Course Wrap-Up

CSE 333 Fall 2022

Instructor: Hal Perkins

Teaching Assistants:

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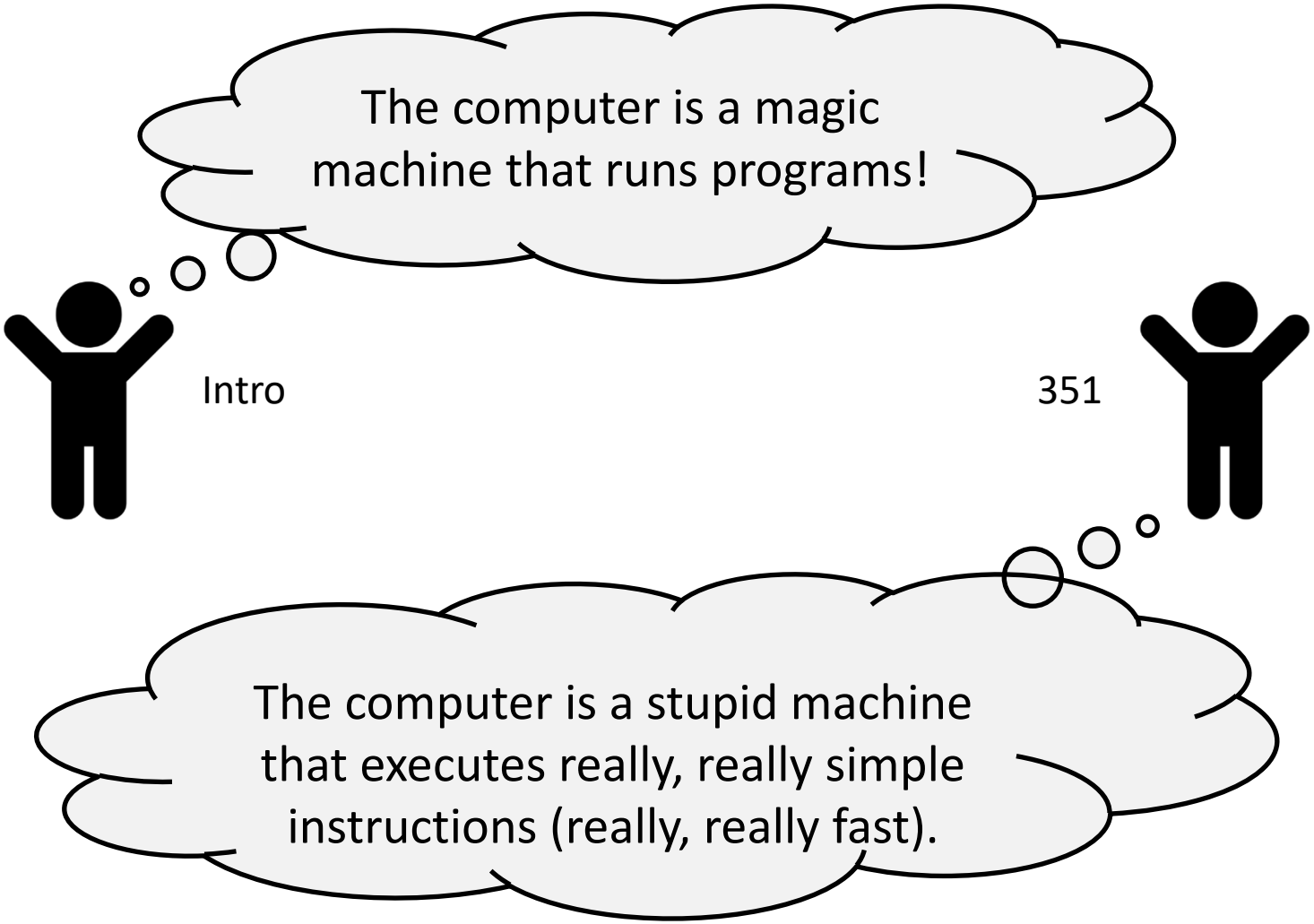
Final Administrivia

