CS 153
Design of Operating Systems

Fall 18

Lecture 1: Course Introduction

Instructor: Heng Yin
Slide contributions from
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Teaching Staff

- Heng Yin
  - I am an Associate Professor in CSE
    - Third year at UCR, but many more elsewhere
  - Office hours Monday 2-3pm, Thursday 11am-12pm, or by appointment
    - Hope to meet many of you during office hours

- Two TAs
  - Hadi Zamani (TA'ed several times) and Yue Duan
    - PhD students in Computer Science
  - Office hours TBA
  - Leads for Labs

Class Overview

- Check class webpage for information
  - https://www.cs.ucr.edu/~heng/teaching/cs153-fall18/

- Lecture slides, homeworks, and projects will be posted on class webpage
- Assignment turn-in through iLearn
  - Digital only, no paper copy
  - Announcements through iLearn and posted on class webpage
- Piazza for discussion forums; link on website
  - Use these please
  - Stay on top of things – falling behind can snowball quickly into trouble

Textbook

- Apraci-Dessau and Apraci-Dessau**, OS, 3 easy pieces** (required + free!)

- Other good books:
  - Anderson and Dahlin, ***Operating Systems: Principles and Practice (recommended)***
  - Silberschatz, Galvin, and Gagne, ***Operating System Concepts***, John Wiley and Sons, 8th Edition **(recommended)**

Class Overview

- Grading breakdown
  - projects (40% total)
    - Xv6 Operating system
    - Book uses examples from it
    - 4 projects (used to be 2, splitting into halves)
      - To keep the TA load under control, they will grade each two together
  - 4 homeworks (16% total)
  - Mid-term (18%)
  - Final (26%)

Projects

- Project framework this time: xv6
  - Projects are in C
  - Very good debugging support
  - Used in OS class at several other universities

- Start to get familiar immediately
  - We will start labs. next week!
  - Go over the xv6 documentation (on the course web page)
  - Optional Lab 0 to help get familiar with what xv6 is

Projects are HARD!

- Probably the hardest class you will take at UCR in terms of development effort
  - You must learn gdb if you want to preserve your sanity! ☺

- Working on the projects will take most of your time in this class

- Biggest reason the projects are hard: legacy code
  - You have to understand existing code before you can add more code
  - Preparation for main challenge you will face at any real job

Project Recommendations

- Easier if you are engaged/excited
- Find a partner that you like/trust
- Do not start working on projects at last minute!
  - A lot of the time will be spent on understanding the code
  - Debugging is integral process of development
- Make good use of help available
  - Post questions on piazza
  - Take advantage of TA office hours
  - Come prepared to Labs
  - Again, learning to debug

Project logistics

- Projects to be done in groups of two
  - When you have chosen groups, send your group info to your TA
  - Use the find a partner feature in piazza
    - email if unable to find partner and we'll form groups
  - Option to switch partners after project two

- First step is to conceptually understand the project
  - Then come up with implementation plan
    - Fail and fail again
    - Debug, debug, debug (systems are unforgiving)
    - →success!!

Homeworks and Exams

- Four homeworks
  - Can expect similar questions on the exams
- Midterm (tentatively November 1)
  - In class
- Final (December 11, 8-11am)
  - Covers second half of class + selected material from first part
    - I will be explicit about the material covered
    - Because first midterm is short (80 minutes)
- No makeup exams
  - Unless dire circumstances

Submission Policies

- Homeworks due on ilearn by the end of the day (will be specified on ilearn)

- Code and design documents for projects due by the end of the day (similarly will be specified on ilearn)

- Late policy (also on course webpage):
  - 15% penalty for every late day up to 3 days
  - Late submission beyond 3 days are not graded

Recipe for success in CS153

- Start early on projects
- Attend labs and office hours
  - Take advantage of available help
- Be engaged, interested, curious
- Make sure to attend lectures
  - Going over slides is not the same
- Try to read textbook material before class
- Ask questions when something is unclear

How *Not* To Pass CS 153

- Do not come to lecture
  - It’s nice out, the slides are online, and the material is in the book anyway
  - Lecture material is the basis for exams and directly relates to the projects
  - I often see capable students hurt themselves badly (fail, or get miserable grades) by not attending

