CS 370: OPERATING SYSTEMS
[INTRODUCTION]

Hiding in Plain Sight, the Operating System
Makes all you do possible
on toasters, tablets, PCs, or servers

With many a role
A referee, an illusionist, and the glue

Balancing competing needs,
resolving conflict, and targeted sharing

Be it
threading the concurrency needle
memory management, scheduling, or
circumventing deadlocks

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COMPUTER SCIENCE DEPARTMENT

COLORADO STATE UNIVERSITY

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Topics covered in this lecture

- Expectations
- Course Overview
- Introduction

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EXPECTATIONS

What it takes to succeed

- You are required to work at least **6-8 hours** per-week outside of class
  - Coding and reviewing material from class
- If you miss a lecture?
  - Add about 3 hours per missed lecture

Pitfalls to avoid?

- Believing that you can learn via osmosis
- **Missing lectures**
  - If you don't have the discipline to come to class, you are unlikely to have the discipline to catch up
- **Procrastinating**
  - Get started on the assignments early

Why attend lectures if all the slides are posted?

- Slides are only part of the story
  - They anchor the discussion
- Any field has a *language* associated with it
- People who have worked in an area for a long time speak the language
  - Sitting in classes helps you learn how to frame questions and responses
- Often there are surprising questions
  - Some of these may be asked by interviewers

Help me help you

- We will have **surveys** at the end of every class
- You will provide a list of
  - 3 concepts you followed clearly
  - 3 concepts you had problems keeping up with
- Problem areas for the majority of the class will be addressed in the next class

Interactions

- You can have discussions with me, the TAs, and your peers
- There are two constraints to these discussions
  - No code can be exchanged under any circumstances
  - No one takes over someone else's keyboard
- Bumps are to be expected along the way
  - But you should get over this yourself
  - It will help you with the next problem you encounter

Communications

- Please DO NOT use Canvas messaging for communications
  - Please send communications to **compsci_cs370@colostate.edu**
- The e-mail account is checked by the entire team and allows us to respond to communications in a timely fashion
- Send e-mails from accounts that match your name
  - **No pseudonyms please**
- Do not post code on the MS Teams Channel

You are not allowed to take learning opportunities away from other students

- If you must use a laptop or tablet (in the keyboard mode) you should
  - Sit in the last row
  - Turn off wireless
  - Sign and turn in pledge forms
  - Use it only for taking notes
- If you are using a tablet in the stylus/pencil-mode, you may sit anywhere in class; also, sign the pledge form
- When the class is in session, put away your cell-phones!
- Please no cross-talking when the class is in-session

Course webpage

- All course materials will be accessible via the public-facing webpage (**https://www.cs.colostate.edu/~cs370**)
  - Schedule (Lecture slide sets for each lecture)
  - Assignments
  - Syllabus
  - Grading
- Grades will be posted on **Canvas**; assignment submissions will be via Canvas
- The course website, MS Teams Channel, and Canvas are all live now

Office Hours: Details on course webpage

- Professor
  - Shrideep Pallickara
  - Fridays 3:00-4:00 pm in CSB-364 and via Zoom
  - Focused on **course concepts**
- TA Office hours focused exclusively on **programming assignments**
  - Office Hours: CSB-120 and MS Teams
  - GTAs: Richi Rodriguez, William Scarbro, and Anindya Chowdhury
  - UTAs: Matthew Maloney, Henry Gates, Cameron Suess, and Hamad Alyami

TA Office Hours: Almost Finalized

****All changes will be reflected on the course webpage**

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Richi Rodriguez	1:00-5:00 pm		4:00-8:00 pm	1:00-5:00 pm	2:00-5:00 pm	
William Scarbro	12:00-5:00 pm	1:00-5:00 pm	10:00 am - 3:00 pm	2:00-4:00 pm		
Anindya.Chowdhury	5:00-6:00 pm	2:00-6:00 pm	5:00-6:00 pm	2:00-6:00 pm	12:00-5:00 pm	
Matthew Maloney	3:000-6:00 pm		3:00-7:00 pm			1-4:00 pm
Henry Gates	4:00-7:00 pm		4:00-7:00 pm		4:00-7:00 pm	
Cameron Suess	11:00-noon	10:00-11:59 am	11:00-noon	10:00-11:59 am	10:00-1:00 pm	
Hamad Alyami	6:00-8:00 pm	7:00-8:00 pm	6:00-8:00 pm	7:00-8:00 pm	3:00-6:00 pm	