- hw4 "due" last night, but really due 11 pm Saturday because everyone has 2 free late days
- Please finish course evals while they are still available
- Please nominate great TAs for the Bandes award. Thanks.
  - Both for CSE 333 and for other courses
- Final exam Wed. Dec. 14, 2:30-4:20, regular classroom
  - Review session Tue., Dec. 13, 4:30-~5:30, CSE2 G20 – bring questions!
  - Topic list on the web now; exam will be somewhat weighted towards 2nd half of the quarter
  - Closed book but you may have two 5x8 cards (or equivalent) with handwritten notes
- Ed postings: *please* use descriptive topics! (not just "15su #7")

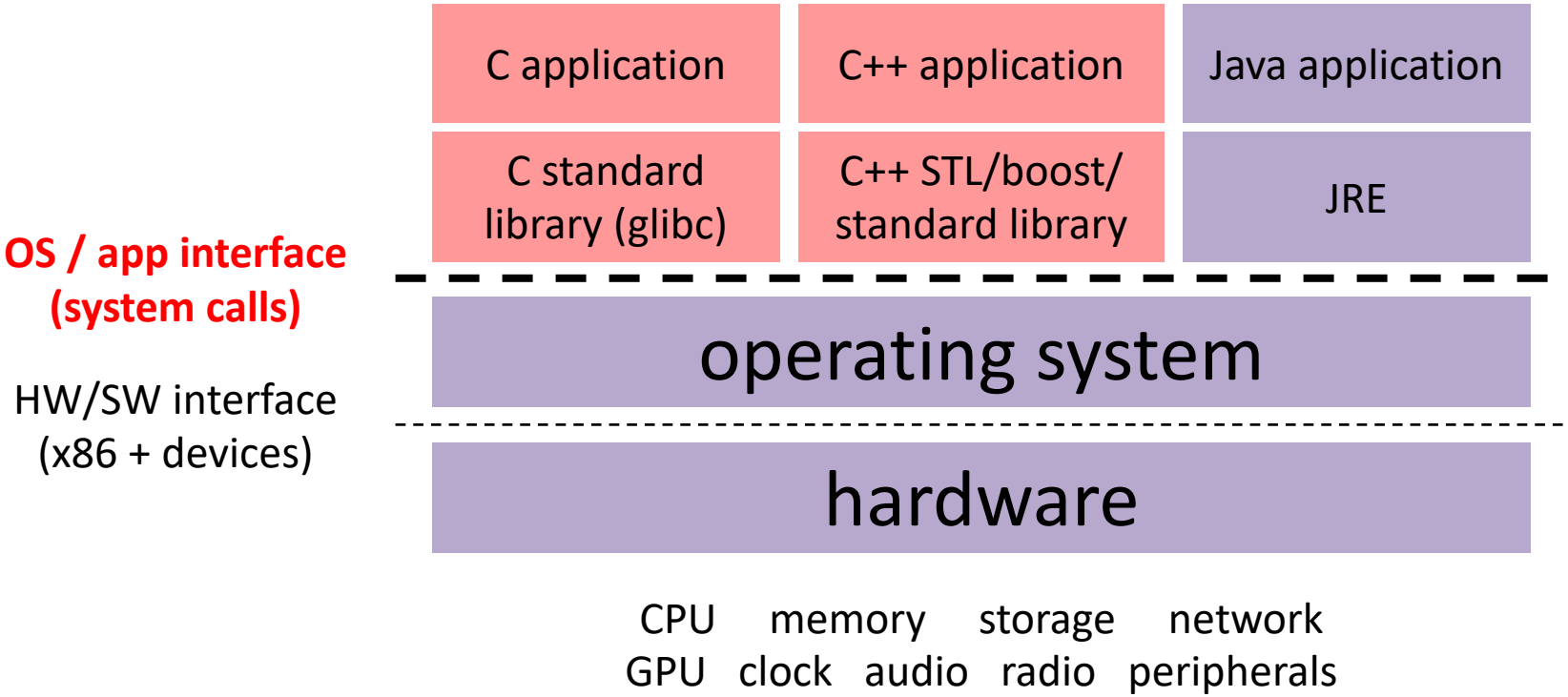
So what have we been doing for the last 10 weeks?