- Do not ask questions in lecture, office hours, or email
  - It’s scary, I don’t want to embarrass myself
  - Asking questions is the best way to clarify lecture material at the time it is being presented
  - Office hours and email will help with projects

How *Not* To Pass (2)

- Wait until the last couple of days to start a project
  - We'll have to do the crunch anyways, why do it early?
  - The projects cannot be done in the last few days
  - Repeat: **The projects cannot be done in the last few days**
  - Each quarter groups learn that starting early meant finishing all of the projects on time…and some do not

Objectives of this class

- In this course, we will study problems and solutions that go into design of an OS to address these issues
  - Focus on concepts rather than particular OS
  - Specific OS for examples

- Develop an understanding of how OS and hardware impacts application performance and reliability

- Examples:
  - What causes your code to crash when you access NULL?
  - What happens behind a printf()?
  - Why can multi-threaded code be slower than single-threaded code?

Questions for today

- Why do we need operating systems course?
- Why do we need operating systems?
- What does an operating system need to do?
- Looking back, looking forward

Soap box – why you should care

- Student surveys show low interest coming in

- Computers are an amazing feat of engineering
  - Perhaps the greatest human achievement
- You get to understand how they work
  - OS, Architecture, Compilers, PL, … are the magic that makes computers possible
- Ours is a young field
  - Our Newtons, Einsteins, LaPlace’s, … happened in the last century
  - Many of our giants are still alive
  - So much innovation at an unbelievable pace
  - You can help write the next chapter

Why an OS class?

- Why are we making you sit here today, having to suffer through a course in operating systems?
  - After all, most of you will not become OS developers
- Understand what you use (and build!)
  - Understanding how an OS works helps you develop apps
  - System functionality, debugging, performance, security, etc.
- Learn some pervasive abstractions
  - Concurrency: Threads and synchronization are common modern programming abstractions (Java, .NET, etc.)
- Learn about complex software systems
  - Many of you will go on to work on large software projects
  - OSes serve as examples of an evolution of complex systems

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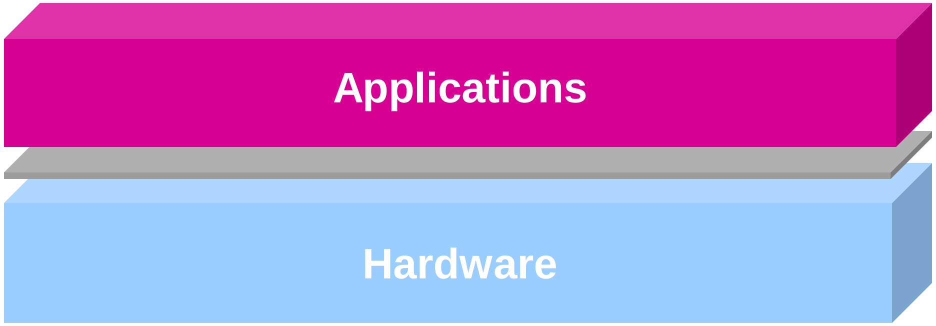
Why have an OS?

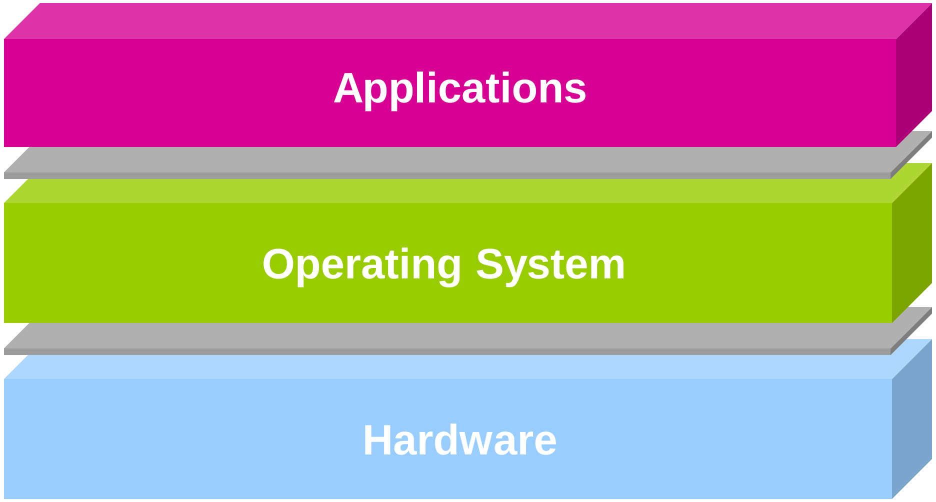
- What if applications ran directly on hardware?



