Poll Everywhere

pollev.com/cse333

What has been your favorite topic group so far?

A. Memory Management: pointers, references, malloc/free, new/delete, memory bugs, smart pointers
B. Data Structures: arrays, structs, containers
C. Object-Oriented Programming: classes, inheritance
D. Modularization: compilation, interfaces, templates
E. I/O: files, buffering, network programming
F. Concurrency
G. I prefer not to say

Course Wrap-Up

CSE 333 Summer 2023

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Relevant Course Information

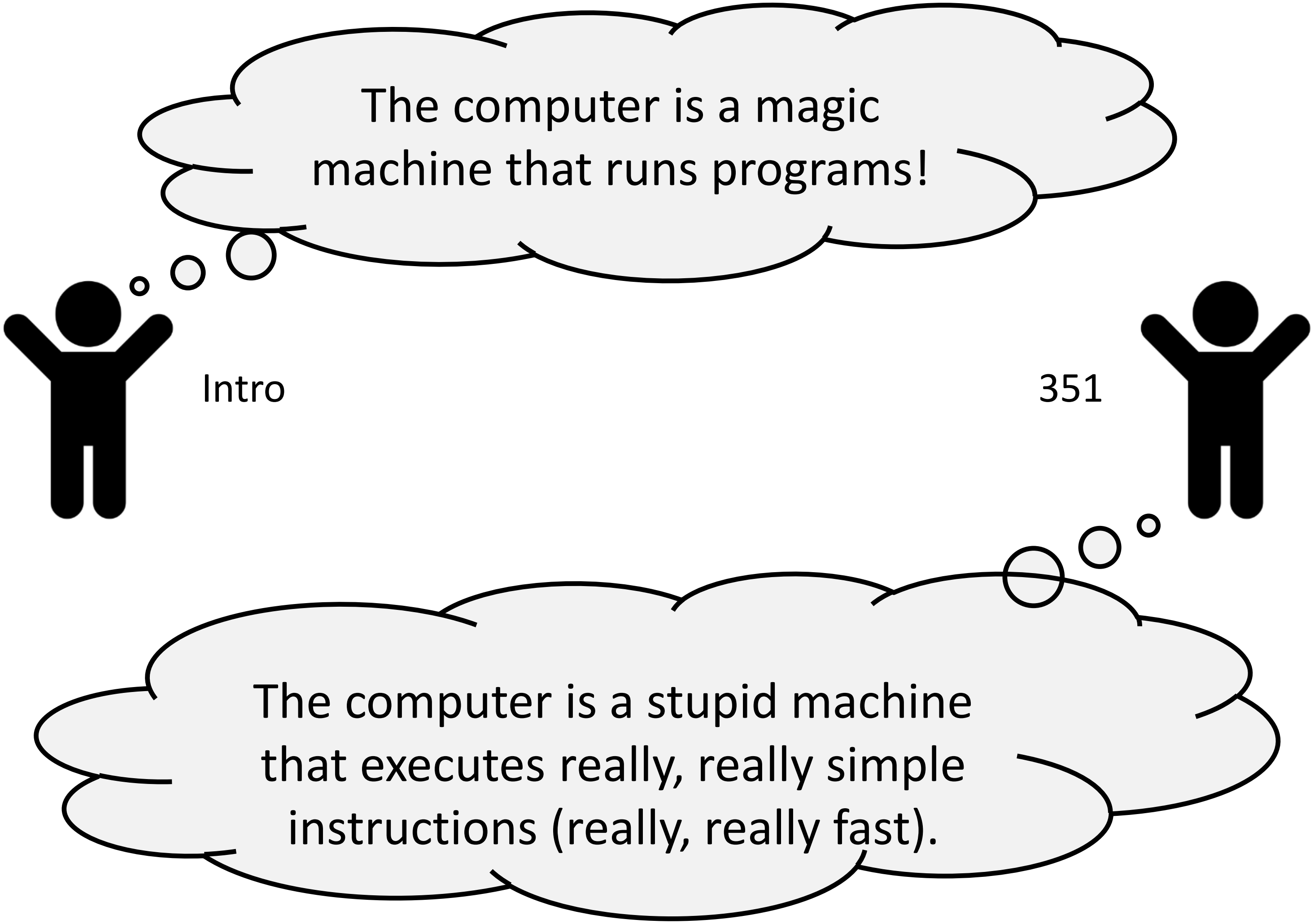
- Homework 4 late due date tonight (8/18) @ 11:59pm
- Quiz 4 due tonight (8/18) @ 11:59pm
- Course evaluations (Ed #404) due tonight @ 11:59pm
- Check grades as Canvas assignments are released

