CS370 Operating Systems

Colorado State University
Yashwant K Malaiya
Fall 2024

Slides based on
- Text by Silberschatz, Galvin, Gagne
- Various sources

CS370: Operating Systems — **Colorado State University**

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Under revision for Fall 2024

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 001: Tu, Th 2-3:15 PM, Biology 136
Sec 801: Lectures available 1-2 hours after on-campus lectures on Canvas

Help Sessions Lectures
TBD (Perhaps some Wed or Thurs 5:30-6:15 as scheduled)

Instructors
Expand email abreviation: C.E = colostate. edu
Yashwant Malaiya
Office: Room CSB 356
Office Hours: TBD
E-mail: malaiya at cs.C.E

Teaching Assistants
Graduate TA: Md Nazmul Islam
mdnazmul.islam at C.E
Hours: TBD

Graduate TA: Anindya Roy Chowdury
anindya.chowdhury at C.E
Hours: TBD Lab/Teams

Undergraduate TA: Jeff Jernberg
Jeff.Jernberg at C.E
Hours: TBD Teams

Undergraduate TA: Kedrick Kinsella
Kedrick.Kinsella at C.E
Hours: TBD Teams

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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, CS250 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.

You must bring your smartphone with the iClicker app every day. You must register your iClicker on Canvas before the beginning of the second week of classes. Unregistered iCliker scores after that will not be taken into account. The phone cannot be used for any other purpose during the lecture. You must be in the class for the full lecture for any possible in-class quizzes. Showing up late just for the iClicker quiz or leaving soon after is disruptive and there is a substantial penalty.

Policies for exams, quizzes and assignments:
The dates for all exams will be announced. There are weekly online quizzes. No collaboration of

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Important Dates:

Aug 20, 2024	First class
Oct 8, 2024	Midterm
Nov 26, 28 2024	Fall Break
S001, local S810: Thurs Dec 12, 9:40-11:40 AM	
S801(non-local): Window Dec 12 9:40-Dec 13 11:40 Comprehensive Final Exam AM	
Dec 17, 2024	Course Letter Grades will be available

Key to Notation
Readings will be from the *Operating Systems Concepts* book by Silberschatz, Galvin, and Gagne 10th edition. John Wiley & Sons, Inc. ISBN-13: 978-1119456339. [SCG]

Additional Useful References
Andrew S Tanenbaum and Herbert Bos. *Modern Operating Systems*. 4th Edition, 2014. Prentice Hall.
ISBN: 013359162X/978-0133591620. [AT]
Operating Systems Principles & Practice (2nd Edition, 2014). Thomas Anderson and Michael Dahlin. Recursive Bc
0985673524/978-0985673529[AD]
Kay Robbins & Steve Robbins. *Unix Systems Programming*, 2nd edition, Prentice Hall
ISBN-13: 978-0-13-042411-2. [RR]
C Programming Language (2nd Edition). Brian W. Kernighan and Dennis M. Ritchie.
Prentice Hall. ISBN: 0131103628/978-0131103627
Concurrent Programming in Java(TM): Design Principles and Pattern (2nd Edition).
Doug Lea. Prentice Hall. ISBN: 0201310090/978-0201310092.

Schedule

Tentative, subject to change. Lecture notes and are posted when only when they are available. The Help Session vid
slides are available when they are ready.

Week	Date	Topic	Assignments	Readings
W1	Aug 20, 22	**Introduction** Lecture 1 (8/20) Lecture 2 (8/22)	Quiz 1	Ch {1} [SGG], Ch {1} [RR] Ch {1} [AD] Ch {1} [AT] Patt & Patel sec {10.2}
W2	Aug 26, 28	**OS Structures, Processes** Lecture 3 (08/26)	Quiz 2	Ch {2,3} [SGG] Ch {2} [AT] Ch {2} [AD]

CC **General**   Posts   Files   +

Let's get the conversation started
Try @mentioning a student or teacher to begin sharing ideas.

August 16, 2022

Malaiya, Yashwant 8/16, 6:48 PM
Welcome to CS370 Sec 002 and Sec 801. The course website is still under construction. You will be able to see the slides (in Schedule web-page) and the video recording (in Canvas Echo360) when they are available.

↵ Reply

August 19, 2022

Malaiya, Yashwant 8/16, 6:50 PM
On-campus students: we will use iClicker Cloud. Please download and setup the app on your phone (not applicable to online students).

Please use your correct student ID and email address used for registering in the class, otherwise iClicker cloud will not recognize you. Please do note use two different iClicker logins with different email addresses. That will cause problems that are very hard to fix.

See less

▾ Collapse all

Encarnacion, Benito 8/18, 11:30 AM
What might the name of the class on iClicker be? I'm searching for it through CSU but can't seem to get any results.

Malaiya, Yashwant 8/19, 4:28 PM
I have just set it up. Try "Operating Systems".