Course Goals

- Explore the gap between:



Course Map: 100,000 foot view



Systems Programming

- 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

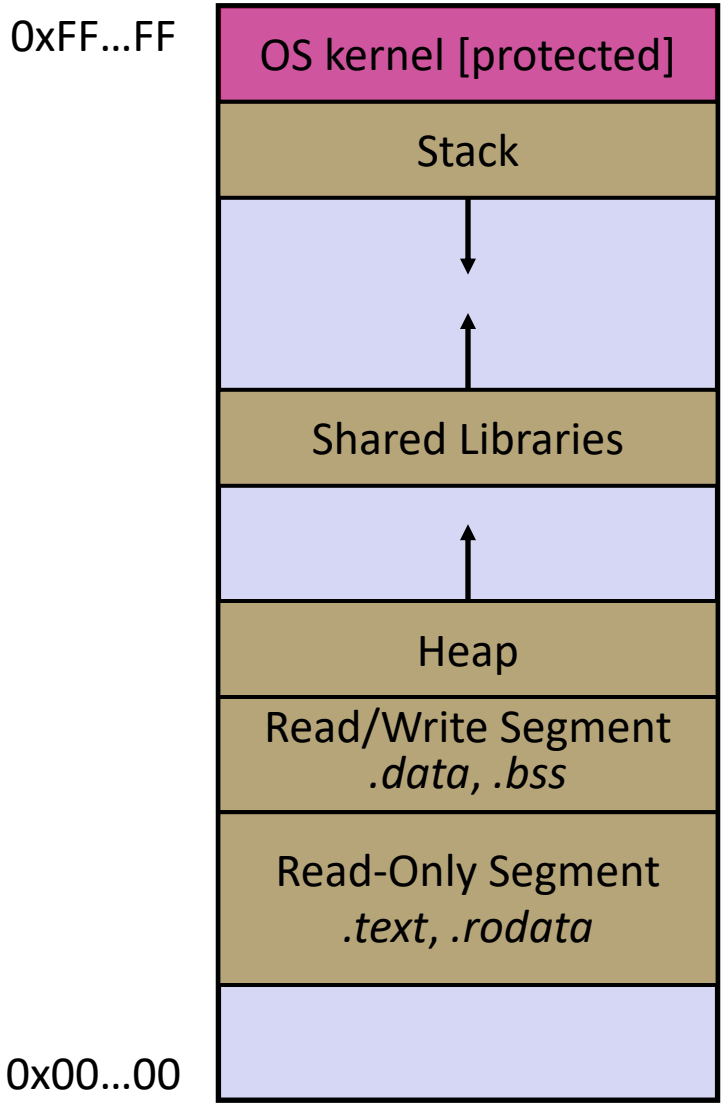
- C
  - Low-level programming language
- C++
  - The 800-lb gorilla of programming languages
  - "better C" + classes + STL + smart pointers + …
- Memory management
- System interfaces and services
- Networking basics – TCP/IP, sockets, …
- Concurrency basics – POSIX threads, synchronization

The C/C++ Ecosystem

- System layers:
  - C/C++
  - Libraries
  - Operating system
- Building Programs:
  - Pre-processor (`cpp`, `#include`, `#ifndef`, …)
  - Compiler: source code → object file (`.o`)
  - Linker: object files + libraries → executable
- Build tools:
  - `make` and related tools
  - Dependency graphs

Program Execution

- What's in a process?
  - Address space
  - Current state
    - SP, PC, register values, etc.
  - Thread(s) of execution
  - Environment
    - Arguments, open files, etc.