What have we been up to for the last 10 weeks?

- Ideally, you would have “learned” everything in this course, but we’ll use red stars ☆ today to highlight the ideas that we hope stick with you beyond this course

Course Goals

- Explore the gap between:



The computer is a magic machine that runs programs!

The computer is a stupid machine that executes really, really simple instructions (really, really fast).

Systems Programming: The Why

- The programming skills, engineering discipline, and knowledge you need to build a system
    1) Understanding the "layer below" makes you a better programmer at the layer above
    2) Gain experience with working with and designing more complex "systems"
    3) Learning how to handle the unique challenges of low-level programming allows you to work directly with the countless "systems" that take advantage of it

What is a System?

- "A **system** is a group of interacting or interrelated entities that form a unified whole. A system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning."
  - https://en.wikipedia.org/wiki/System

- But hopefully you have a better idea of what a system in CS is now.

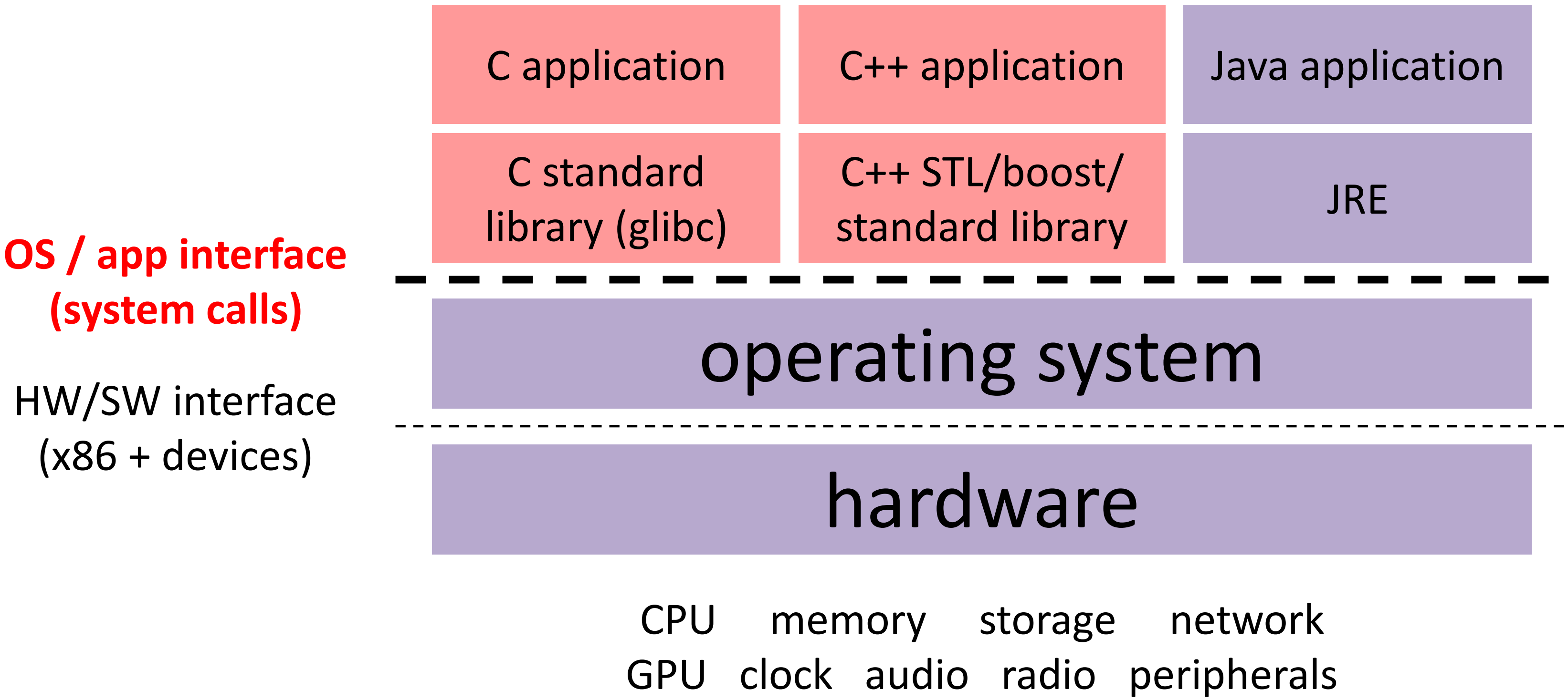
Software System

- Writing complex software systems is *difficult*!
  - Modularization and encapsulation of code
  - Resource management
  - Documentation and specification are critical
  - Robustness and error handling
  - Must be user-friendly and maintained (not write-once, read-never)

- **Discipline:** cultivate good habits, encourage clean code
  - Coding style conventions
  - Unit testing, code coverage testing, regression testing
  - Documentation (code comments, design docs)

The Computer as a System

- Modern computer systems are increasingly complex!
  - Networking, concurrency/parallelism, distributed systems
  - Buffered vs. unbuffered I/O, blocking calls vs. polling, latency


C application
C++ application
Java application
C standard library (glibc)
C++ STL/boost/ standard library
JRE
OS / app interface (system calls)
operating system
HW/SW interface (x86 + devices)
hardware
CPU memory storage network
GPU clock audio radio peripherals

A Network as a System

- A networked system relies heavily on its connectivity
  - Depends on materials, physical distance, network topology, protocols
