Administrivia

HW4 due tonight, 11 pm
- Usual late days (up to 2) apply if you still have any left

Exam Friday in class
- Review Q&A in section tomorrow
- Topic list and old exams on the web
  - Anything all quarter is possible, but probably biased toward 2nd half
- Course overview in class today
So what have we been doing for the last 10 9 weeks?
Course goals

Explore the gap between

- Intro: the computer is a magic appliance that runs programs
- CSE 351: the computer is a stupid appliance that executes really, really simple instructions
Course map: 100,000 foot view

**OS / app interface (system calls)**

C standard library (glibc) → C application

C++ STL / boost / standard library → C++ application

JRE → Java application

**HW/SW interface (x86 + devices)**

CPU → Java application

memory → C++ application

storage → C standard library (glibc)

network → C application

GPU → C++ STL / boost / standard library

clock → C++ application

audio → Java application

radio → C application

peripherals → C standard library (glibc)

**operating system**

**hardware**

CPU, memory, storage, network, GPU, clock, audio, radio, peripherals
Goals

Skills
- Programming closer to the hardware: C/C++
- Disciplined design, testing, debugging

Knowledge
- OS interface and semantics, languages, some networking
- A deep understanding of “the layer below”
  ‣ quiz: when is the data safely on disk after a write? Actually received over the network? How many copies are made along the way?
Main topics

C Programming, tools, and workflow

Memory management

System interfaces and services (files, etc.)

C++ : the 800-lb gorilla of programming languages
  - “better C” + classes + STL + smart pointers + ...

Networking basics: TCP/IP, sockets, ...

Drilling deeper...
The C/C++ Ecosystem

System layers: C/C++, libraries, operating system

Building programs

- cpp: #include, #ifndef, and all that
- compiler (cc1): source -> .o
- loader (ld): .o + libraries -> executable
Program execution

What’s a process?

- Address space
- Thread(s) of execution
- Environment (arguments, open files, ...)

<table>
<thead>
<tr>
<th>$0x00000000$</th>
<th>$0xFFFFFFFF$</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS kernel [protected]</td>
<td></td>
</tr>
<tr>
<td>stack</td>
<td></td>
</tr>
<tr>
<td>shared libraries</td>
<td></td>
</tr>
<tr>
<td>heap (malloc/free)</td>
<td></td>
</tr>
<tr>
<td>read/write segment $\text{.data, .bss}$</td>
<td></td>
</tr>
<tr>
<td>read-only segment $\text{.text, .rodata}$</td>
<td></td>
</tr>
</tbody>
</table>
C language

Structure of C programs

- Header files and implementations; declaration vs definition
- Internal vs external linkage
- Standard types and operators (scalars including things like uint64_t, structs, arrays, typedef, etc.)
- Functions: defining, using, execution model
- Standard libraries and data structures (strings, streams, ...)
  - C standard library, system calls, and how they are connected
- Handling errors in a language without exception handling
  - return codes, errno, and friends
Memory

Object scope and lifetime (static, automatic, dynamic)

Pointers and associated operators ( & , * , -> , [ ] )
  - Using pointers for call-by-reference as well as linked data

Dynamic memory allocation (malloc/free; new/delete)
  - Who is responsible for dynamic memory & what happens if not done right (dangling pointers, memory leaks, ...)

Tools: debuggers (gdb), monitors (valgrind), ...
  - Most important tool: thinking(!)
C++

A “better C”
- Type-safe streams and memory mgmt (new, delete, delete[ ]), etc.

References and const

C with classes (and objects)
- Constructors, copy constructor, destructor, assignment

Subclasses and inheritance
- Dynamic vs static dispatch & why it matters, virtual functions, vtables
- Pure virtual functions and abstract classes

C++ casts - what are they and why so many (compared to C)?
Templates, STL, and smart ptrs

Templates: parameterized classes and functions
- How the idea is similar to Java generics and what’s different
- How C++ implements templates (expansion)

STL: basic vector, list, map containers and iterators
- Copy semantics

Smart pointers: unique, shared, and weak
- Reference counting, resource management

Using class hierarchies with STL
- Pointer vs value semantics, assignment slicing
Networking

Layered protocol model, particularly TCP and IP
- What they do, how they are related, how they differ

Network addressing and protocols: IP addresses, DNS, IPv4, IPv6, ports

Application protocols: where HTTP fits in the scheme
## Network Programming

### Client side
1. get IP address / port
2. create socket
3. **connect** socket to server
4. **read** / **write** data
5. **close** socket

### Server side
1. get IP address / port
2. create socket
3. **bind** socket to address / port
4. indicate that socket is a **listener**
5. **accept** connection from client
6. **read** / **write** data
7. **close** socket
Concurrency

Why?
- Better resource utilization
- Better throughput

Processes
- Heavyweight, isolated, created by cloning: fork()

Threads
- Lightweight, share address space, pthreads

Synchronization (particularly threads)
- What are the main issues
## Processes vs threads on one slide

<table>
<thead>
<tr>
<th>parent</th>
<th>child</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>SP</td>
</tr>
<tr>
<td>PC</td>
<td>PC</td>
</tr>
</tbody>
</table>

- **OS kernel [protected]**
  - stack
  - shared libraries
  - heap (malloc/free)
  - read/write segment `.data`, `.bss`
  - read-only segment `.text`, `.rodata`

- **parent**
  - fork

- **OS kernel [protected]**
  - stack
  - shared libraries
  - heap (malloc/free)
  - read/write segment `.data`, `.bss`
  - read-only segment `.text`, `.rodata`

- **child**
  - SP
  - PC

- **OS kernel [protected]**
  - stack
  - shared libraries
  - heap (malloc/free)
  - read/write segment `.data`, `.bss`
  - read-only segment `.text`, `.rodata`
Phew! That’s it!!

But that’s a lot!!!

Studying for the exam

- Review lecture slides, assignments, exercises
- Try some of the end-of-lecture problems for practice
- Look at old exams and topic list on the web
- Study groups! Ask questions / trade ideas on the discussion board! Ask course staff questions
- The goal is learning and mastery
That’s it (almost)

Congratulations and good luck on the exam!!

And a big thanks to Soumya & Chuong

- This doesn’t happen without great help

And one last thing - course evals

- Constructive feedback (positive we hope, but negative when called for) is what helps us get better

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

See you Friday!