Malaiya, Yashwant 8/19, 4:43 PM
In case you need it go to join.iClicker.com and use code, BS16Y

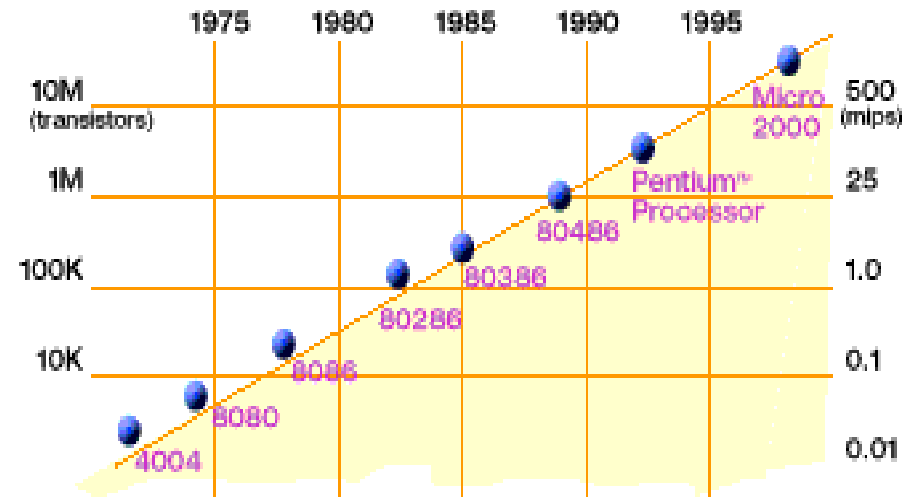**Colorado State University**

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

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Technology Trends: Moore's Law

2X transistors/Chip Every 1.5 years
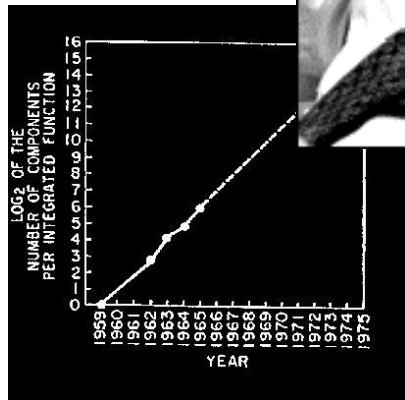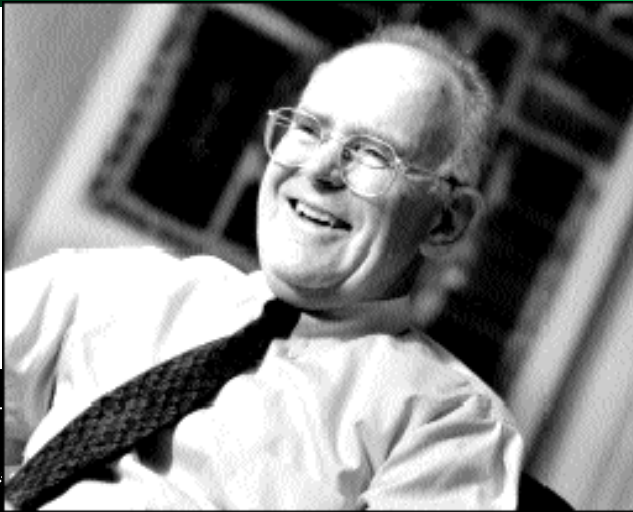
Called "[Moore's Law]"