- Problems:
  - Portability
  - Resource sharing

What is an OS?

- The operating system is the software layer between user applications and the hardware



- The OS is "*all the code that you didn't have to write*" to implement your application

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Roles an OS plays

- Beautician that hides all the ugly low level details so that anyone can use a machine (e.g., smartphone!)
- Wizard that makes it appear to each program that it owns the machine and shares resources while making them seem better than they are
- Referee that arbitrates the available resources between the running programs efficiently, safely, fairly, and securely
  - Managing a million crazy things happening at the same time is part of that – concurrency
- Elephant that remembers all your data and makes it accessible to you -- persistence

More technically...

- **Abstraction**: defines a set of logical resources (objects) and well-defined operations on them (interfaces)

- **Virtualization**: Isolates and multiplexes physical resources via spatial and temporal sharing

- **Access Control**: who, when, how
  - Scheduling (when): efficiency and fairness
  - Permissions (how): security and privacy

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Lecture 1.2: Historical perspective

Instructor: Heng Yin

Some Questions to Ponder

- What is part of an OS? What is not?
  - Is the windowing system part of an OS? Java? Apache server? Compiler? Firmware?

- Popular OS's today include Windows, Linux, and OS X
  - How different/similar do you think these OSes are?

- Somewhat surprisingly, OSes change all of the time
  - Consider the series of releases of Windows, Linux, OS X…
  - What are the drivers of OS change?
  - What are the most compelling issues facing OSes today?

Pondering Cont'd

- How many lines of code in an OS?
  - Vista (2006): 50M (XP + 10M)
    - What is largest kernel component?
  - OS X (2006): 86M
  - Debian 3.1 (2006): 213M

- What does this mean (for you)?
  - OSes are useful for learning about software complexity
    - The mythical man month
    - KDE (X11): 4M
    - Browser : 2M+, …
  - If you become a developer, you will face complexity
    - Including lots of legacy code

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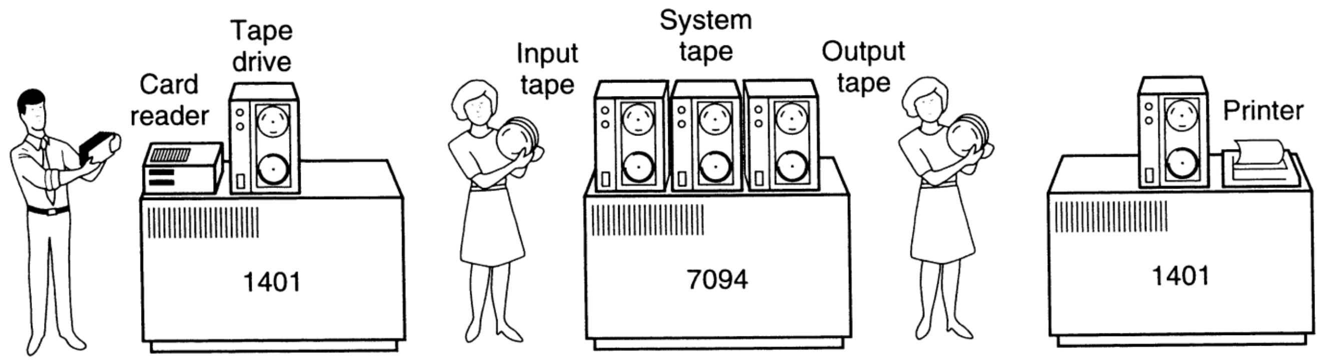
A brief history—Phase 0

- In the beginning, OS is just runtime libraries
  - A piece of code used/sharable by many programs
  - Abstraction: reuse magic to talk to physical devices
  - Avoid bugs