- Conceptual abstraction layers
  - Physical, data link, network, transport, session, presentation, application
  - Layered *protocol* model
    - We focused on IP (network), TCP (transport), and HTTP (application)
- Network addressing
  - MAC addresses, IP addresses (IPv4/IPv6), DNS (name servers)
- Routing
  - Layered packet payloads, security, and reliability

Systems Programming: The What

- The programming skills, engineering discipline, and knowledge you need to build a system
  - **Programming:** C / C++
  - **Discipline:** design, testing, debugging, performance analysis
  - **Knowledge:** long list of interesting topics
    - Concurrency, OS interfaces and semantics, techniques for consistent data management, distributed systems algorithms, …
    - Most important: a deep understanding of the “layer below”

Main Topics

- C
  - Low-level programming language
- C++
  - The 800-lb gorilla of programming languages
  - “better C” + classes + STL + smart pointers + …
- Memory management
- System interfaces and services
- Networking basics – TCP/IP, sockets, …
- Concurrency basics – POSIX threads, synchronization

Topic Theme: Abstraction

- C: `void*` as a generic data type
- C: abstracted data types to hide system-specific details
  - *e.g.*, `size_t`, `int32_t`, `sa_family_t`, `pthread_mutex_t`
- ☆ C++: hide execution complexity in simple-looking code
  - *e.g.*, operator overloading, dispatch, containers & algorithms
- C++: templates to generalize code
- ☆ OS: abstract away details of interacting with system resources via system call interface
- Networking: 7-layer OSI model hides details of lower layers
  - *e.g.*, DNS abtracts away IP addresses, IP addresses abstract away MAC addresses

Topic Theme: Using Memory

- Variables, scope, and lifetime
  - *Static*, *automatic*, and *dynamic* allocation / lifetime
  - C++ objects and destructors; C++ containers and copying
- Pointers and associated operators (`&`, `*`, `->`, `[]`)
  - Can be used to link data or fake "call-by-reference"
- Dynamic memory allocation
  - `malloc`/`free` (C), `new`/`delete` (C++), smart pointers (C++)
  - Who is responsible? Who owns the data? What happens when (not if) you mess this up? (dangling pointers, memory leaks, …)
- Tools
  - Debuggers (`gdb`), monitors (`valgrind`)
  - Most important tool: thinking!