Gordon Moore (co-founder of Intel) predicted in 1965 that the transistor density of semiconductor chips would double roughly every 18 months.
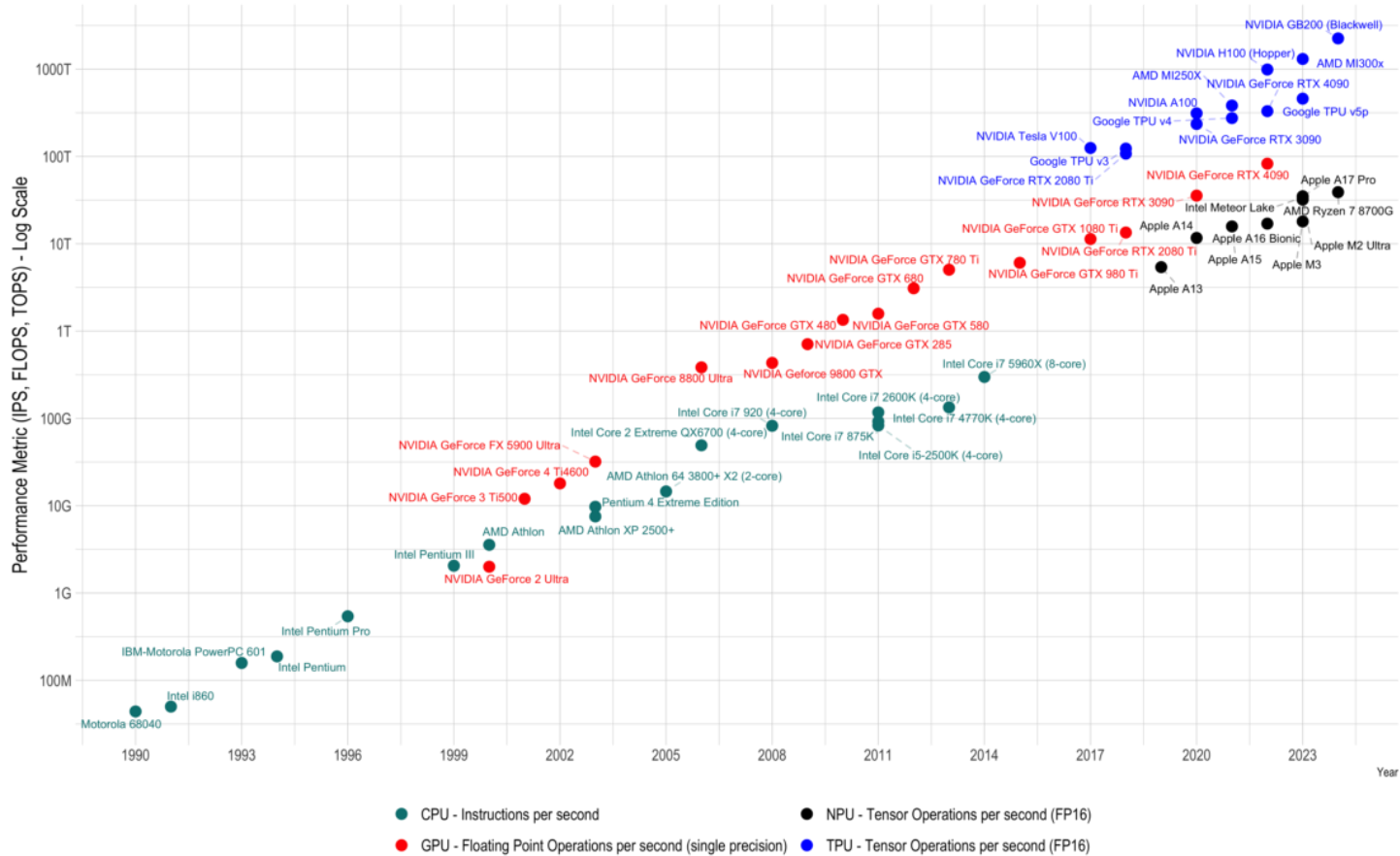
Microprocessors have become smaller, denser, and more powerful.

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Moore's law is dead? / not dead?

CPU, GPU, TPU and NPU performance throughout history

https://factored.ai/nvidia-ai-hardware-race/

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

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Storage Capacity
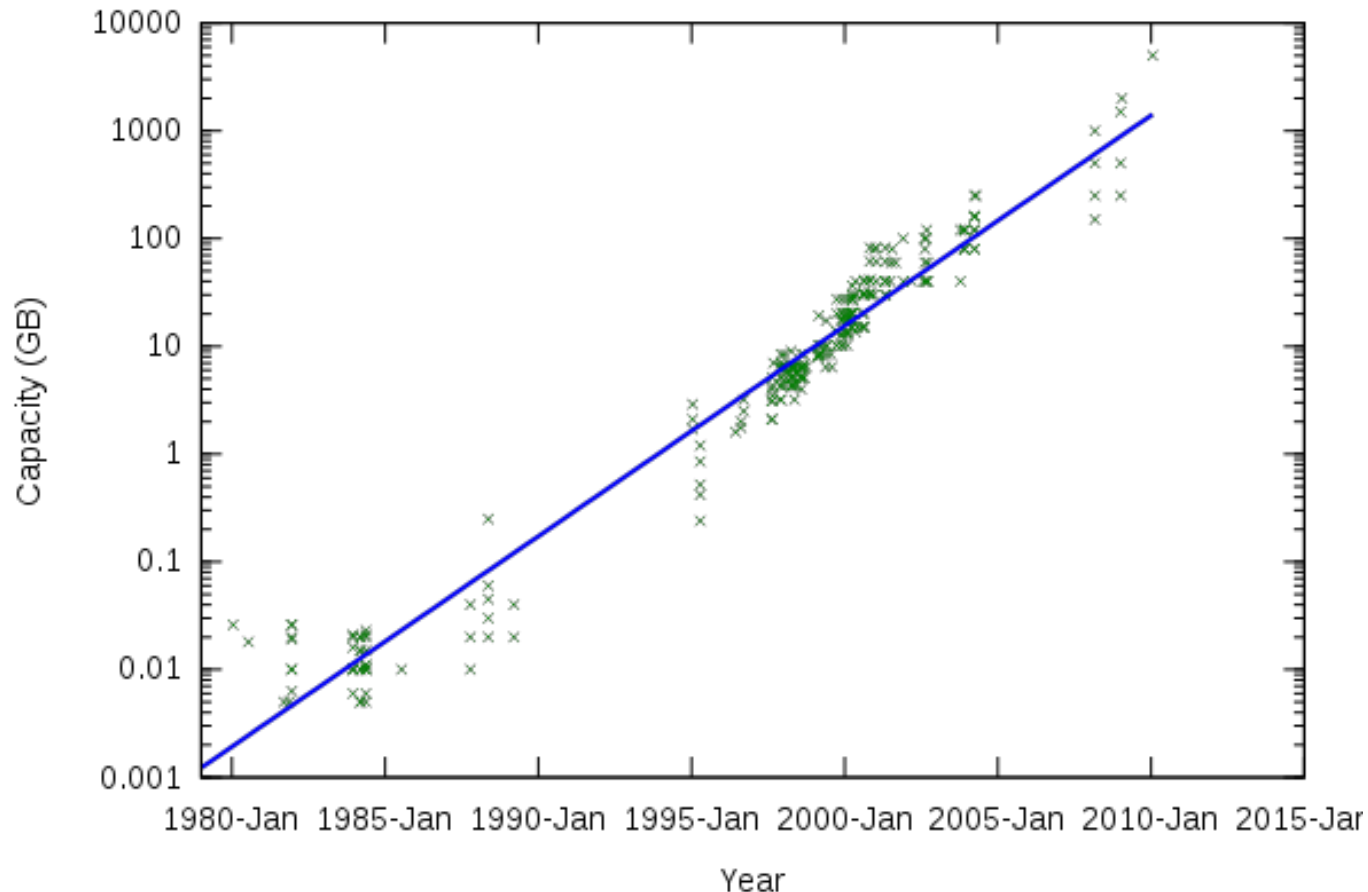
- *Retail* hard disk capacity in GB
  (source: http://www.digitaltonto.com/2011/our-emergent-digital-future/)