- User scheduled an exclusive time where they would use the machine

- User interface was switches and lights, eventually punched tape and cards
  - An interesting side effect: less bugs

Phase 1: Batch systems (1955-1970)



- Computers expensive; people cheap
  - Use computers efficiently – move people away from machine
- OS in this period became a program loader
  - » Loads a job, runs it, then moves on to next
  - » More efficient use of hardware but increasingly difficult to debug
    - Still less bugs ☺

Advances in OS in this period

- SPOOLING/Multiprogramming
  - Simultaneous Peripheral Operation On-Line (SPOOL)
    - Non-blocking tasks
    - Copy document to printer buffer so printer can work while CPU moves on to something else
  - Hardware provided memory support (protection and relocation)
  - Scheduling: let short jobs run first
  - OS must manage interactions between concurrent things
- OS/360 from IBM first OS designed to run on a family of machines from small to large

Phase 1, problems

- Utilization is low (one job at a time)
- No protection between jobs
  - But one job at a time, so?
- Short jobs wait behind long jobs
- Coordinating concurrent activities
- People time is still being wasted
- Operating Systems didn't really work
  - Birth of software engineering

Phase 2: 1970s

- Computers and people are expensive
  - Help people be more productive
- Interactive time sharing: let many people use the same machine at the same time
- Emergence of minicomputers
  - Terminals are cheap
- Persistence: Keep data online on fancy file systems

Unix appears

- Ken Thompson, who worked on MULTICS, wanted to use an old PDP-7 laying around in Bell labs
- He and Dennis Richie built a system designed by programmers for programmers
- Originally in assembly. Rewritten in C
  - In their paper describing unix, they defend this decision!
  - However, this is a new and important advance: portable operating systems!
- Shared code with everyone (particularly universities)

Unix (cont'd)

- Berkeley added support for virtual memory for the VAX
  - Unix BSD
- DARPA selected Unix as its networking platform in arpanet
- Unix became commercial
  - …which eventually lead Linus Torvald to develop Linux

Phase 3: 1980s

- Computers are cheap, people expensive
  - Put a computer in each terminal
  - CP/M from DEC first personal computer OS (for 8080/85) processors
  - IBM needed software for their PCs, but CP/M was behind schedule
  - Approached Bill Gates to see if he can build one
  - Gates approached Seattle computer products, bought 86-DOS and created MS-DOS
  - Goal: finish quickly and run existing CP/M software
  - OS becomes subroutine library and command executive

Phase 4: Networked/distributed systems--1990s to now?

- Its all about connectivity
- Enables parallelism but performance is not goal
- Goal is communication/sharing
  - Requires high speed communication
  - We want to share data not hardware
- Networked applications drive everything
  - Web, email, messaging, social networks, …

New problems

- Large scale
  - Google file system, mapreduce, …
- Parallelism on the desktop (multicores)
- Heterogeneous systems, IoT
  - Real-time; energy efficiency
- Security and Privacy

Phase 5

- New generation?

- Computing evolving beyond networked systems
  - Cloud computing, IoT, Drones, Cyber-physical systems, computing everywhere
  - But what is it?
  - …and what problems will it bring?

Where are we headed next?

- How is the OS structured? Is it a special program? Or something else?
  - How do other programs interact with it?

- How does it protect the system?
  - What does the architecture/hardware need to do to support it?

Why Start With Architecture?

- Recall: Key roles of an OS are
  1) Wizard: isolation and resource virtualization
  2) Referee: efficiency, fairness and security

- Architectural support can greatly simplify –or complicate– OS tasks
  - Easier for OS to implement a feature if supported by hardware
  - OS needs to implement everything hardware doesn‘t

- OS evolution accompanies architecture evolution
  - New software requirements motivate new hardware
  - New hardware features enable new software

Some questions to get you thinking

- What is the OS? Software?
- Is the OS always executing?
  - If not, how do we make sure it gets to run?
- How do we prevent user programs from directly manipulating hardware?

Sleeping Beauty Model

- Answer: Sleeping beauty model
  - Technically known as Controlled direct execution
  - OS runs in response to “events”; we support the switch in hardware
- Most of the time the OS is sleeping
  - Good! Less overhead
  - Good! Applications are running directly on the hardware