CS370 Operating Systems

Colorado State University
Yashwant K Malaiya

Spring 2022

Slides based on

- Text by Silberschatz, Galvin, Gagne
- Various sources

CS370 Web site: https://www.cs.colostate.edu/~cs370

CS370: Operating Systems Colorado State University

[Home] [Syllabus] [Schedule] [Canvas]

Under revision for Spring 2022

Announcements: **Course Objectives:**
CS370 is a core undergraduate CS course. The objective of this course is to understand the broad range of issues that underlie the modern Operating Systems. We focus on key *concepts* and algorithms that are used in both commercial and open-source operating systems. This course will cover the following broad areas:

1. Operating systems - perspective, terminology, structure.
2. Processes, threads, concurrency and deadlocks
3. CPU Scheduling algorithms
4. Deadlocks and resource management
5. Memory - address translation and virtual memory
6. Storage architecture and File System
7. Virtual Machines, Containers and data centers

We may discuss advanced topics (security and reliability) and recent development based on time available.

Lecture Coordinates
Sec 002: Tu, Th 12:30-1:45 PM, Clark A 201
Sec 801: Lectures available 1-2 hours after on-campus lectures on Canvas

Help Sessions Lectures
Some Wed or Thurs 5:30-6:15 as scheduled

Instructors
Exapand email abreviation: C.E = colostate. edu
Yashwant Malaiya
Office: Room CSB 356
Office Hours: Wed 12:30 PM-1:30 PM, 3:30-4:30 PM
E-mail: malaiya at cs.C.E

Teaching Assistants

Graduate TA: Changsoo Jung
Changsoo.Jung at C.E
Hours: M,F 10-12AM Lab/Teams

Graduate TA: Varshik Chebrolu
Varshik.Chebrolu at C.E
Hours: T,Th 5-7PM Lab/Teams

Undergraduate TA: Blake Martin
Blake.Martin at C.E
Hours: 4-6PM Teams

Undergraduate TA: Joseph Riva
Joseph.Riva at C.E
Hours: W 1-3PM Teams

CS370: Operating Systems [Spring 2022] Colorado State University

[Home] [Syllabus] [Schedule] [Canvas]

Grading

The weights associated with different elements of the course are listed below.

Course Element	Weight
Assignments (programming/written)	25%
Quizzes & interaction (on-line and in-class)	20%
Mid Term	20%
Project	10%
Final	25%

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. We will not cut higher than this, but we *may* cut lower.

Syllabus

Prerequisites: CS165/CS200 with a C [2.0] or better, CS270 with a C [2.0] or better.

Required Texts **Instructors**

Avi Silberschatz, Peter Galvin, Greg Gagne.
Operating Systems Concepts, Edition 10e,
Wiley etext package
Publisher - John Wiley & Sons, Inc.
ISBN-13: 978-1119127482.

Responsibilities
Track Canvas, MS Teams and the schedule page of the course website daily. You are required to attend all lectures. Make sure that you refresh the web pages.
Ensure that you complete the quizzes and the homework assignments.
Use of any laptops, handheld devices or phones is not permitted. Exception for note-taking devices may be requested for special cases. The student must submit a pledge to use them only in the last row and use them only for taking class notes (which you need to submit every two weeks). Each instance of the unauthorized use of such devices may result in a penalty determined by the professor.

Policies for exams, quizzes and assignments:
The dates for all exams, excluding quizzes, will be announced. All quizzes will be online.

CS370: Web pages, Canvas, Teams

CS370: Operating Systems
[Spring 2022]

Colorado State University

[Home] [Syllabus] [Schedule] [Canvas]

Grading

The weights associated with different elements of the course are listed below.

Course Element	Weight
Assignments (programming/written)	25%
Quizzes & interaction (on-line and in-class)	20%
Mid Term	20%
Project	10%
Final	25%

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. We will not cut higher than this, but we *may* cut lower.

Syllabus

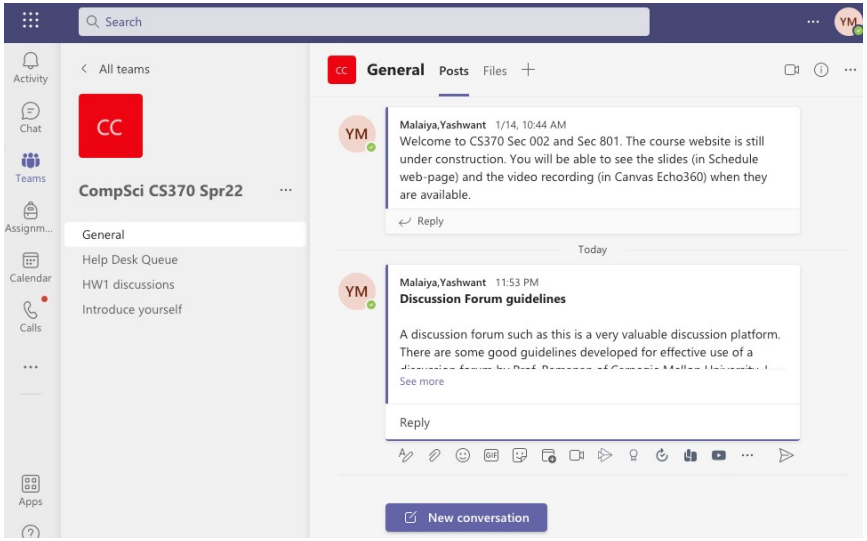
Prerequisites: CS165/CS200 with a C [2.0] or better, CS270 with a C [2.0] or better.