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Course Resources

- Microsoft Teams
  - Help Desk, discussions, announcements
- Canvas: Assignments, quizzes, submission, grades
  - Separate for sec 001 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

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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

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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 ..

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Contacting us

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

    Yashwant Malaiya (CSB 356)

- TAs: Office Hours on course website (MS Teams and Lab)

    Md Nazmul Islam, Graduate TA

    Anindya Roy Chowdury, Graduate TA

    Jeff Jernberg, Undergraduate TA

    Kedrick Kinsella, Undergraduate TA Teams

    - The subject should start as **CS370: …**

- Teams: Discussions, Help Desk, Updates etc.
- Canvas: Quizzes, assignments, tests, grades, recordings

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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

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Textbook

- Operating Systems Concepts, 10th edition

  Avi Silberschatz, Peter Galvin, and Greg Gagne

  etext package or zyBook

- 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.

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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

- Help sessions (one for each programming assignment)

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Grading breakdown

- Assignments: 25%
  - Programming & written (note policies)
- Quizzes & interaction 20%
  - Weekend (Fri-Mon)
  - ICQ daily for on-campus using iClicker Cloud
- Mid Term: 20%
- Project: 10%
- Final exam: 25%
- Midterm/final: Using canvas/Respondus Lockdown Browser
  - in classroom: for Sec 001 & local Sec 801
  - for non-local Sec 801 remote online

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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.

- 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

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Grading Policy II

- Plan: Every programming assignment will be posted 10-14 days before the due date. A 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: 10% off per day for two days 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 overall standard

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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.

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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 daily
- Programming (about 6) / written (1) assignments
- Occasional help-sessions late afternoons
  - Attend or view recordings (required)
- Self exercises: Do them yourselves

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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

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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](#)

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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

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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

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Help Sessions for Programing Assignments

- Some afternoons (perhaps 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

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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
  - Reviewing material from class
  - Designing, coding and testing programs
  - Do research for the project

- Concentrate in the class. The class have **many new terms and concepts**.

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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"
  - You will miss concepts needed in following lectures

- Get started on the assignments late. Note that they incorporate new concepts, including multiple processes and threads.
  - TA help limited to 10 minutes during the last two days

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Interactions on Teams

- You must join Team CompSci CS370 Fall24
- 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
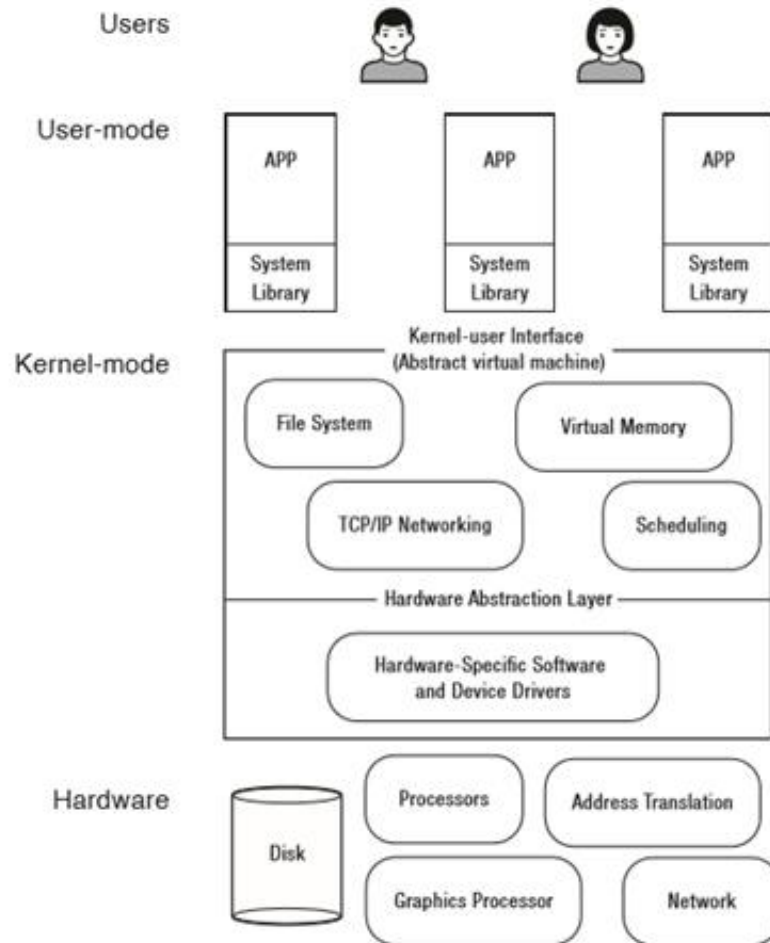
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Switchboard Operator

