Operating Systems

CS3281 / CS5281

Spring 2024

Team

- Instructors
  - Dr. Andy Gokhale, Dr. Abhishek Dubey, Dr. Shervin Hajiamini
- Graduate TAs
  - Bo Ni, Saman Kittani
- Graders
  - Salomon Dushimirimana, Mohammed Khan, Rana Muhammad Shahroz Khan, Ilayda Koca, Chuci Liu, Xiaohan Liu, Binh Mai, Akash Munagala, Yurui Xu, Robert Sheng

Top Hat

- You will receive an email for your section. Please join.
- Then you will receive a question about github id. Do join.

- Visit https://www.tophat.com and enter the join code:
  - Section 1: 331346
  - Section 2: 924961
  - Section 3: 846201

Office Hours

- See on github.

Important Links

Textbook	http://pages.cs.wisc.edu/~remzi/OSTEP/
Discussion Forum & Announcements	https://piazza.com/vanderbilt/spring2024/cs32815281
Lectures	https://github.com/cs3281/lectures
Programming Assignments	https://classroom.github.com/classrooms/30844110-cs3281-classroom-spring2024
Announcements & Administration	https://vanderbilt.edu/brightspace/

Programming Assignments

- Administered through GitHub Classroom
  - Requires admission to the `cs3281` repository using your GitHub ID

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[TOPHAT GITHUB ID COLLECTION]

Programming Assignments

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- Graded using the VUIT-provided AWS Virtual Machines
  - Access your WorkSpace on a virtual machine in a browser at https://webclient.amazonworkspaces.com

    or download the AWS WorkSpaces client from: https://clients.amazonworkspaces.com/

  - Enter the following registration code: SLiad+DGTNYL

  - Log in with your VUNetID and password

Programming Assignments

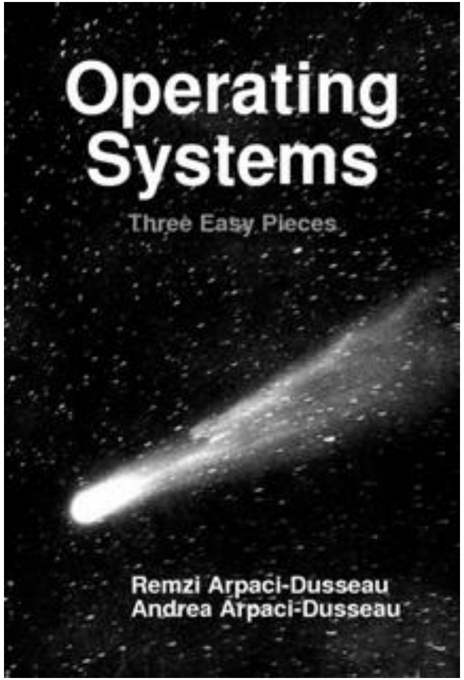
- Full instructions for using xv6 are at: https://github.com/cs3281/lectures/wiki
- Automate GitHub credentials:
  - Go to https://github.com/settings/tokens
  - Click "Generate new token (classic)"
    - Note: Development
    - Expiration: No expiration
    - Select scopes: repo, user, codespace
  - Click "Generate token"
  - Copy Personal Access Token and write it down or save it somewhere
  - In a terminal, run "git clone https://github.com/cs3281/lectures.git"
    - When prompted, enter you GitHub username and enter the above-generated Personal Access Token as your password
    - You should never be prompted to do enter these credentials again
  - In a terminal, run "git config --global credential.helper store"
    - Git should save your token in ~/.git-credentials file

GDB reads gdbinit file from the current directory in your virtual machine

- In a terminal, run:
  - mkdir -p $HOME/.config/gdb && echo "set auto-load safe-path /" > $HOME/.config/gdb/gdbinit

Textbook

- We will draw material from a variety of sources
- Primary textbook: Operating Systems: Three Easy Pieces
  - Available for free at http://pages.cs.wisc.edu/~remzi/OSTEP/
- Other possible texts:
  - The Linux Programming Interface
  - Computer Systems: A Programmer’s Perspective
  - Linux Kernel Development