Topics that we will cover in CS 370

- Processes and Threads
- Process Synchronization (plus Atomic Transactions)
- CPU Scheduling: MFQ, CFS
- Deadlocks
- UNIX I/O
- Memory Management
- File System interface and management. Unix file system. NTFS.
- Storage Management including SSDs and Flash Memory
- Virtualization and Containers

Course Textbook

- *Operating Systems Concepts, 10th edition*
  Avi Silberschatz, Peter Galvin, and Greg Gagne Publisher - John Wiley & Sons, Inc.
  ISBN-13: 978-1119800361

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When I make slides, I usually refer to several texts. These include …

- *Andrew S Tanenbaum and Herbert Bos. Modern Operating Systems. 4th Edition, 2014. Prentice Hall. ISBN: 013359162X/ 978-0133591620*
- *Thomas Anderson and Michael Dahlin. Operating Systems: Principles and Practice, 2nd Edition. Recursive Books. ISBN: 0985673524/978-0985673529*
- *Remzi Arpaci-Dusseau and Andrea Arpaci-Dusseau. Operating Systems: Three Easy Pieces. 1st edition. CreateSpace Independent Publishing Platform. ISBN-13: 978-1985086593*
- *Kay Robbins & Steve Robbins. Unix Systems Programming, 2nd edition, Prentice Hall ISBN-13: 978-0-13-042411-2*
- I always list my references at the end of every slide set

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INFOSPACES (**https://infospaces.cs.colostate.edu**)

- **Knowledge repository** my lab has been building to enhance learning
- All videos are designed to be less than 2 minutes
- Improving INFOSPACES
  - Let us know what you would like to see
  - If you'd like to contribute to this repository let us know!

Plagiarism detection

- Use of generative AI (GitHub co-pilot, ChatGPT, Maude and their ilk) is expressly disallowed at stage (include ideation) for coding or the term project report
  - Will be considered plagiarism and cheating
- All programming assignments will be subject to pair-wise comparisons
  - Colluding, coping from the same source on the internet, and using paid-versions of GenAI for solutions will all be detected

GRADING

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Grading breakdown

- Assignments: 45%
  - 5 programming assignments (3 C, 1 Java, and 1 C++)
- Quizzes: 10%
- Mid Term: 20%
- Comprehensive Final Exam: 25%
- Two sets of extra credit (optional) opportunities
  - Programming Exercises: 1.5% in total
  - Page faults assignment: 2% in total

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Grading Policy I

- Letter grades will be based on the following standard breakpoints:
  - >= 90 is an A, >= 88 is an A-,
  - >=86 is a B+, >=80 is a B, >=78 is a B-,
  - >=76 is a C+, >=70 is a C,
  - >=60 is a D, and <60 is an F.
- I will not cut higher than this, but I *may* cut lower.
- There will be **no make-up exams**
  - Exceptions for extenuating circumstances with documentation

Grading Policy II

- Every assignment will be posted at least 2 weeks before the due date.
  - Every assignment will include information about how much it will count towards the course grade, and how it will be graded.
- Late submission penalty: 10% per-day for the first 2 days and a ZERO thereafter.
  - Detailed submission instructions posted on course website.
  - Programming assignments will be graded within 30-60 seconds of submission

For the Quizzes and Tests

- I will only ask questions about what I teach
  - If I didn't teach it, I won't ask from that portion
- If the concepts were covered in my slides
  - You should be be able to answer the questions
- I won't ask questions about arcane aspects of some esoteric device controller

Exams

- There will be one mid-term (20%)
- The final exam is comprehensive (25%)
- There will be 13 quizzes **in-class**
  - 3 quizzes where you had your lowest scores will be dropped
    - We will compute the average of your 10 highest scores
      - 10% of your course grade