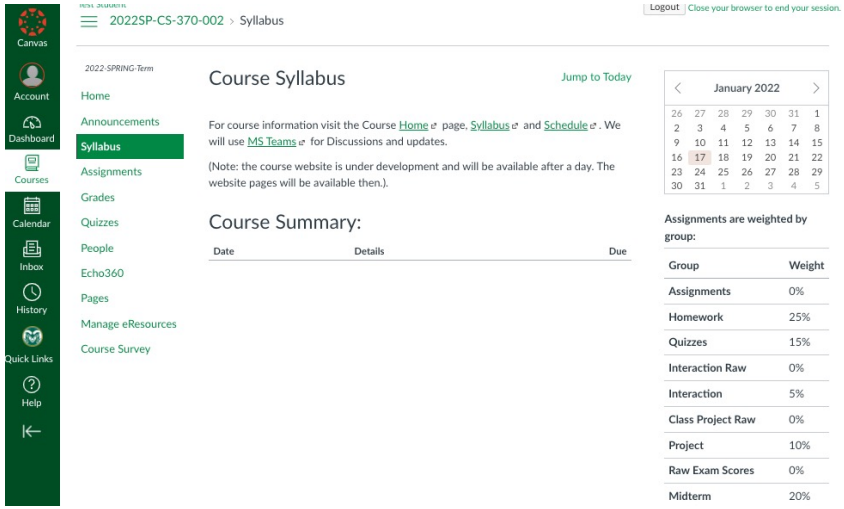
Required Texts **Instructors**

Avi Silberschatz, Peter Galvin, Greg Gagne.
Operating Systems Concepts, Edition 10e,
Wiley etext package
Publisher - John Wiley & Sons, Inc.
ISBN-13: 978-1119127482.

Responsibilities
Track Canvas, MS Teams and the schedule page of the course website daily. You are required to attend all lectures. Make sure that you refresh the web pages.
Ensure that you complete the quizzes and the homework assignments.
Use of any laptops, handheld devices or phones is not permitted. Exception for note-taking devices may be requested for special cases. The student must submit a pledge to use them only in the last row and use them only for taking class notes (which you need to submit every two weeks). Each instance of the unauthorized use of such devices may result in a penalty determined by the professor.

Policies for exams, quizzes and assignments:
The dates for all exams, excluding quizzes, will be announced. All quizzes will be online.





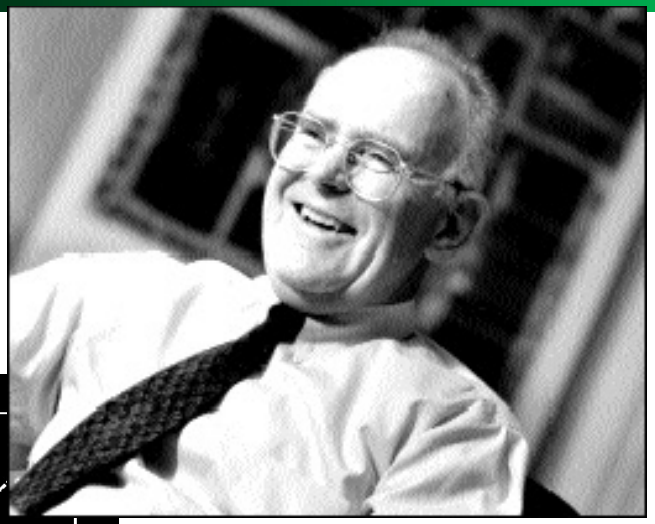
Colorado State University

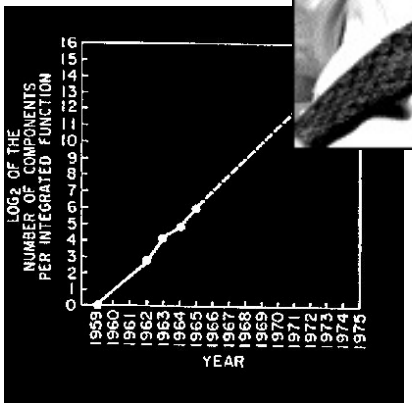
Operating Systems: What & Why

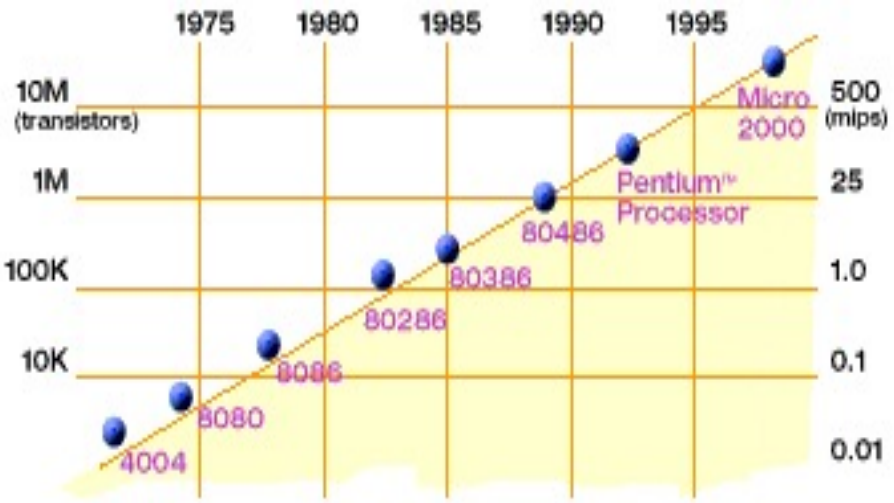
Operating Systems

- Part 1: How to do things
  - concurrently/in parallel
- Part 2: How to find stuff
  - Information in a many layered memory system
- Continued technological evolution
  - Techniques and challenges will evolve
  - Very high performance and capacity needed for modern applications: AI, Big Data