Course Assessment

- Programming assignments: 50%
  - Learn by doing
- In-Class assignments/quizzes: 10%
- Mid-term exam: 15%
- Final exam: 25%
- Participation, Professionalism, Attendance: ±2%

Late days

- You have a total of 4 late days that you can use across programming assignments as you wish
  - A maximum of two late days can be used on a given programing assignment
  - Example: assignment is due by 11:59pm Monday; you can use two late days to submit that assignment by 11:59pm Wednesday with no penalty
- To use late days: push a file named late_days.md to the top-level directory of your assignment repo with a line stating whether you're using one or two late days
- Assignments submitted more than two days late will <u>not be accepted</u>
- **No collaborations unless explicitly permitted**

Regrade Requests

- Grading errors can and do happen
  - Not malicious!
- You can “challenge” if you believe an error was made
- If you are wrong, you may lose a late day

ChatGPT and AI assistants

- We have entered a new era with AI assistants
- Our goal is to use them to enhance the learning experience
- We are adopting a new experimental policy
  - You can use ChatGPT and other AI tools however you want!
  - However, you must document your use
    - No points will be deducted for use of AI, so please document your use authentically
    - We want you to reflect on how these technologies are helpful and how they aren’t. We want to know both how it failed, as well as how it succeeded!
- This policy is experimental, and is subject to change at the instructor’s discretion

Linux

- The Linux operating system is open source but very complex
  - Over 25 million source lines of code!
  - Many performance optimizations, which can obscure fundamental concepts
- You should learn to use Linux as it is widely used in industrial settings, and many applications, especially in research, use it exclusively
- It is unreasonable to implement many course concepts in Linux itself
- Watch this video: https://www.youtube.com/watch?v=actgZVvs_Jk

xv6

- Instead, we will use the teaching-oriented operating system xv6
- xv6 developed and used in OS class at MIT
  - Only ~5,000 source lines of code
  - Also used at many other universities
- We will use some existing xv6 assignments and some of our own
  - Posting or sharing solutions is a serious violation of the honor code and will be treated as such
  - Copying solutions from the web is also an honor-code violation and will be directed to the honor council

Course expectations

- You are expected to read the material for a lecture beforehand and participate in class discussions
  - We may occasionally assign videos to watch; please watch them ahead of time so you can participate in class discussions
- All assignments can be found on Brightspace
  - Check back frequently
  - Brightspace may be updated up to a week before any given lecture based on class progress and timeline

Course expectations: Office Hours

- We will use an office-hour policy similar to the one listed here: https://www2.seas.gwu.edu/~gparmer/resources/2021-09-20-Office-Hours-HOWTO.html
  - Please read this policy carefully and adhere to its guidelines
  - It will help you and us

Development Environment

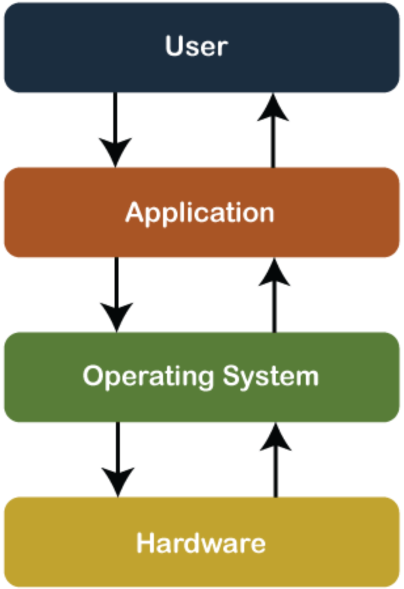
- Most of this course will use C
  - This is an OS course, not a course on C
  - While some C material will be discussed, it is up to you to learn and build your proficiency in C if you aren't proficient already
    - Remember, you can ask ChatGPT for help!
- We will assume Ubuntu as the development environment
  - VMs provided through VUIT
  - You're free to choose your development environment, but your work will be tested and evaluated on the Ubuntu VM environment
  - We do not support alternative environments
- We will use GitHub and git for content and assignment management