Term project

- Team project
  - Team size is 2-3
- Based on the Raspberry Pi
  - Plus, a sensor and desktop: Released

Assignments schedule

	Release	Due Date
Programming Exercises [Extra Credit & Optional]	21-Jan	1/29, 2/5, and 2/12
HW1	21-Jan	5-Feb
HW2	29-Jan	19-Feb
HW3	5-Feb	26-Feb
HW4	19-Feb	12-Mar
HW5	24-Mar	16-Apr
Term Project	TP-D1	5-Feb
	TP-D2	26-Mar
	TP-D3	7-May
HW-Extra Credit [Optional]	2-Apr	23-Apr

ABOUT ME

About me

- I do research in the area of large-scale computing systems, Big Data, and GeoAI
- My research has been funded by agencies in the United States and the United Kingdom
  - These include the National Science Foundation, the Department of Homeland Security (including the *Long Range* program), the Environmental Protection Agency, the Department of Agriculture, the National Institute of Food & Agriculture, the National Endowment for the Humanities/Teagle and the U.K's e-Science program
  - Recipient of the National Science Foundation's CAREER Award
  - I direct the Center for eXascale Spatial Data Analytics and Computing (XSD) @ CSU [**https://spatial.colostate.edu**]

My research has been deployed in

- Urban sustainability
- Commercial internet conferencing systems
- Defense applications
- Precision Agriculture
- Earthquake sciences
- Epidemic modeling
- Healthcare
- Bioinformatics
- Brain Computer Interfaces
- High energy physics
- Visualizations

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OPERATING SYSTEMS: A BRIEF OVERVIEW

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A modern computer is a complex system

- Multiple processors and co-processors
- Main memory and Disks
- Keyboard, Mouse and Displays
- Network interfaces
- I/O devices

Why do we need Operating Systems?

- If every programmer had to understand how *all* these components work?
  - Software development would be arduous
- Managing all components and using them optimally is a challenge

Computers are equipped with a layer of software

- Called the **Operating System**
- Functionality:
  - Provide user programs with a better, simpler, cleaner model of the computer
  - Manage resources efficiently

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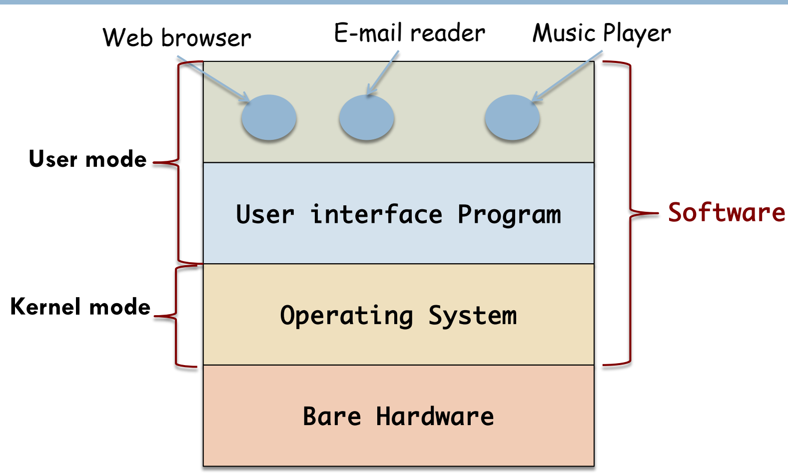
Where the operating system fits in [1/3]



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Where the operating system fits in [2/3]

- The OS runs on bare hardware in **kernel mode**
  - *Complete access* to all hardware
  - Can execute *any* instruction that the machine is capable of executing
- Provides the base for all software
  - Rest of the software runs in **user-mode**
    - Only a **subset** of machine instructions is available

Where the operating system fits in [3/3]

- Users interact with applications
  - Applications execute in an environment provided by the operating system
    - And the operating system mediates access to the underlying hardware

The application context is much more than a simple abstraction on top of hardware devices

- Applications execute in a virtual environment that is more **constrained** (to prevent harm)
- More **powerful** (to mask hardware limitations), and …
- More **useful** (via common services) than the underlying hardware

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The OS as an extended machine

- The **architecture** of a computer includes
  - Instruction set, memory organization, I/O, and bus structure
- The architecture of most computers at the machine language level
  - Primitive and awkward to program especially for I/O

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Let's look at an example of floppy disk I/O done using NEC PD765

- The PD765 has 16 commands
  - For reading and write data, moving the disk arm, formatting tracks, etc.
  - Specified by loading 1-9 bytes into the device register
- Most basic commands are for read and write
  - 13 parameters packed into 9 bytes
    - Address of disk block, number of sectors/track, inter-sector gap spacing etc.