©UCB

Computer Operators

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What is an Operating System?

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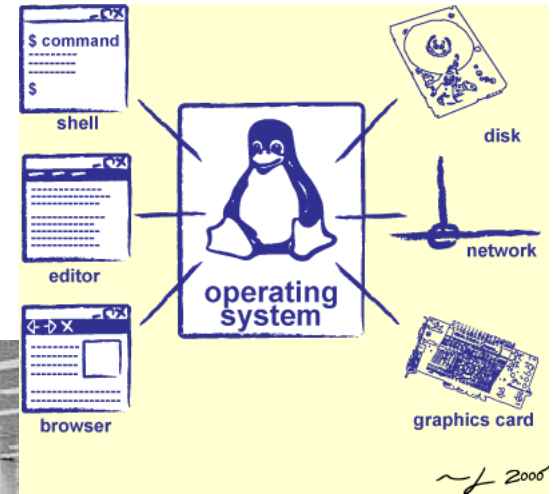
Introductions

- 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)
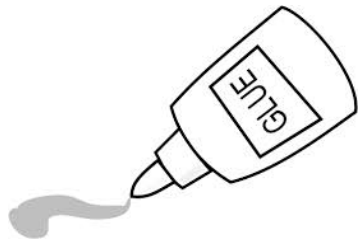   - Degree you are working for, area of interest

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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

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Traditional Computer

- CPU: fetches, interprets and executes machine instructions
  - Has some registers that hold data, addresses, instructions
  - Modern computers have multiple CPUs (cores)

- Memory (ROM, RAM): holds instructions, data
  - Caches to make them faster

- I/O ports: access to external devices: printer, network
  - Connected using different types of buses

- Storage (Disk etc): holds instructions, data

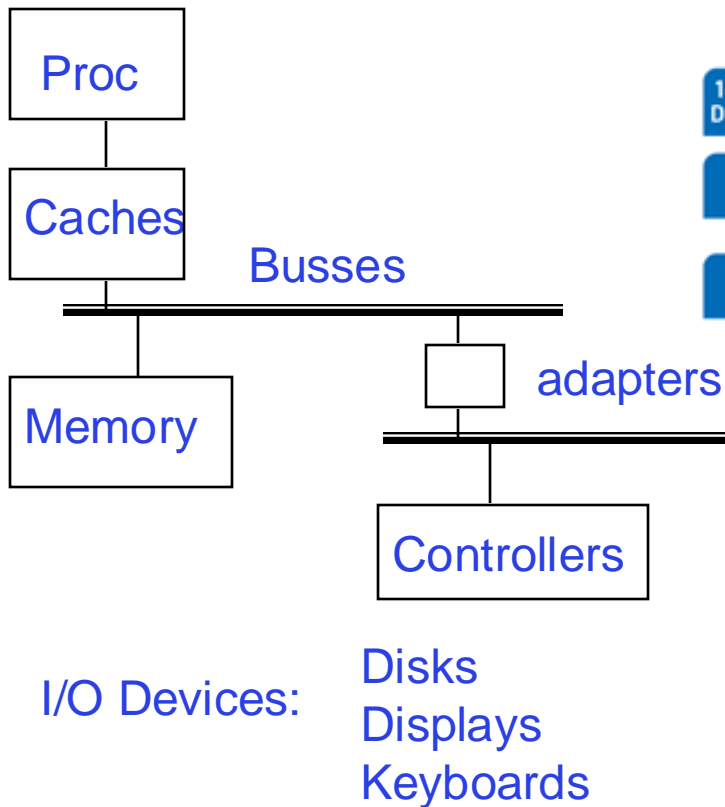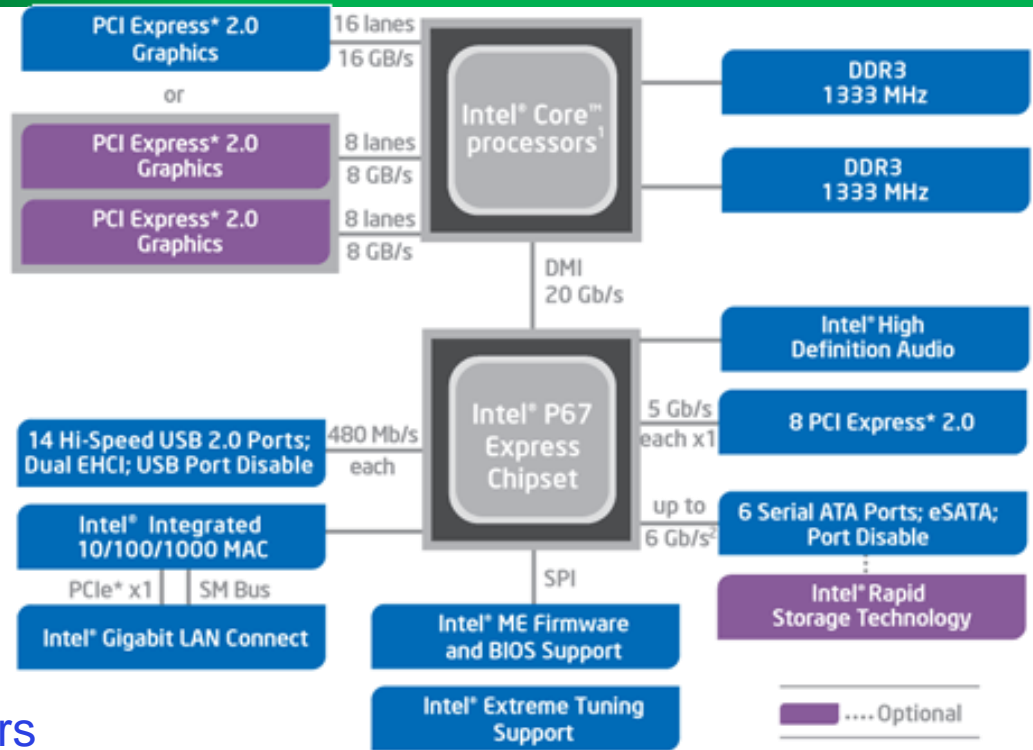**Colorado State University**