Development Environment

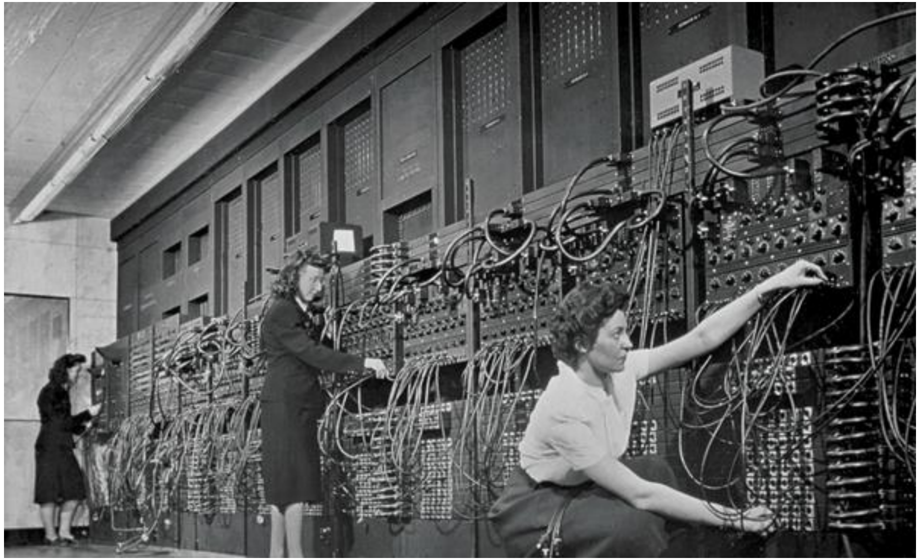
- We will use the MIT-sponsored “xv6” teaching OS for most assignments
  - Based on the original UNIX kernel
  - Allows us to actually hack on a real kernel
  - Runs on a RISC-V architecture which will be emulated on your VM through the QEMU application
  - Good idea to read relevant sections of the “xv6 book” while doing homework assignments: https://pdos.csail.mit.edu/6.S081/2023/xv6/book-riscv-rev3.pdf
  - Exit xv6/QEMU by pressing “Ctrl+a” followed by “x”

Course Goals

- Understand operating systems by learning their architecture and services
- Experience with low-level systems development



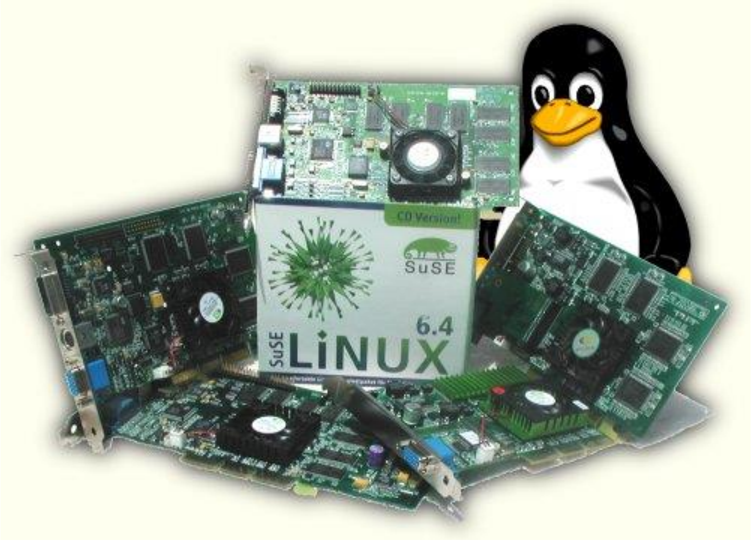
Historical Perspective



Early computers did not have an operating system. People manually performed functions that are now controlled in software systems that operate the machine

Why is this important?