But that's not the end of it …

- When the operation is completed
  - Controller returns 23 status and error fields packed into 7 bytes
- You must also check the status of the **motor**
  - If it is off? Turn it on before reading or writing
  - Don't leave the motor on for too long
    - Floppy disk will wear out
  - TRADEOFF: Long start-up delay *versus* wearing out disk

Of course, the average programmer does not want to have any of this

- What they would like is a simple, high-level **abstraction** to deal with
- For a disk this would mean a collection of named **files**
  - Operations include open, read, write, close, etc.
  - BUT NOT
    - Whether the recording should use frequency modulation
    - The state of the motor

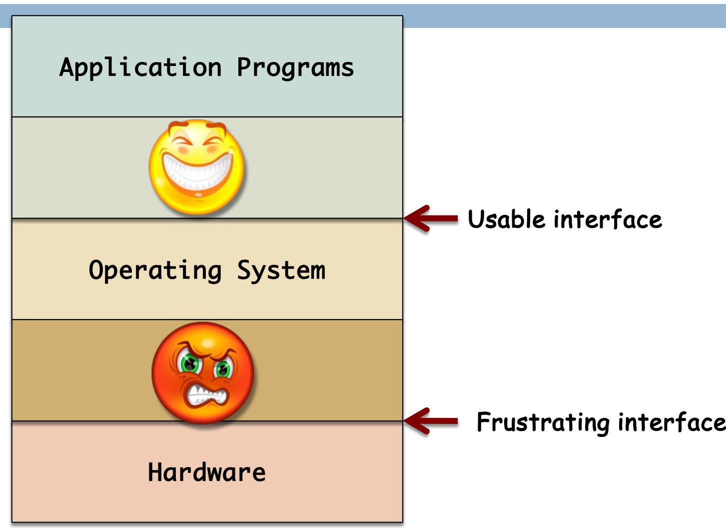
Why do processors, disks, etc. present difficult, awkward, idiosyncratic interfaces ?

- Backward compatibility with older hardware
- Desire to save money
- Sometimes hardware designers don't realize (or care) how much trouble they cause!

Why abstractions are important

- Abstraction is the key to managing **complexity**
- Good abstractions turn a nearly impossible task into two manageable ones
  1. Defining and implementing abstractions
  2. Using abstractions to solve problem
- Example
  - File

Operating systems turn frustrating hardware into usable interfaces



Roles of an Operating System

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The three roles of an Operating System

- **Referee**
  - Isolate applications from each other
- **Illusionist**
  - Provide an abstraction of physical hardware to simplify application design
  - Because applications are written to a higher level of abstraction, the OS can invisibly change the amount of resources assigned to each application
- **Glue**
  - Provides a set of common services to facilitate sharing among applications
  - As a result, *cut-and-paste* works uniformly across the system; a file written by one application can be read by another

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Referee: Facilitating resource sharing

- Provide **orderly** and **controlled** allocation of resources to programs competing for them
  - Processors, memories, and I/O devices

Referee: The OS a Resource Allocator

- An OS may receive numerous & conflicting requests for resources
  - Prevent errors and improper use
- Resources are scarce and expensive
- The OS allocates resources to specific programs and users
  - The allocation must be efficient and fair
  - Must increase overall system throughput
- Seemingly trivial differences in how resources are allocated can impact user-perceived performance

Referee: Providing isolation

- An operating system must protect itself and other applications from programmer bugs
  - Debugging would be vastly harder if an error in one program could corrupt data structures in other applications
- **Fault isolation** requires restricting the behavior of applications to less than the full power of the underlying hardware

Referee: Facilitating Communications

- The flip side of isolation is the need for **communication** between different applications and different users
- In setting up boundaries, an OS must also allow those boundaries to be crossed in **carefully controlled ways** when the need arises!