Technology Trends: Moore's Law







2X transistors/Chip Every 1.5 years

Called "Moore's Law"

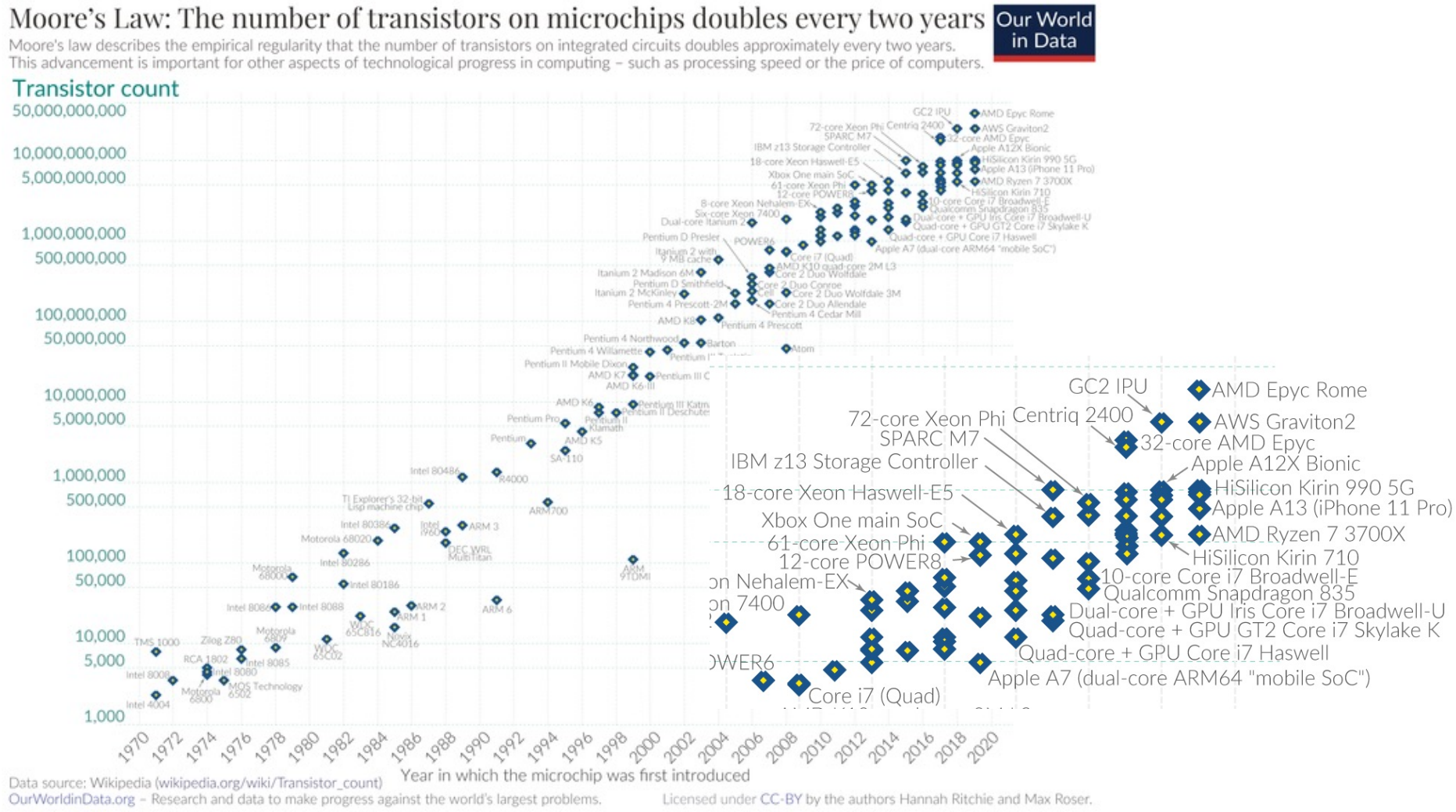
Gordon Moore (co-founder of Intel) predicted in 1965 that the transistor density of semiconductor chips would double roughly every 18 months.

Moore's law is dead? / not dead?

Microprocessors have become smaller, denser, and more powerful.