- Operating system is responsible for
  - Abstracting the hardware details for convenience and portability



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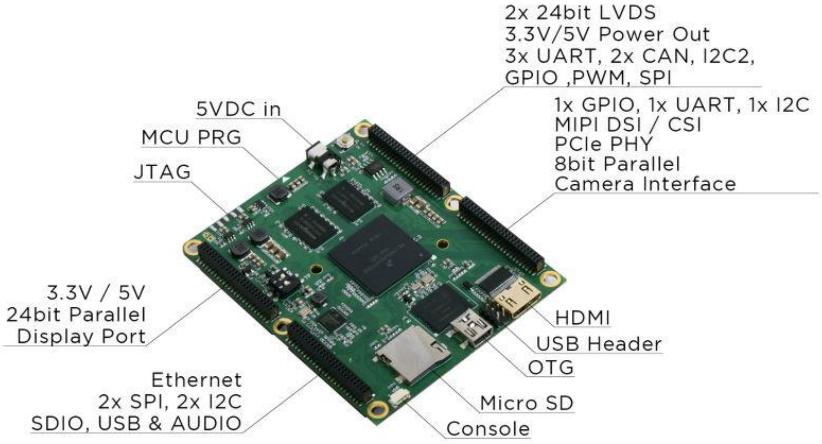
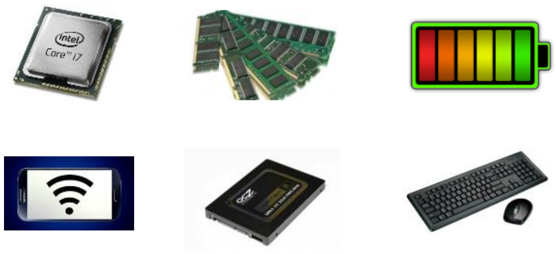
  - Multiplexing the hardware among multiple applications





Why is this important?

- Operating system is responsible for
  - Abstracting the hardware details for convenience and portability
  - Multiplexing the hardware among multiple applications
  - Isolating applications to contain bugs

