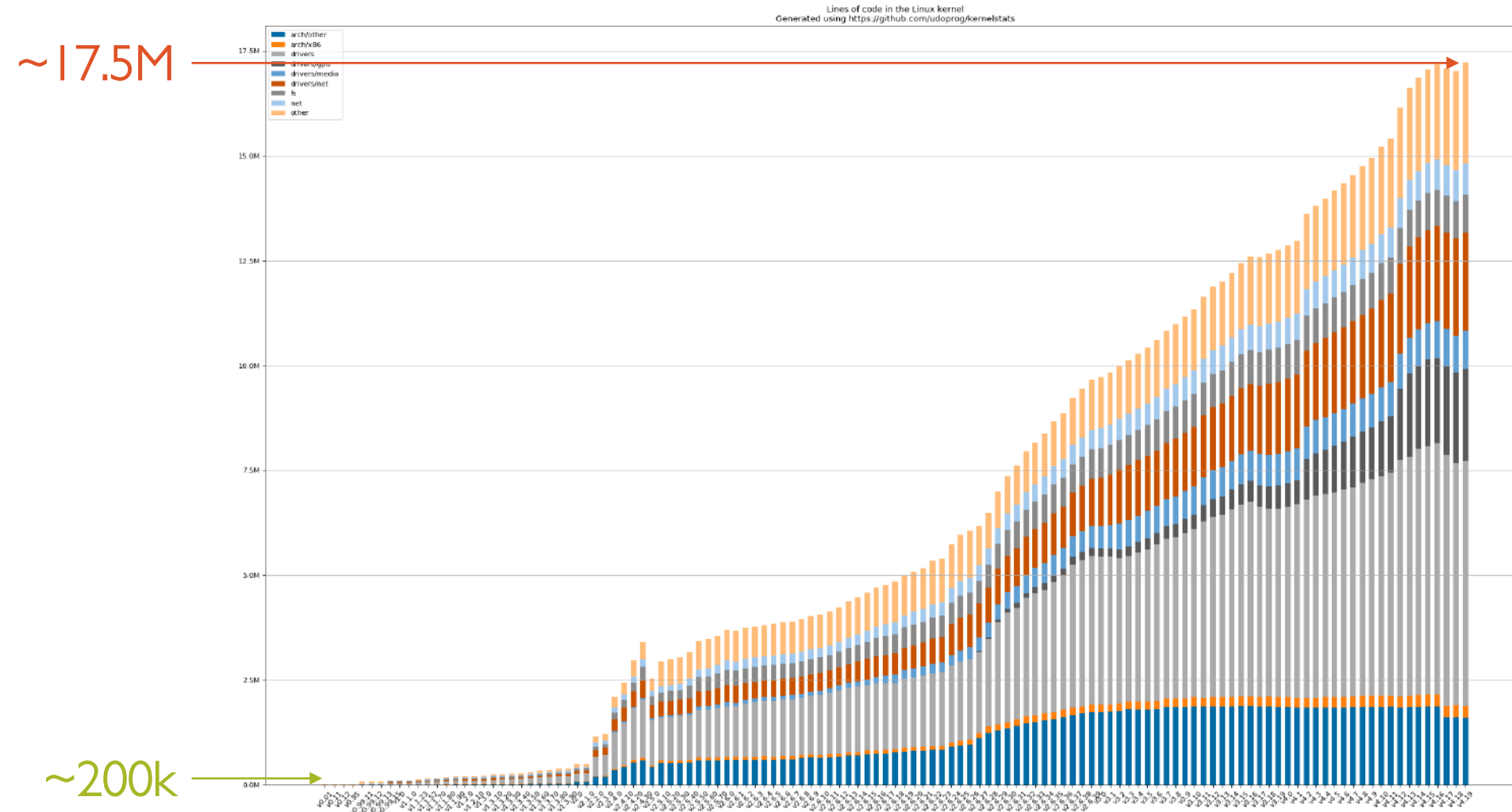
New Trends in OS Design

- Active field of research
 - OS demand is growing (many computing devices are available)
 - New application settings (Web, Cloud, mobile, cars, etc.)
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 - Hardware is rapidly changing (new CPUs coming out)
- Open-source OS (Linux)
 - Allows developers to contribute to OS development
 - Excellent research platform to experiment with

Linux Kernel Size (Lines of Code)



Why Study OSs?