Structure of C Programs

- Standard types and operators
  - Primitives, extended types, structs, arrays, typedef, etc.
- Functions
  - Defining, invoking, execution model
- Standard libraries and data structures
  - Strings, streams, etc.
  - C standard library and system calls, how they are related
- Modularization
  - Declaration vs. definition
  - Header files and implementations
  - Internal vs. external linkage
- Handling errors without exception handling
  - `errno` and return codes

C++ (and C++11)

- A "better C"
  - More type safety, stream objects, memory management, etc.
- References and const
- Classes and objects!
  - So much (too much?) control: constructor, copy constructor, assignment, destructor, operator overloading
  - Inheritance and subclassing
    - Dynamic vs. static dispatch, virtual functions, vtables and vptrs
    - Pure virtual functions and abstract classes
    - Subobjects and slicing on assignment
- Copy semantics vs. move semantics

C++ (and C++11)

- C++ Casting
  - What are they and why do we distinguish between them?
  - Implicit conversion/construction and `explicit`
- Templates – parameterized classes and functions
  - Similarities and differences from Java generics
  - Template implementations via expansion
- STL – containers, iterators, and algorithms
  - `vector`, `list`, `map`, `set`, etc.
  - Copying and types
- Smart Pointers
  - `unique_ptr`, `shared_ptr`, `weak_ptr`
  - Reference counting and resource management

Memory

- Object scope and lifetime
  - *Static*, *automatic*, and *dynamic* allocation / lifetime
- Pointers and associated operators (`&`, `*`, `->`, `[]`)
  - Can be used to link data or fake "call-by-reference"
- Dynamic memory allocation
  - **`malloc`**/**`free`** (C), **`new`**/**`delete`** (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!

Networking

- 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

Network Programming

Client side

1) Get remote host IP address/port
2) Create socket
3) Connect socket to remote host
4) Read and write data
5) Close socket