Colorado State University

Moore's Law



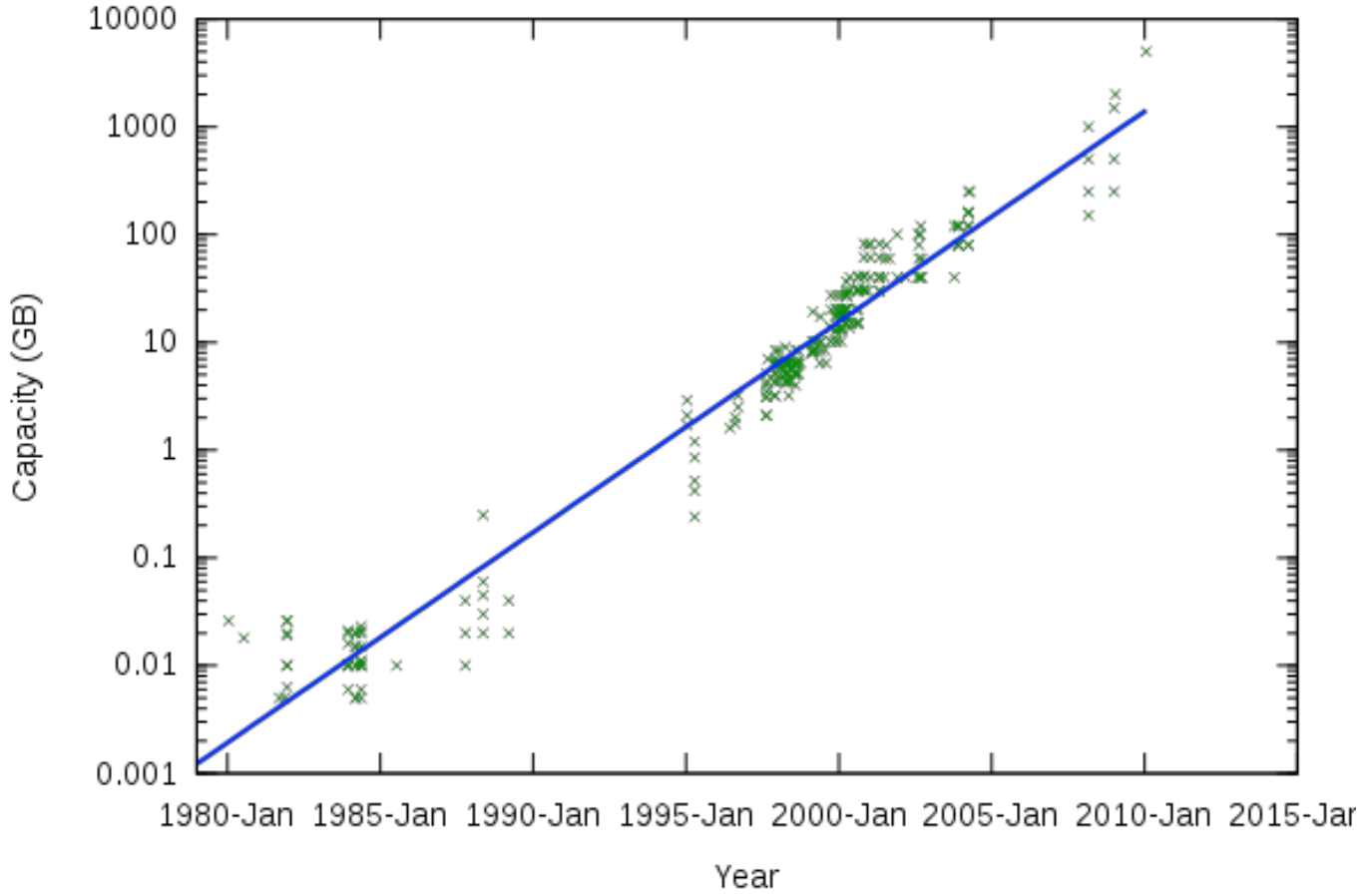
Colorado State University

Computer Performance Over Time

	1981	1997	2014	Factor (2014/1981)
Uniprocessor speed (MIPS)	1	200	2500	2.5K
CPUs per computer	1	1	10+	10+
Processor MIPS/$	$100K	$25	$0.20	500K
DRAM Capacity (MiB)/$	0.002	2	1K	500K
Disk Capacity (GiB)/$	0.003	7	25K	10M
Home Internet	300 bps	256 Kbps	20 Mbps	100K
Machine room network	10 Mbps (shared)	100 Mbps (switched)	10 Gbps (switched)	1000
Ratio of users to computers	100:1	1:1	1:several	100+

Anderson Dahlin 2014

Storage Capacity



- *Retail* hard disk capacity in GB

  (source: http://www.digitaltonto.com/2011/our-emergent-digital-future/)

Course Resources

- Microsoft Teams
  - Help Desk, discussions, announcements
- Canvas: Assignments, quizzes, submission, grades
  - Separate for sec 002 and sec 801!
  - Exams for non-local distance students
- Webpage http://www.cs.colostate.edu/~cs370
  - Home: Overview, contacts
  - Syllabus: Grading, Text, Responsibilities, Policies, Conduct
  - Schedule: Key dates, weekly schedules, slides, assignments, suggested readings
- Textbook: Avi Silberschatz, Peter Galvin, Greg Gagne, Operating Systems Concepts, Edition 10e

ABOUT ME: Yashwant K. Malaiya

- My Research approach
  - Explore what has not been examined
  - Concepts contributed: Antirandom testing, Detectability Profile, New Vulnerability Discovery models, new Software reliability models

Areas in which I have published:

- Computer security
  - Vulnerability discovery
  - Risk evaluation
  - Assessing Impact of security breaches
  - Vulnerability markets
- Hardware and software
  - Testing & test effectiveness
  - Reliability and fault tolerance
- Results have been used by industry, researchers and educators

About me: Yashwant K. Malaiya

- Teaching
  - Computer Organization (CS270) ,Operating systems (CS370)
  - Computer Architecture (CS470)
  - Fault tolerant computing (CS530), Quantitative Security (CS559)
- Professional
  - Organized International Conferences on Microarchitecture, VLSI Design, Testing, Software Reliability
  - Computer Science Accreditation: national & international
  - Professional lectures
  - Advised more than 65 graduate students ..