- To learn important concepts of computer science
 - **Abstraction**
 - Virtualize any physical resource (CPUs, memory, I/O, etc.)

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 - Performance vs. Complexity of OS design
 - HW vs. SW implementation of key features

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 - Systems Design Tradeoffs
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- **How computers work**

Large Computer Systems

- The world is increasingly dependent on computer systems
 - Large, complex, interconnected, distributed, etc.

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OS is a great example of a large computer system

OS as Large Computer System

- Designing large computer systems requires you to know
 - Each computer:
 - Architectural details
 - High-level programming language (mostly, C/C++)
 - Memory management
 - Concurrency and scheduling
 - File system and I/O

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 - Across clusters of computers:
 - Server architectures
 - Distributed file systems and computing frameworks

OS Design Issues (I)

- **Structure** → How the whole system is organized
- **Concurrency** → How parallel tasks are managed
- **Sharing** → How resources are shared
- **Naming** → How resources are identified by users
- **Protection** → How critical tasks are protected from each other
- **Security** → How to authenticate, authorize, and ensure privacy
- **Performance** → How to make it more efficient (quick, compact)

OS Design Issues (2)

- **Reliability** → How to deal with failures
- **Portability** → How to write once and run anywhere
- **Extensibility** → How to add new features/capabilities
- **Communication** → How to exchange information
- **Scalability** → How to scale up as demand increases
- **Persistency** → How to save task's status
- **Accounting** → How to claim on control resource usage

Architectural Trends: CPU

*Million Instructions Per Second

**1 MHz = 1,000,000 clock cycles per second

	1971 (Intel 4004)	Today (Intel Core i9)	Δ (orders of magnitude)
MIPS*	~0.09	~400,000+	+7
Instructions (fetch, decode, execute) per clock cycle	~0.12	~100+	+3
Clock frequency (MHz)**	0.74	~5,000	+4
Cheap size (μm)	10	0.014	-3

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Moore's law: the number of transistors in a dense integrated circuit doubles about every two years

Architectural Trends: Main Memory

	1973 (DEC PDP-8)	Today (Samsung DDR4)	Δ (orders of magnitude)
Capacity (kB)	12	128,000,000	+7
Cost (\$/MB)	~400,000	~0.005	-8

Architectural Trends: Disk

	1956 (IBM RAMAC 305)	Today (Western Digital)	Δ (orders of magnitude)
Capacity (MB)	5	15,000,000	+7
Size (inch)	24 (x50)	3.5	-3
Cost (\$/MB)	640 (per month)	~0.000018	-9

Architectural Trends: Orders of Magnitude



$$10^0 = 1$$

source: Powers of Ten (1977)

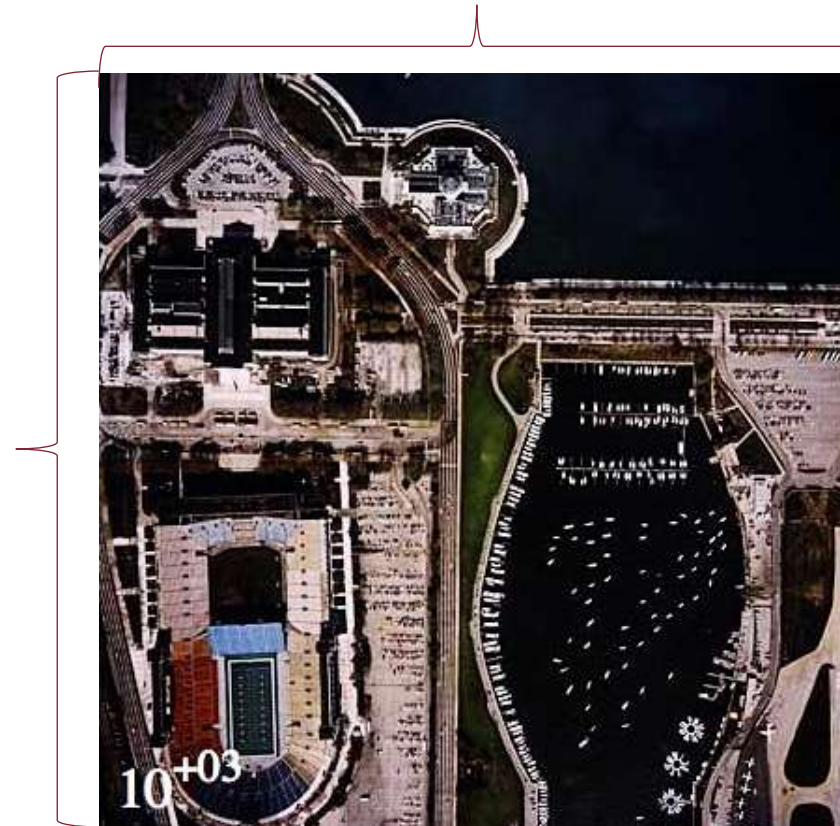
<https://www.youtube.com/watch?v=0fKBhvDjuy0>