A Modern CPU Chip
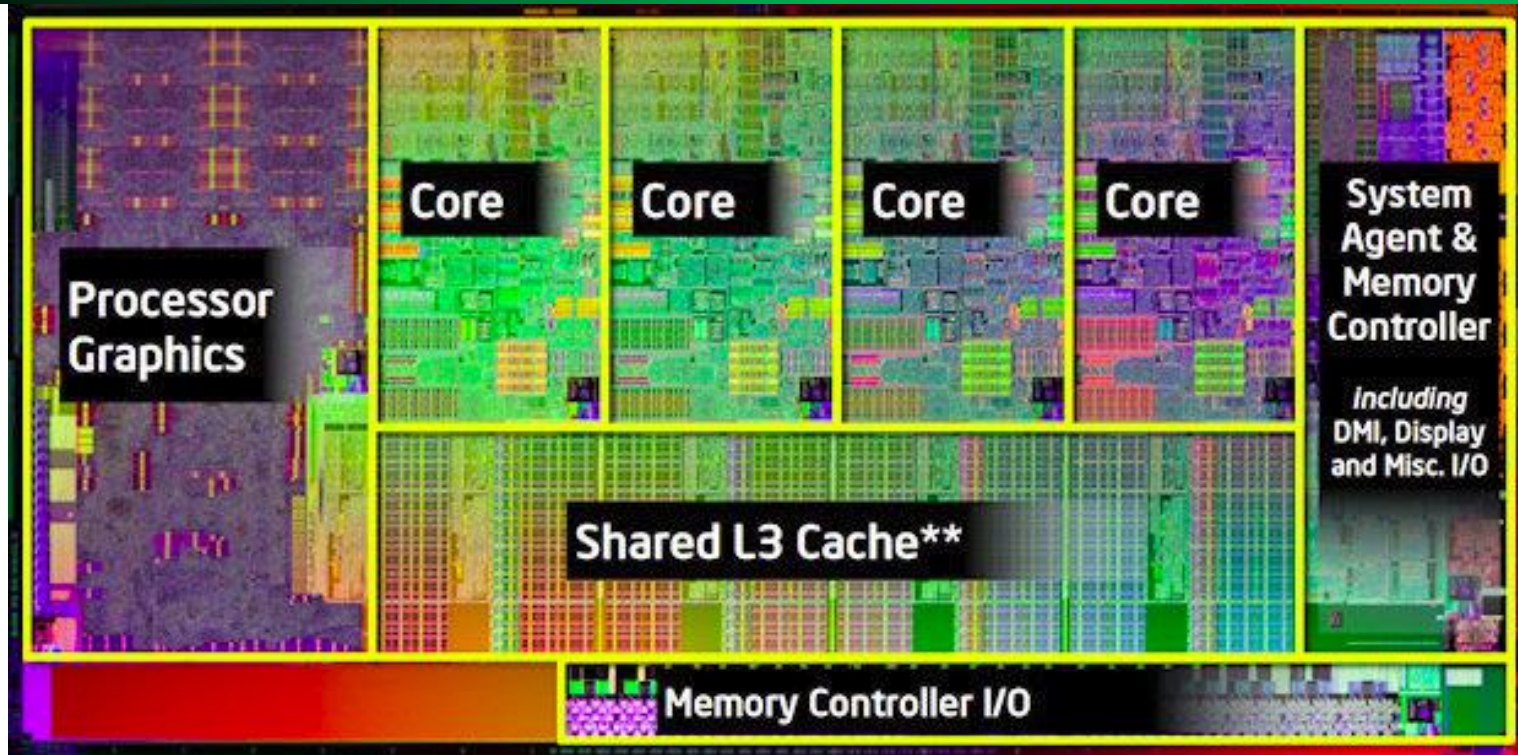
- Package: LGA 1155
  - 1155 pins
  - 95W design envelope
- Cache:
  - L1: 32K Inst, 32K Data (3 clock access)
  - L2: 256K (8 clock access)
  - Shared L3: 3MB – 20MB