Contacting us

- Office hours, email addresses: Course website
- Instructors: use Teams/email

  Yashwant Malaiya (CSB 356)

  TAs, Office Hours on course website

  Changsoo Jung, Graduate TA Lab/Teams

  Varshik Chebrolu, Graduate TA Lab/Teams

  Blake Martin, Undergraduate TA Teams

  Joseph Riva, Undergraduate TA Teams
- e-mail: General email: cs370@cs.colostate.edu
  - The subject should start as **CS370: …**
- Teams: Discussions, Help Desk, Updates etc.
- Canvas: Quizzes, assignments, tests, grades, recordings

Topics we will cover in CS 370

- Processes
  - Processes and Threads
  - CPU Scheduling
  - Process Synchronization and Deadlocks
- Memory Management
  - Address translation
  - Virtual memory
- File System interface and management
  - Storage Management
  - File systems
- Virtualization
  - Data centers
  - Containers

Textbook

- Operating Systems Concepts, 10th edition

  Avi Silberschatz, Peter Galvin, and Greg Gagne

  etext package
- May also use materials from other sources including
  - Andrew S Tanenbaum, Modern Operating Systems
  - Thomas Anderson and Michael Dahlin, Operating Systems Principles & Practice
  - System Documentation, articles, news etc.

On the schedule page

- Topics that will be covered and the order in they will be covered
- Readings -chapters that I will cover
- May also see chapters mentions of other resources besides the textbook
- Schedule for when the assignments will be posted and when they are due
  - Subject to dynamic adjustment

Grading breakdown

- Assignments: 25%
  - Programming & written (note policies)
- Quizzes & interaction 20%
  - Weekend (Fri-Mon)
  - ICQ (Tu-Wed) for on-campus using iClicker Cloud
- Mid Term: 20%
- Project: 10%
- Final exam: 25%
- Midterm/final:
  - in classroom for Sec 002 & local Sec 801
  - Using canvas/Honorlock for non-local Sec 801

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.

- We will not cut higher than this, but I may cut lower.
- There will be no make-up exams
  - Except for documented
    - required university event
    - acceptable family or medical emergency

Grading Policy II

- Plan: Every programming assignment will be posted 7-14 days before the due date. Written assignments will be posted 6-7 days before due date.
  - Every assignment will include specifications and will indicate it will be graded.
- Late submission penalty: 20% off for the 24 hours and a ZERO thereafter.
- Detailed submission instructions included in the assignment sheets (see canvas)
- Plan: Assignments will be graded within 2 weeks of submission
- The two sections are separately graded classes with the same standards

What will Quizzes and Tests include?

- Questions about what we discuss, or ask you to study,
  - If I didn't teach it, I won't ask from that portion
  - Some on-line quiz questions about current state of technology may require you to search for an answer on the web
- If the concepts were covered in my lectures, slides or assignments
  - You should be able to answer the questions
  - You should be able to apply the concepts
- I will try to avoid questions about arcane aspects of some device controllers etc.

Exams & Assignments

- One mid-term
- The final exam is comprehensive, but more emphasis on the later part
- Quizzes: An on-line quiz every week Fri-Mon. ICQ interaction quizzes/feedback Tu-Wed.
- Programming (about 6) / written (1) assignments
- Occasional help-sessions Tues or Wed 5:30 PM Including coming week
  - Attend or view recordings (required)
- Self exercises: Do them yourselves

Term Project

- Group based
  - Second half of the semester
- Options:
  - Research paper on current/developing technology
    - Paper and presentation
    - Suggested topics will be announced
  - Development
    - IoT/Embedded system with sensor/communication
    - Design and evaluation needed
    - Demo and presentations

Electronic devices in lecture room

- Use of Laptops, phones and other devices are not permitted.
- Exception: only with the required pledge (see Canvas) that you will
  - Must have a reason for request
  - use it only for class related note taking, which must be submitted on 1st and 15th of each month.
  - not distract others, turn off wireless, last row
- Laptop use lowers student grades, experiment shows, Screens also distract laptop-free classmates
- The Case for Banning Laptops in the Classroom
- Laptop multitasking hinders classroom learning for both users and nearby peers

Be kind to everyone

- You will be courteous to fellow students, instructor and the teaching assistants
  - Classroom, outside, discussions on MS Teams
- Do not distract your peers
  - Turn microphones off unless needed

Help me help you

- Survey questions after each class (included in ICQ Exit Poll or Quizzes)
- You will provide a list of
  - 1-2 concepts you liked / followed clearly
  - 1-2 concepts you had problems with
- Questions of interest for the majority of the class will be addressed in the next class

Help Sessions

- Some Tues/Wed 5:30 – 6:15 PM,
- TAs will discuss key techniques and skills
  - Participation strongly encouraged
  - Slides and videos will be on the web site
  - You must be familiar with Help Session materials
- Coming week
  - C pointers, dynamic memory allocation
  - Needed for upcoming programming assignment

EXPECTATIONS

- You are expected to attend all classes.
- You must be present during the complete class
- Assignments & quizzes must be done by yourself individually. We will check.
- Expect to work at least 6-8 hours per week outside of class
  - Designing, coding and testing programs
  - Reviewing material from class
  - Do research for the project
- Concentrate in the class. The class have **many new terms and concepts**.

Expert view on How to get bad grades

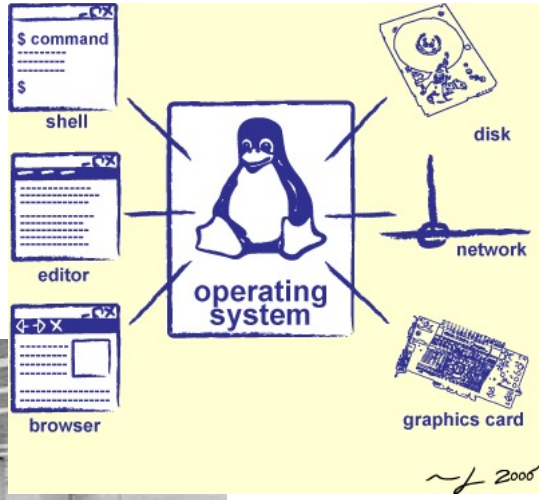
- Believing that you can learn via osmosis
- Missing lectures
  - "If you don't have the discipline to show up, you will most likely not have the discipline to catch up"
  - Procrastinating
- Get started on the assignments late. Note that they incorporate new concepts, including multiple processes and threads.