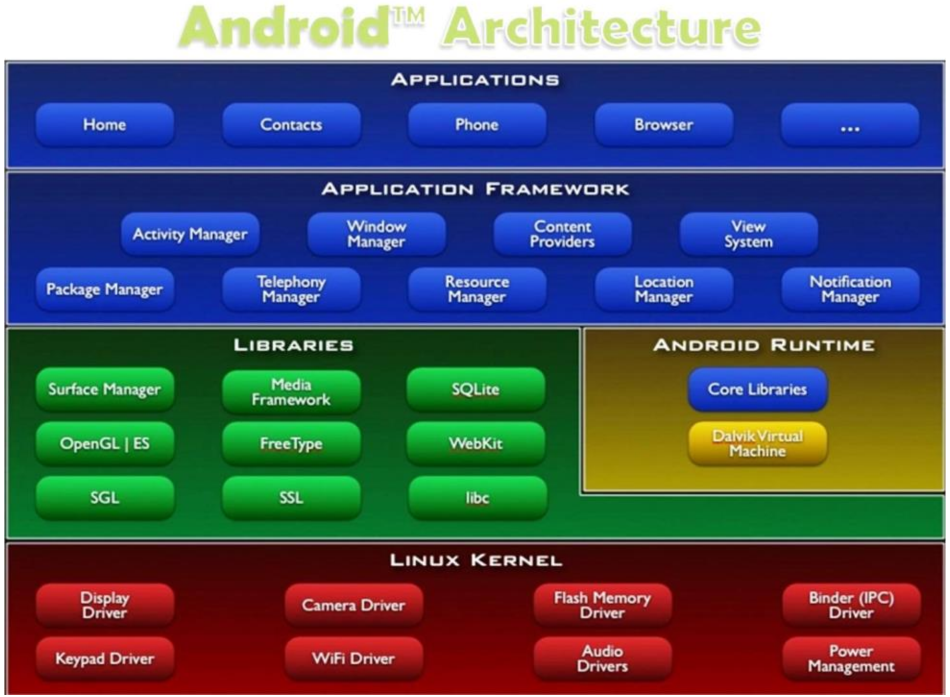
Example: USB device insertion

- Consider what happens when you plug-in a USB device to your laptop
  - USB controller informs its driver
    - The driver is part of the kernel
  - The driver asks the device to identify itself
    - Device sends back an ID
  - Controller uses ID to match a driver to the new device

A typical USB connector, called an "A" connection

Inside a USB cable: There are two wires for power -- +5 volts (red) and ground (brown) -- and a twisted pair (yellow and blue) of wires to carry the data. The cable is also shielded.

Layers of a modern computing system



- Application – the user program
- Application framework
  - Helpful libraries for providing modularity and reuse
- System Libraries – the core services of the OS are encapsulated by these libraries, e.g. libc
- The operating system kernel