In its role as referee, an OS is like a particularly patient kindergarten teacher.
It balances needs, separates conflicts, and facilitates sharing.

The OS as an Illusionist: Masking Limitations

- **Physical constraints limit hardware resources** — a computer has only a limited number of processors and a limited amount of physical memory, network bandwidth, and disk
- Since the OS must decide how to *divide its fixed resources* among the various applications running at each moment …
  - A particular application can have differing amounts of resources from time to time, even when running on the *same* hardware

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The OS as a Glue: Providing Common Services

- Providing a set of common, standard services to applications to simplify and standardize their design
- The OS serves as an **interoperability layer** so that both applications and devices can evolve independently
- OSes provide a set of standard user interface widgets
  - Facilitates a common "look and feel" to users so that frequent operations — such as pull-down menus and "cut" and "paste" commands — are handled consistently across applications

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Defining Operating Systems

- Solves the problem of creating a usable computing system
  - Makes solving problems easier
- Control, allocate and mediate access to resources
- It is the one program that is running all the time: **kernel**

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A (VERY) BRIEF HISTORY OF OPERATING SYSTEMS

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The first true digital computer was designed by Charles Babbage (1792-1871)

- Spent most of his life and fortune trying to build the analytical engine
- Never got it working properly
  - Purely mechanical
  - Technology of the day could not produce wheels, cogs, gears to the required precision
- Did not have an operating system

Babbage realized he would need software for his analytical engine

- Hired Ada Lovelace as the worlds first programmer
  - Daughter of British poet Lord Byron
- The programming language Ada® is named after her

The First Generation (1945-55) Vacuum Tubes

- First fully functioning digital computer built at Iowa State University
  - Prof. John Atanasoff and grad student Clifford Berry
- All programming in absolute machine language
  - Also, by wiring up electrical circuits
    - Connect 1000s of cables to plug boards to control machine's basic functions
  - Operating Systems were unheard of
- Straightforward numerical calculations
  - Produce tables of sines, cosines, logarithms

The Second Generation (1955-1965): Transistors and Batch Systems

- **Separation** between designers, builders, operators, programmers, and maintenance
- Machines were called **mainframes**
- Write a program on paper, then punch it on cards
  - Give card deck to operator and go drink coffee
  - Operator gives output to programmer

The Third Generation (1965-1980) ICs and Multiprogramming

- Managing different product lines was expensive for manufacturers
  - Customers would start with a small machine, and then outgrow it
- IBM introduced the Systems/360
  - Series of **software-compatible** machines
  - All machines had the same instruction set
    - Programs written for one machine could run on all machines

The Fourth Generation (1980-Present) Personal Computers

- Large Scale Integration circuits (LSI)
  - Thousands of transistors on a square centimeter of silicon
- 1974: Intel came out with the 8080
  - General purpose 8-bit CPU
- Early 1980s IBM designed the IBM PC
  - Looked for an OS to run on the PC
  - Microsoft purchased Disk Operating System and went back to IBM with MS-DOS

The contents of this slide-set are based on the following references

- *Andrew S Tanenbaum and Herbert Bos. Modern Operating Systems. 4th Edition, 2014. Prentice Hall. ISBN: 013359162X/ 978-0133591620* [Chapter 1]
- *Avi Silberschatz, Peter Galvin, Greg Gagne. Operating Systems Concepts, 9th edition. John Wiley & Sons, Inc. ISBN-13: 978-1118063330.* [Chapter 1]
- *Thomas Anderson and Michael Dahlin. Operating Systems: Principles and Practice, 2nd Edition. Recursive Books. ISBN: 0985673524/978-0985673529. [Chapters 1-2]*
- *Kay Robbins & Steve Robbins. Unix Systems Programming, 2nd edition, Prentice Hall ISBN-13: 978-0-13-042411-2.* [Chapter 1]