Interactions on Teams

- You must join Team CompSci CS370 Spring22
- You can have discussions with your peers, the Tas and the instructor
- But note
  - No code can be exchanged under any circumstances
  - No one takes over someone else's keyboard
  - No code may be copied and pasted from anywhere, unless provided by us
- Appropriate use

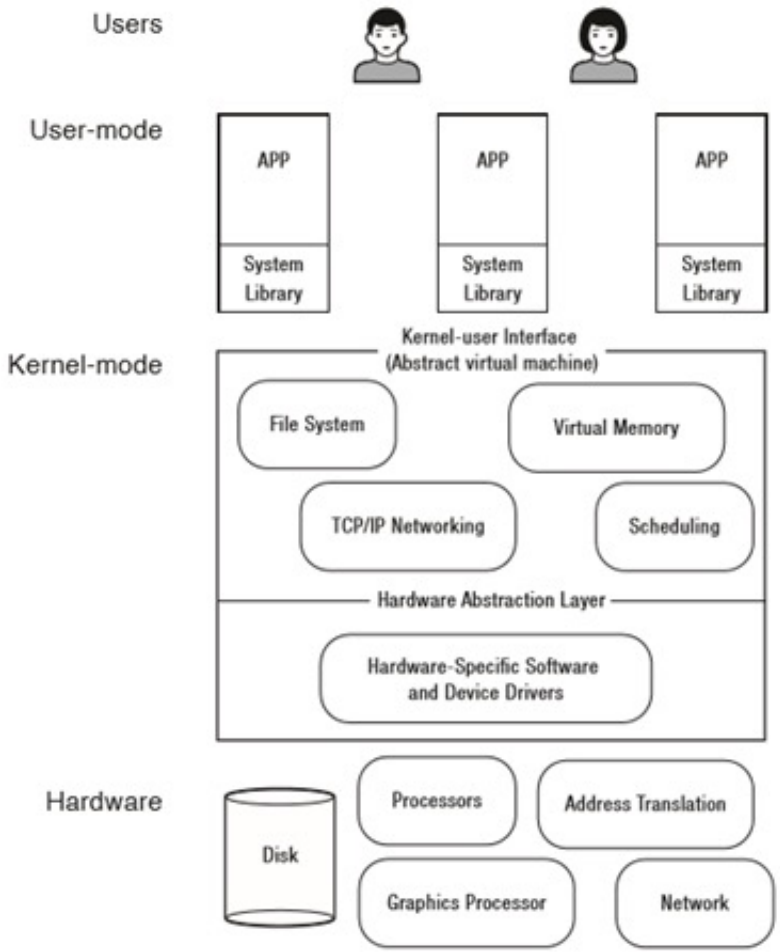
From Operator to Operating System

Switchboard Operator



Computer Operators

What is an Operating System?



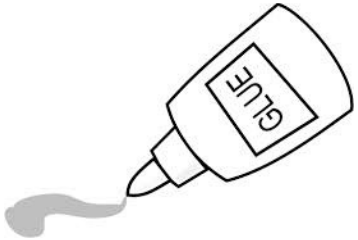
Introductions

- We will finish that in 2-3 lectures
- When I call your name,
  - Please enable your camera, and speak
    - your name,
    - where you are from (city, country)
    - Degree you are working for, area of interest

What is an Operating System?

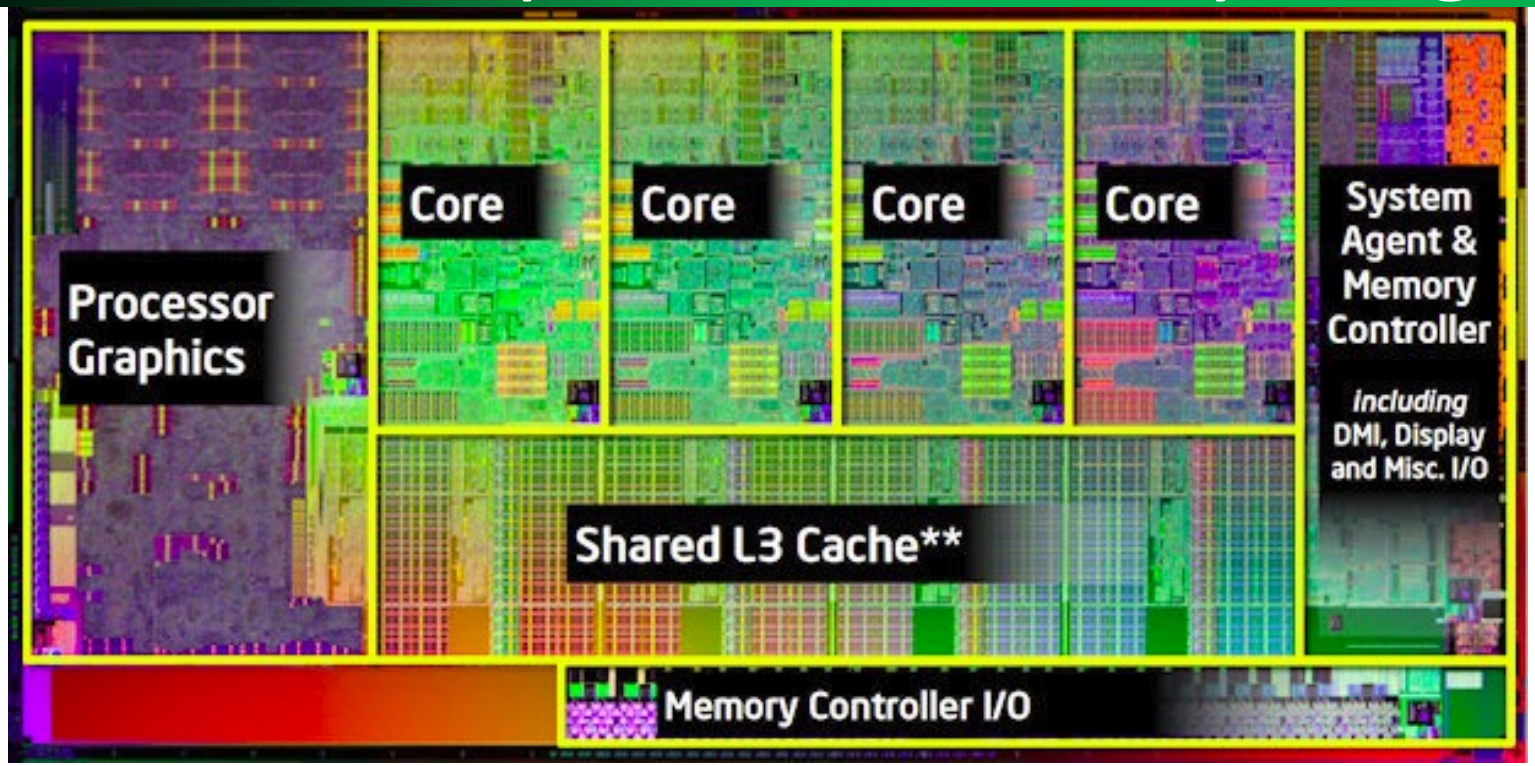
- Referee
  - Manage sharing of resources, Protection, Isolation
    - Resource allocation, isolation, communication
    - Isolation among threads, processes, users, virtual machines/containers