- Transistor count:
  - 504 Million (2 cores, 3MB L3)
  - 2.27 Billion (8 cores, 20MB L3)

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Functionality comes with great complexity!

SandyBridge I/O Configuration

Proc

Caches

Busses

Memory

adapters

Controllers

I/O Devices:
Disks
Displays
Keyboards

Networks

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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 time
  - 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

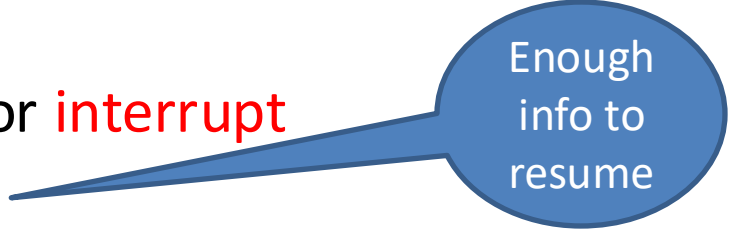**Colorado State University**

One Processor One program View

Simple view of a processor:

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

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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

Enough info to resume

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

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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**
  - Locks of data
  - External devices have their own timing
    - DMA (direct memory access) with interrupts
 - Disk is external!

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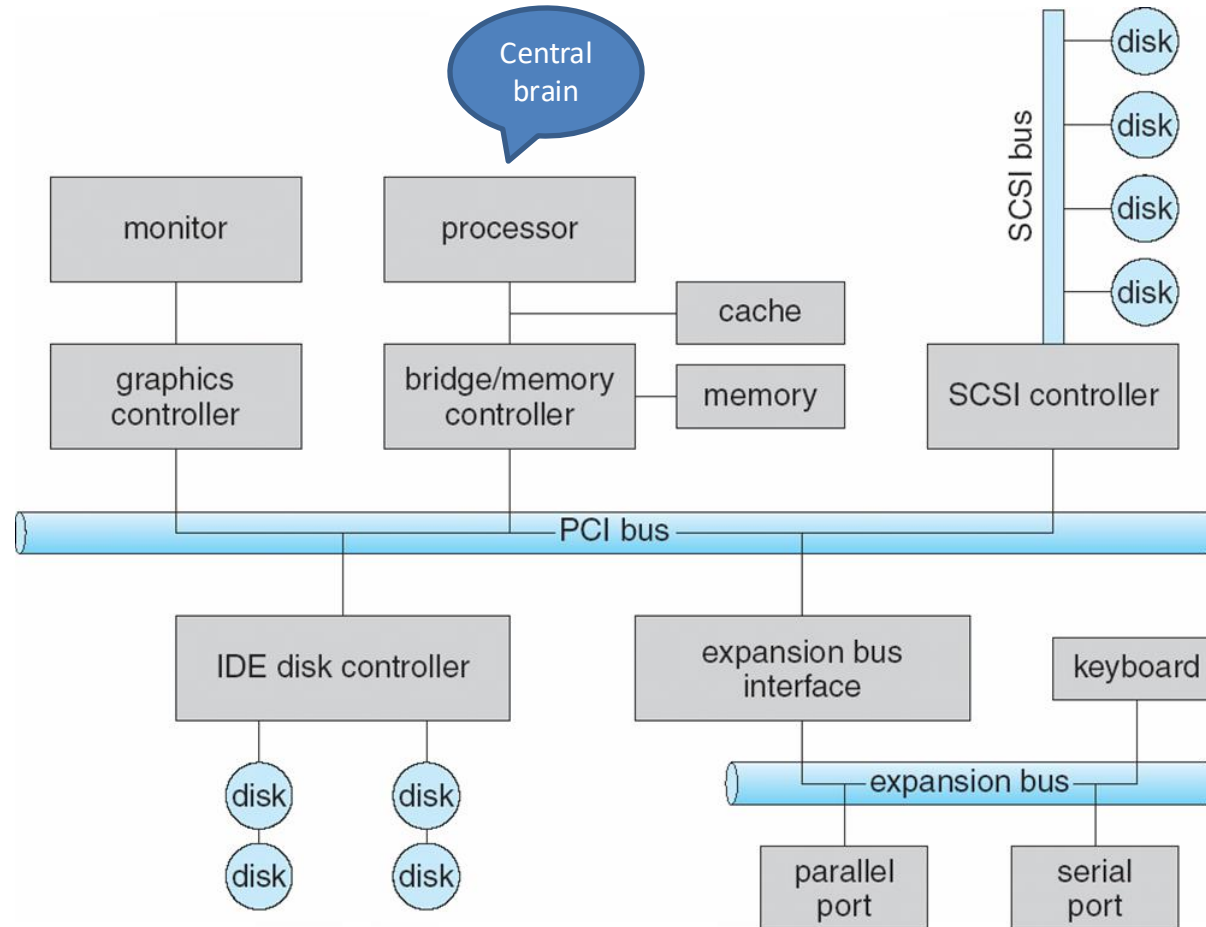
I/O Hardware (Cont.)