Topic Theme: Data Passing

- C: output parameters
- Processes: status codes (*e.g.*, `EXIT_SUCCESS`)
- Threads: return values or shared memory/resources
  - Leads to synchronization concerns
- I/O to send and receive data from outside of your program (*e.g.*, disk/files, network, streams)
  - Linux/POSIX treats all I/O similarly
  - Takes a LONG time relative to other operations
  - Blocking vs. polling
- Buffers can be used to temporarily hold passed data
  - Buffering can be used to reduce costly I/O accesses, depending on access pattern

Topic Theme: Optimize for your User

- Readability:
  - Properly **modularize** your code using functions, classes, namespaces, and header files
    - Takes advantage of the preprocessor and linker
  - **Documentation** should be thorough, up-to-date, and easy to find (*e.g.*, public interface)
  - Error reporting behaviors should be documented properly
- Usability:
  - Use proper linkage and encapsulation to avoid namespace collisions
  - Make building easy and efficient via build tools (*e.g.*, Makefile)
  - Your programs should be **robust** – no unexpected or unexplained crashes

Congratulations!

- Look how much we learned!

- Lots of effort and work, but lots of useful takeaways:
  - Debugging practice and metacognition (`gdb`, bug journals)
  - Reading documentation
  - Tools (`git`, `valgrind`, makefiles)
  - C and C++ familiarity, including multithreaded and networked code

- Go forth and build cool systems!
  - But carefully consider who can/should use it as well as what values are embedded in it

Future Courses – Systems Courses

- CSE 451: Introduction to Operating Systems
  - How do you manage all of the computer's resources?
- CSE 452: Introduction to Distributed Systems
  - How do you get large collections of computers to collaborate (correctly!)?
- CSE 461: Introduction to Computer Communication Networks
  - How to design a network to transmit data?
- CSE 401: Introduction to Compiler Construction
  - How does a compiler work? (theory + programming + systems!)
- CSE 444: Database Systems Internals
  - How to build a database management system?

Future Courses – Courses in C/C++

- EE/CSE 474: Intro to Embedded Systems
  - How to interact with computers with limited resources (*e.g.*, RAM) and "real time" requirements
- CSE 455: Computer Vision
  - Theory-heavy course on the representation and analysis of images (*e.g.*, colors, object recognition)
  - C first half, Python in second half
- CSE 457: Computer Graphics
  - Theory- and coding-heavy course on creating digital art
  - Graphics almost always use C++ or C#

Future Courses – Otherwise Related

- CSE 331: Software Design and Implementation
  - Dedicated to good software practices, design, modularity, and more – “core” knowledge for being a good software dev
- CSE 332: Data Structure and Parallelism
  - Use parallelism (a form of concurrency) in Java at the end
- CSE 484: Computer Security
  - Analyze (and sometimes exploit) security vulnerabilities
- Various Web Programming Courses:
  - CSE 154: Web Programming
  - INFO 340: Client-Side Development
  - INFO 441: Server-Side Development
    - Website design and building

Thanks for a great quarter!

- Special thanks to the course content creators!!!

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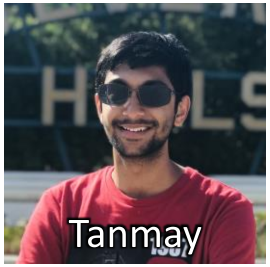
- Huge thanks to your awesome TAs!



Ask Me Anything

That's all Folks!