- Illusionist
  - Provide clean, easy to use abstractions of physical resources
    - Infinite memory, dedicated machine
    - Higher level objects: files, users, messages
    - Masking limitations, virtualization



- Glue
  - Common services
    - Storage, Window system, Networking
    - Sharing, Authorization
    - Look and feel

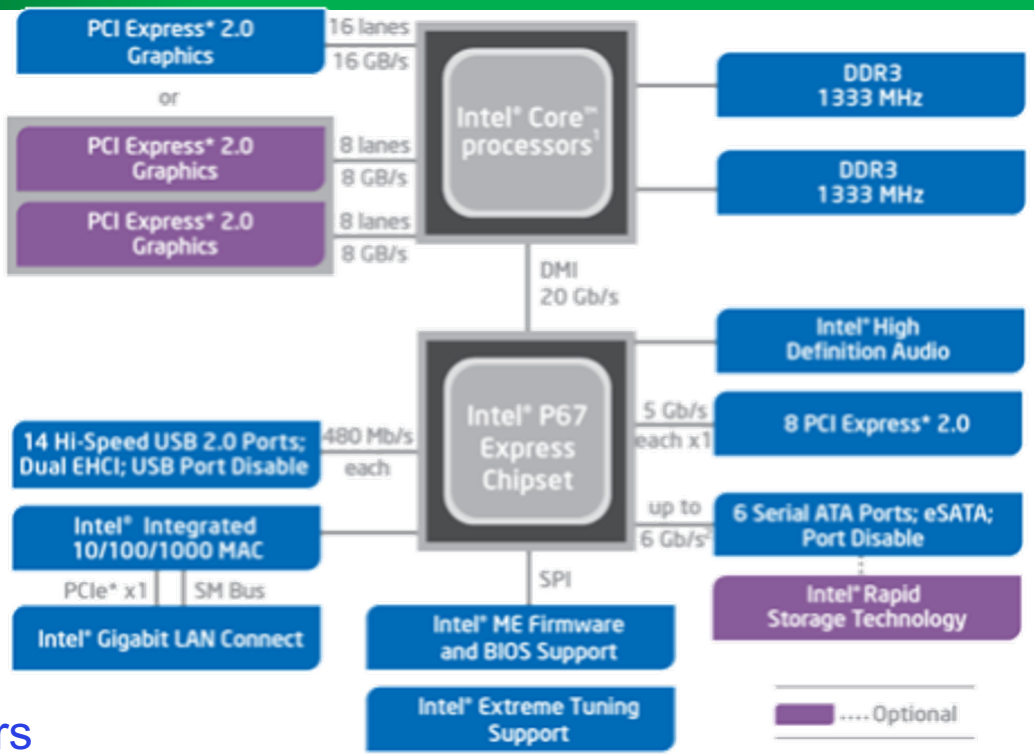
A Modern processor: SandyBridge

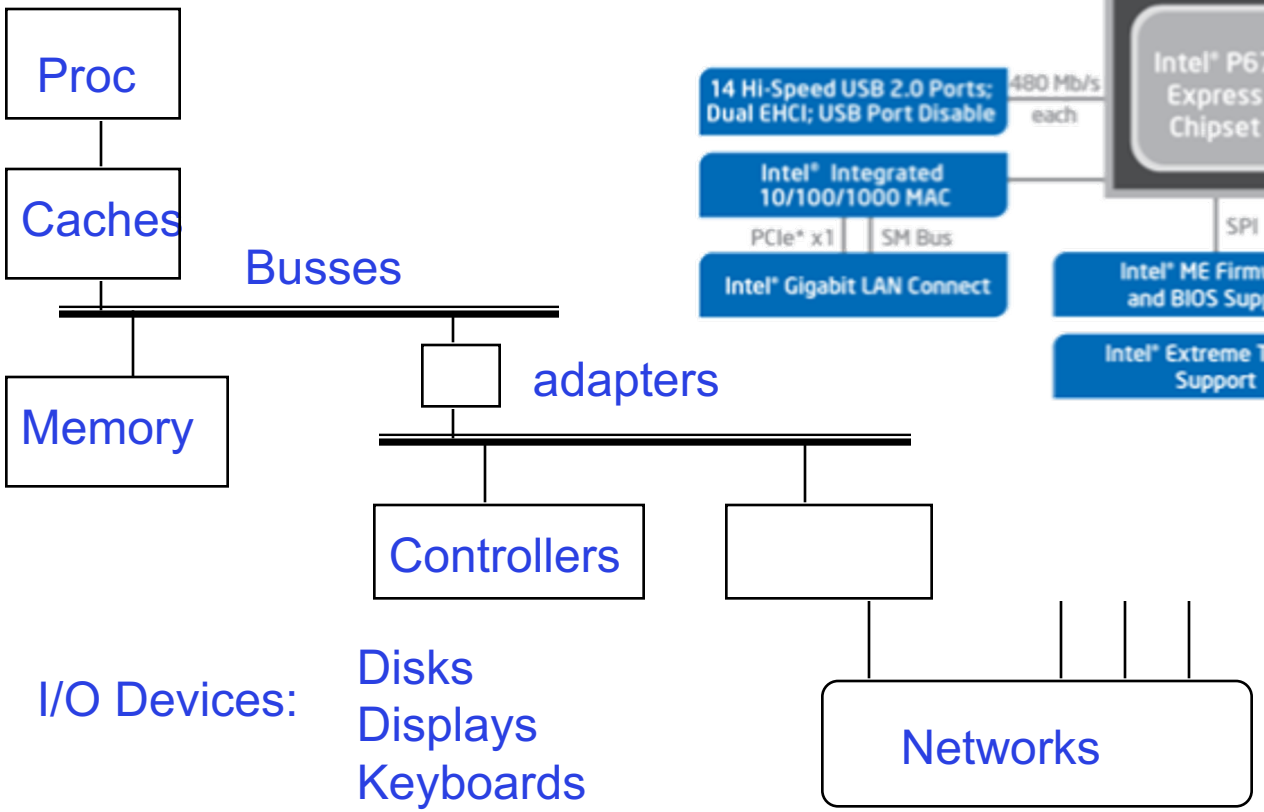


- Package: LGA 1155
  - 1155 pins
  - 95W design envelope
- Cache:
  - L1: 32K Inst, 32K Data (3 clock access)
  - L2: 256K (8 clock access)
  - Shared L3: 3MB – 20MB
- Transistor count:
  - 504 Million (2 cores, 3MB L3)
  - 2.27 Billion (8 cores, 20MB L3)

Functionality comes with great complexity!

SandyBridge I/O Configuration





Colorado State University

Short History of Operating Systems

- One application at a time
  - Had complete control of hardware
- Batch systems
  - Keep CPU busy by having a queue of jobs
  - OS would load next job while current one runs
- Multiple programs on computer at same tim
  - Multiprogramming: run multiple programs at seemingly at the "same time"
  - Multiple programs by multiple or single user
- Multiple processors in the same computer
- Multiple OSs on the same computer

1960s 80286 (1984)

Dual core 2004

Vt-x 2005

Colorado State University

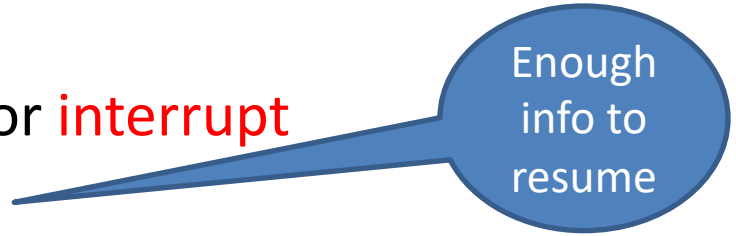
One Processor One program View

Early processors (LC-3 is an example)

- Instructions and data fetched from Main Memory using a program counter (PC)