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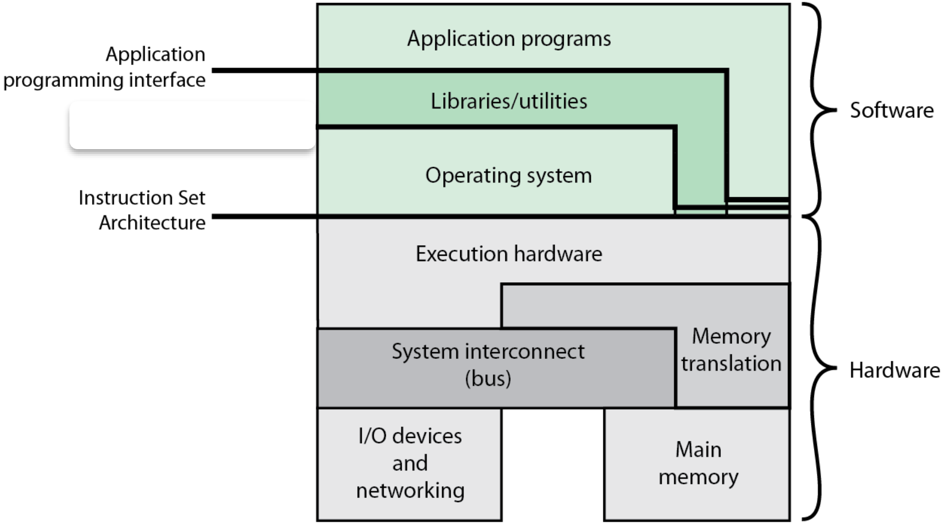
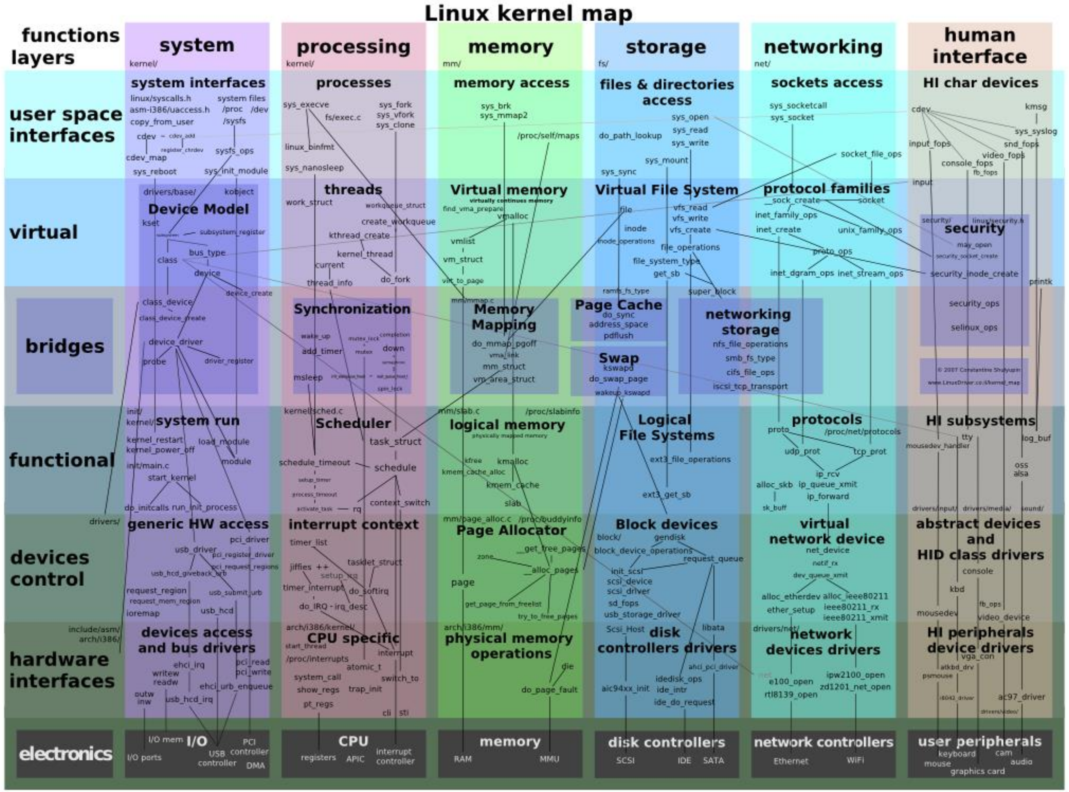
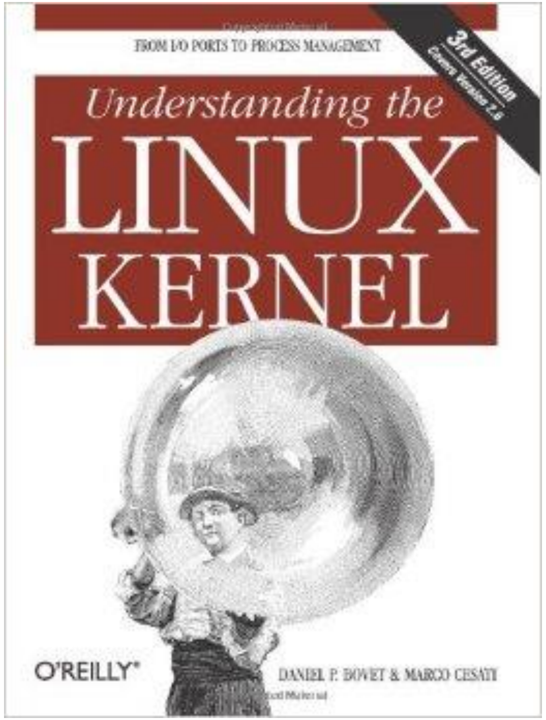


Another view of the layers

In this course we will primarily focus on The kernel and the system libraries.