- I/O Devices have associated registers where device driver places commands, addresses, and data
  - Data-in register, data-out register
  - status register, control register
  - Typically, 1-4 bytes, or FIFO buffer
- Devices have associated addresses, used by
  - Direct I/O instructions
  - Memory-mapped I/O
    - Device data and command registers mapped to processor address space

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I/O Transfer rates MB/sec

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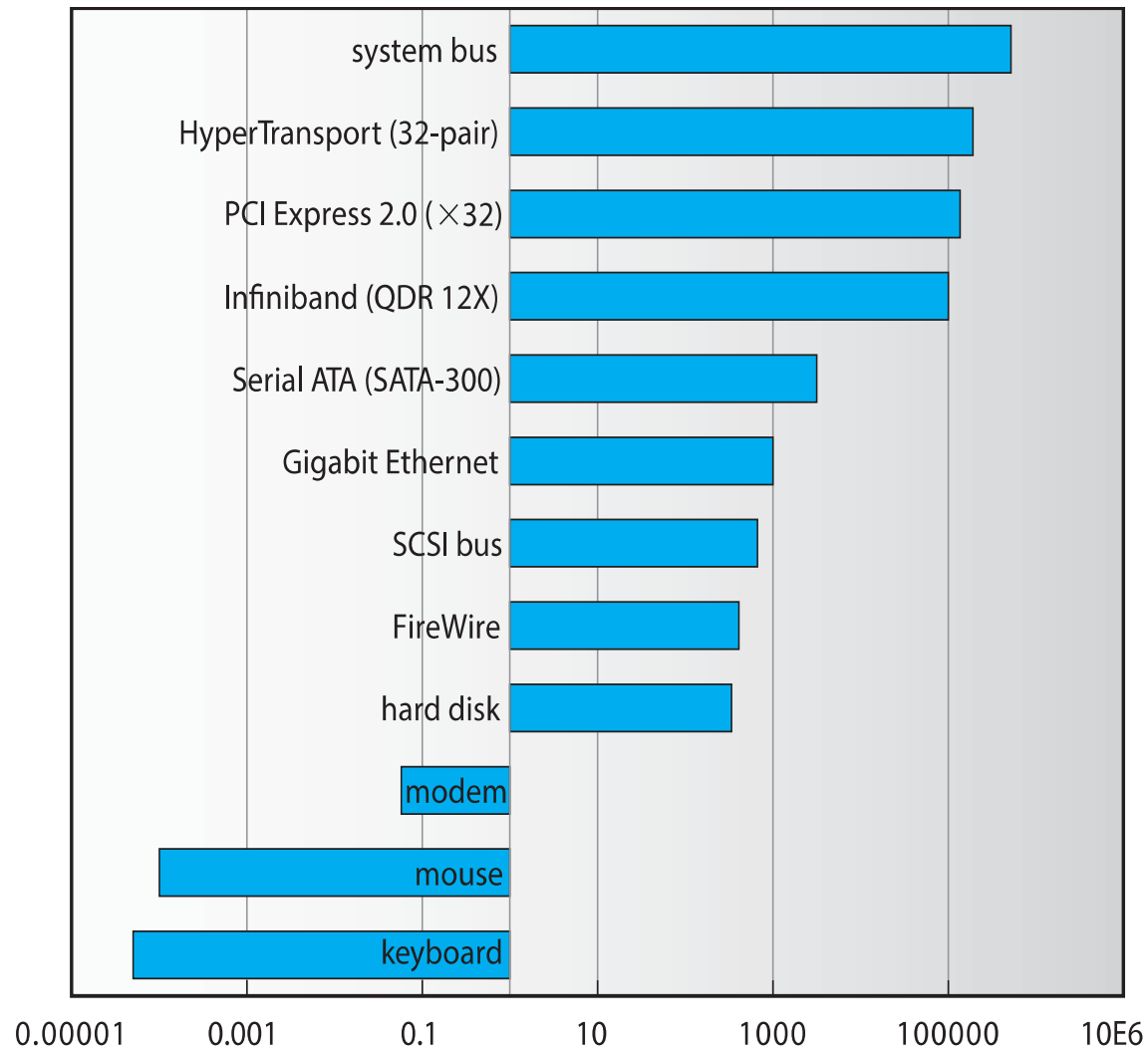
Acknowledgments

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

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