Architectural Trends: Orders of Magnitude



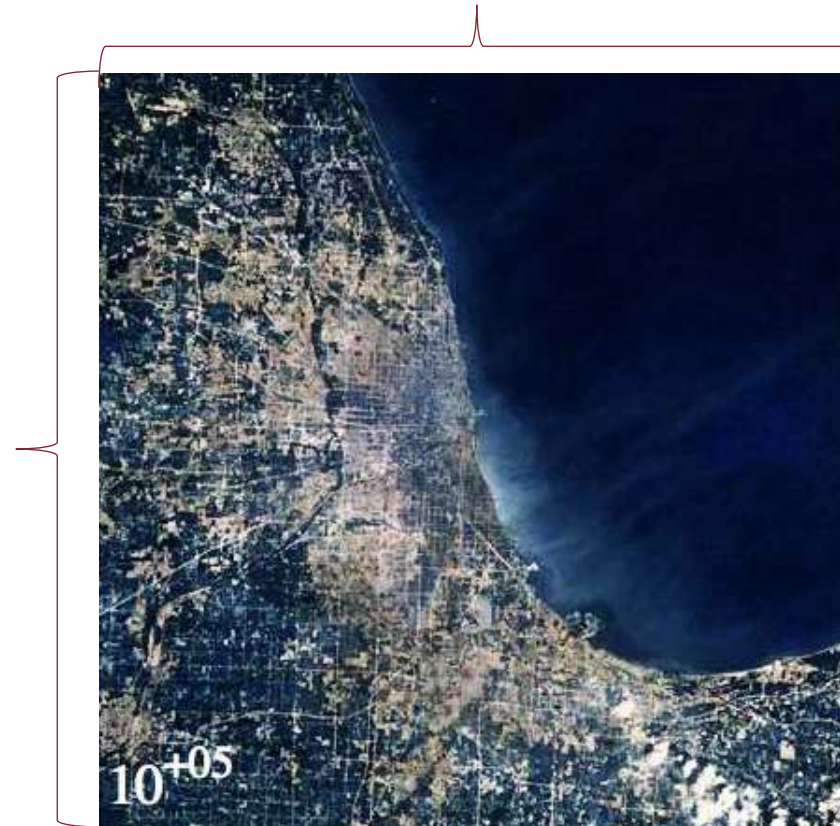
$$10^1 = 10$$

Architectural Trends: Orders of Magnitude



$$10^3 = 1,000$$

Architectural Trends: Orders of Magnitude



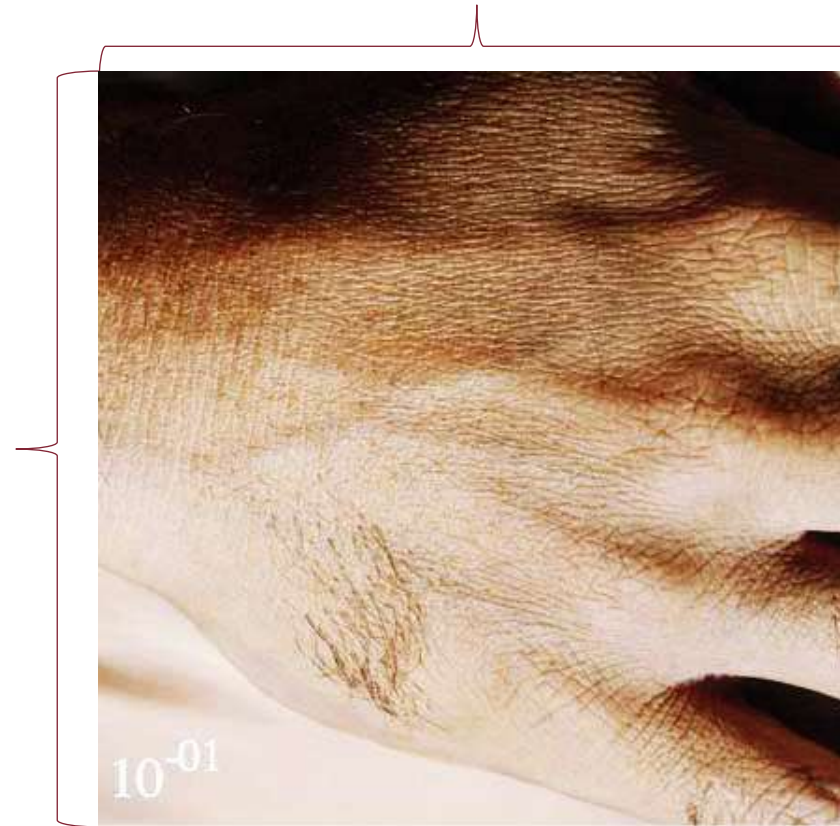
$$10^5 = 100,000$$

Architectural Trends: Orders of Magnitude



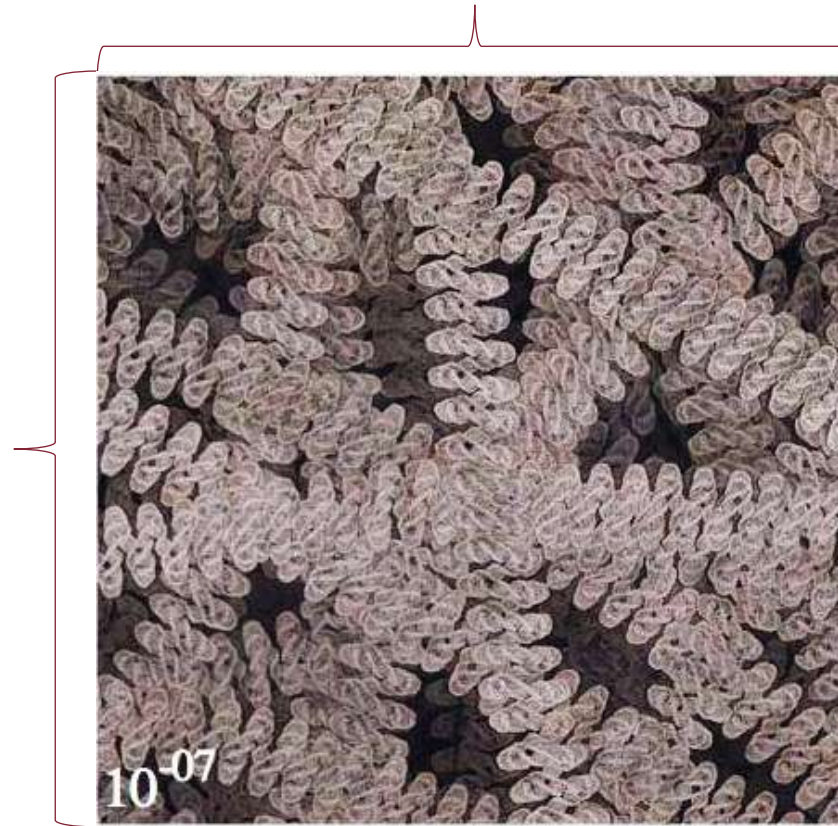
$$10^8 = 100,000,000$$

Architectural Trends: Orders of Magnitude



$$10^{-1} = 0.1$$

Architectural Trends: Orders of Magnitude



$$10^{-7} = 0.0000001$$

What's Next?

- Moore's law has hit its limit(?)
 - chip size has physical constraints
 - power vs. heat tradeoff
 - alternatives have already pushed forward the end of it:
 - multicore-manycore processors
- other approaches are subject of research:
 - molecular/DNA transistors
 - quantum computing

Summary

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- Operating Systems as large and complex computer systems

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- Basic roles of an Operating System
- A brief history of Operating Systems
- Operating Systems as large and complex computer systems
- New architectural trends open up novel opportunities and challenges in Operating System design