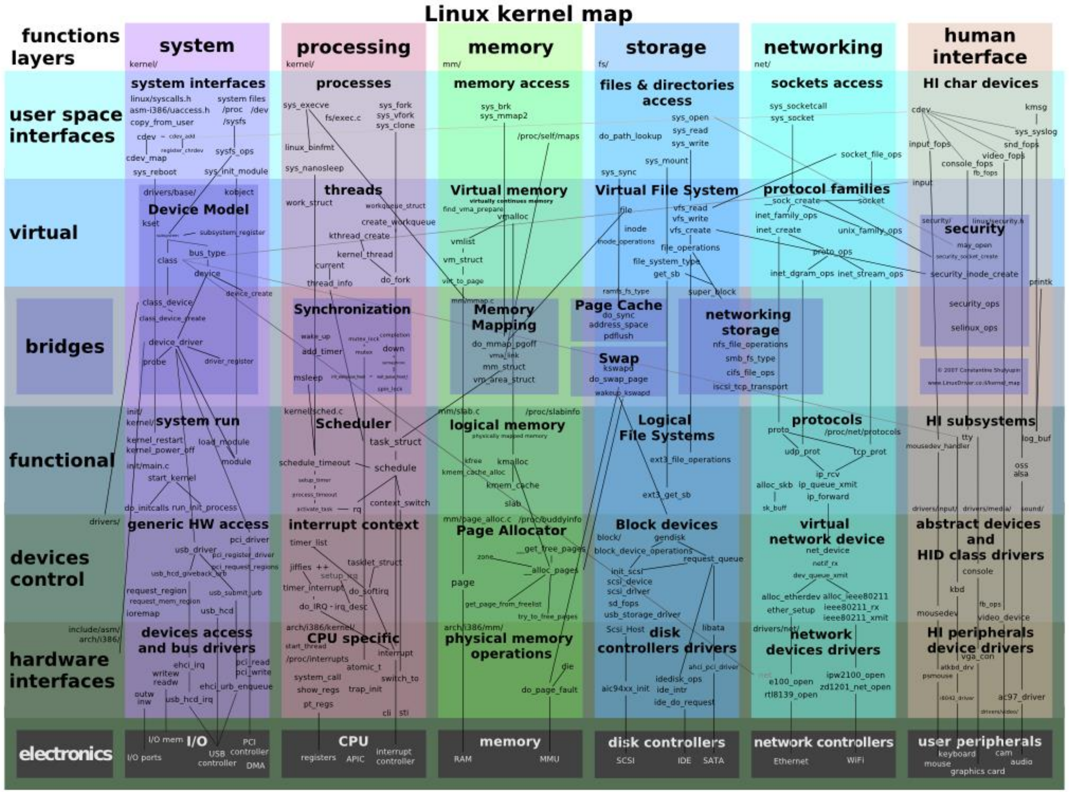
The OS Kernel





FROM I/O PORTS TO PROCESS MANAGEMENT
3rd Edition
Covers Version 2.6
Understanding the
LINUX
KERNEL
O'REILLY
DANIEL P. BOVET & MARCO CESATI

The OS Kernel



- Process management
- Memory management
- File-system management
- Security
- Communication and networking
- Time Synchronization
- Many others: users, IPC, network, time, terminals

How do we interact with the kernel?

- Applications only see them via system calls (system calls are the API of the kernel)
- Examples, from UNIX / Linux:

```
pid_t pid = getpid();
printf("mypid is %d\n", pid);
```

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printf("mypid is %d\n", pid);
```

```
brk(0x18c9000)                    = 0x18c9000
clone(child_stack=0,
flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_
SETTID|SIGCHLD,
child_tidptr=0x7fbf4bda1a10) = 3710
getpid()                    = 3709
fstat(1, {st_mode=S_IFCHR|0620,
st_rdev=makedev(136, 6), ...}) = 0
write(1, "mypid is 3709\n", 14mypid is 3709
)        = 14
exit_group(0)
```

Strace output (system calls in bold)

Why OS design is challenging

- The environment is unforgiving: weird h/w, hard to debug
- It must be efficient (thus low-level?)
  - but abstract/portable (thus high-level?)
- Powerful (thus many features?)
  - but simple (thus a few composable building blocks?)
- Features interact: `fd = open(); ...; fork()`
- Behaviors interact: CPU priority vs memory allocator
- Open problems: security, multi-core

Before Next Class

- Ensure that you have full access to your VUIT Amazon AWS Virtual Machine
- Ensure that you can access the CS 3281 GitHub repo, including
  - https://github.com/cs3281/lectures
  - https://github.com/cs3281/lectures/wiki
- Verify access to Brightspace and Piazza

Additional Reference Material

- https://github.com/cs3281/coding-interview-university
- https://missing.csail.mit.edu/ - The Missing Semester of Your CS Education
  - Videos and material which will be very useful for you.