- Traps and Subroutines
  - Obtaining address to branch to, and coming back
  - Using Stack Frames for holding
    - Prior PC, FP
    - Arguments and local variables
- Dynamic memory allocation and heap
- Global data

One Processor One program View

- External devices: disk, network, screen, keyboard etc.
- Device interface: Status and data registers
- User and Supervisor modes for processor
- I/O
  - Device drivers can use polling or interrupt
  - Interrupts need *context switch*
  - I/O done in supervisor mode
  - System calls invoke devise drivers



What a simple view doesn't include

- Cache between CPU and main memory
  - Makes the main memory appear much faster
- Direct memory access (DMA) between Main Memory and Disk (or network etc)
  - Transfer by blocks at a time
- Neglecting the fact that memory access slower than register access
- Letting program run *concurrently* (Multiprogramming) or with many threads
- Multiple processors in the system (like in Multicore)
- Multiple OSs in the same system

Information transfer in a system

- CPU Registers – (Caches) - Memory
  - CPU addresses memory locations
  - Bytes/words at a time
  - We will see some details
- Memory – (Controllers hw/sw) - external devices
  - Chunks of data
  - External devices have their own timing
    - DMA with interrupts
  - Disk is external!

Acknowledgments

- Past CS370 instructors, specifically Shrideep Pallickara, GTAs, UTAs and students for contributions to the class including ideas, materials and methods