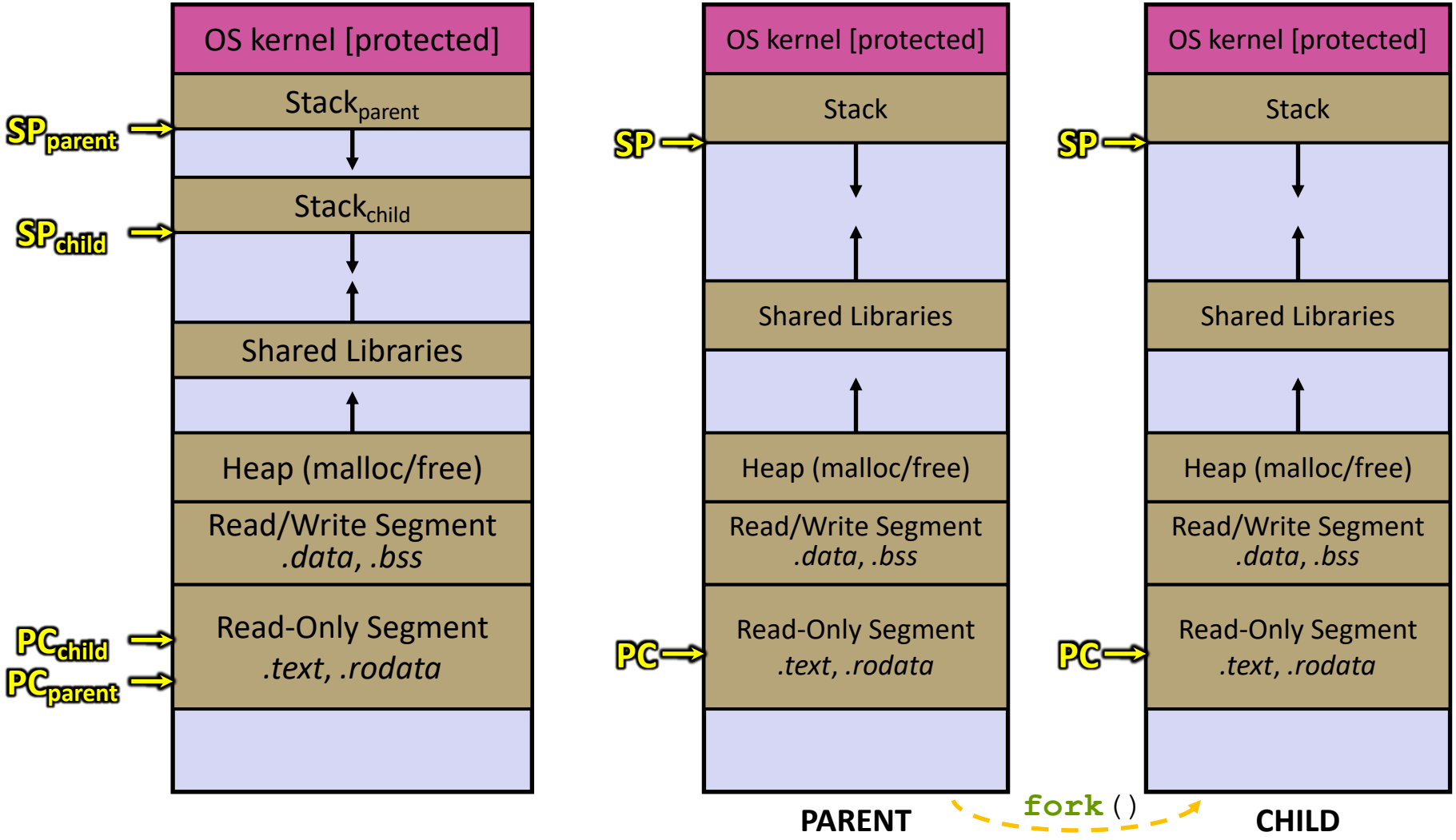
Server side

1) Get local host IP address/port
2) Create socket
3) Bind socket to local host
4) Listen on socket
5) Accept connection from client
6) Read and write data
7) Close socket

Concurrency

- Why or why not?
  - Better throughput, resource utilization (CPU, I/O controllers)
  - Tricky to get right – harder to code and debug
- Threads – "lightweight"
  - Address space sharing; separate stacks for each thread
  - Standard C/C++ library: pthreads
- Processes – "heavyweight"
  - Isolated address spaces
  - Forking functionality provided by OS
- Synchronization
  - Data races, locks/mutexes, how much to lock…

Processes vs Threads on One Slide



Phew! That's it!

- But that's a lot!!

- Take a look back and congratulate yourself on what you've accomplished – particularly during this quarter and this strange year

One last thing…

- Studying for the exam: (your mileage may vary)
  - Review *first*, make notes
    - Review lecture slides, exercises, sections, end-of-lecture problems
    - Look at topic list on website to check your coverage and help organize
    - Brainstorm and trade ideas with colleagues
  - "Simulate" an old exam
    - Do it in one timed sitting
    - Working problems is far more important than reading old answers!
  - "Grade" yourself, then go back and review problems
    - If still unsure why, ask the staff or your fellow students
    - Rinse and repeat!

Courses: What's Next?

- **CSE401:** Compilers (pre-reqs: 332, 351)
  - *Finally* understand why a compiler does what it does
- **CSE451:** Operating Systems (pre-reqs: 332, 333)
  - How do you manage all of the computer's resources?
- **CSE452:** Distributed Systems (pre-reqs: 332, 333)
  - How do you get large collections of computers to collaborate (correctly!)?
- **CSE461:** Networks (pre-reqs: 332, 333)
  - The networking nitty-gritty: encoding, transmission, routing, security
- **CSE455:** Computer Vision
- **CSE457:** Computer Graphics

This doesn't happen without lots of help…

- Thanks to a fantastic staff – it can't work without them!!

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- And thanks to the folks who put the course together:
  - Steve Gribble, John Zahorjan, me, Justin Hsia, Hannah Tang, Aaron Johnston, Travis McGaha, many others

And thanks to…

You

We're more back-to-normal this year than last, but we're still feeling effects from the pandemic and all the disruptions that created. You should be proud of your resilience and what you've done. Please take care of yourself, watch your health, stay active, and help yourself, your friends, your community.

Congratulations and best wishes!

You've learned a *lot* – go out and build great things!

Come by and say hello in the future – I'd love to know what you've been up to after CSE 333!


That's all Folks!