Computer Systems and Networks

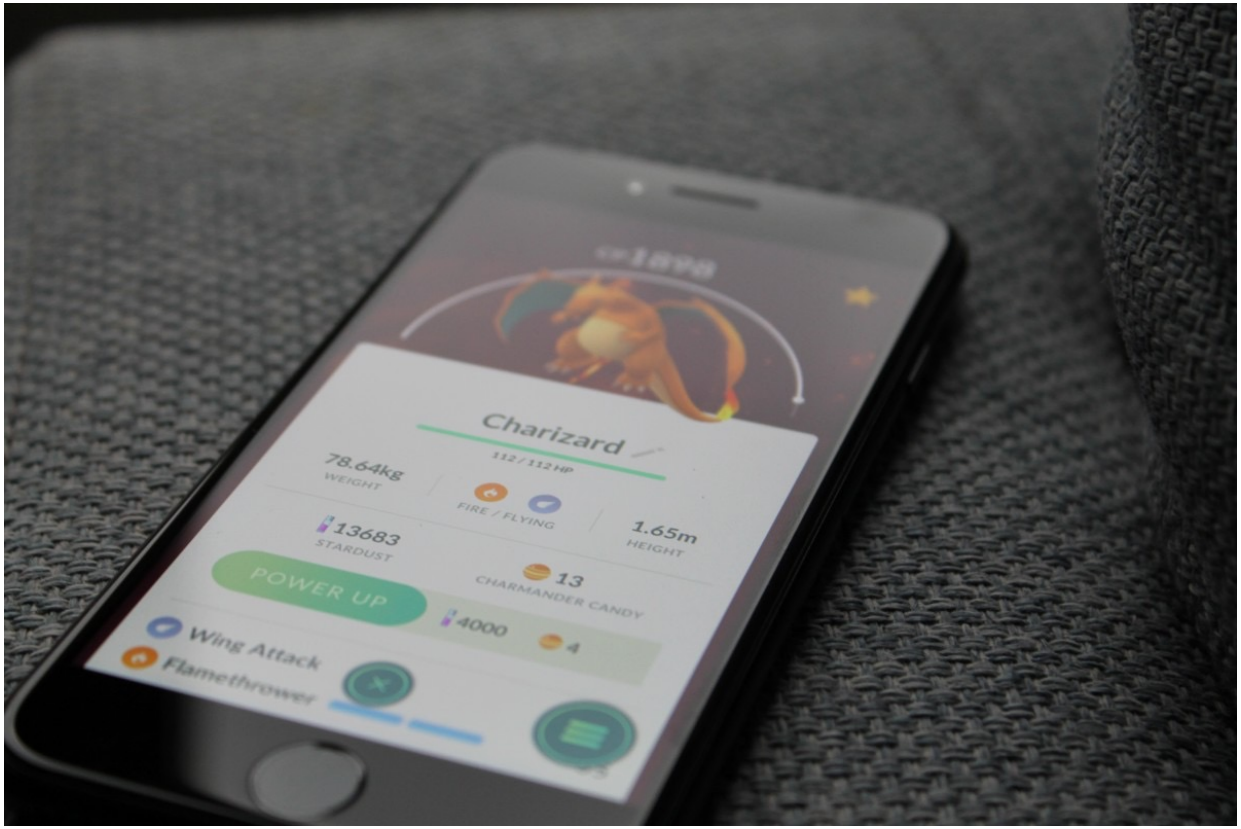
ECPE 170 – Instructor: Vivek Pallipuram– University of the Pacific

Introduction

These slides are credited to Dr. Jeffrey Shafer

A Modern Computer – iPhone XS

Applications



Application – Pokemon Go

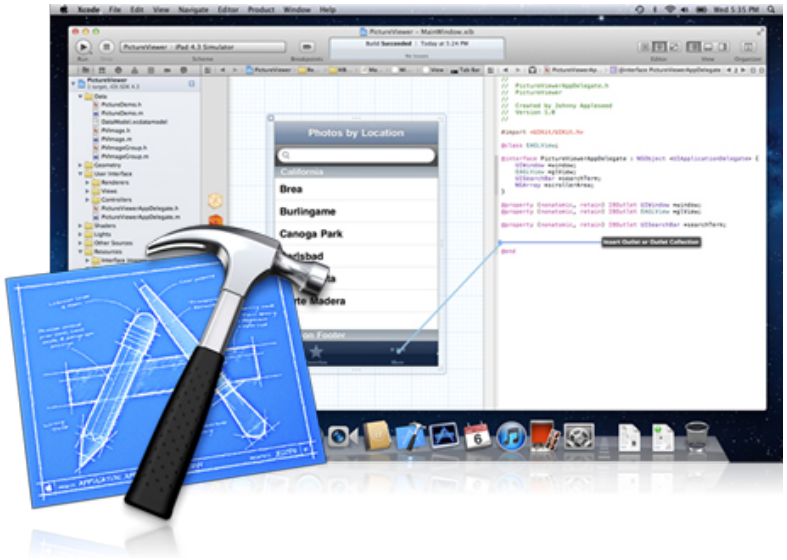
- Written in a high level language (Objective C)
- What **resources** does *Pokemon Go* need to run? (i.e. what does the executable file need to execute?)
  - Hardware
    - Processor(s) – Run program, display graphics, …
    - Memory – Store programs, store data
    - I/O – Touch screen, storage, network, 3-axis gyro, …
  - Software - Operating system

Software - Operating System

- Apple iOS – Used in iPads, iPhones, iPods, Apple TV
  - Variant of Mac OS X operating system used on traditional Macs
- **What are some jobs of this operating system?**
  - Manage hardware
  - Manage applications (multitasking)
- Written in high-level languages
  - C, C++, Objective C (varies by component)
  - **Can we run this code directly on the processor?**

Software - Compilers / Interpreters

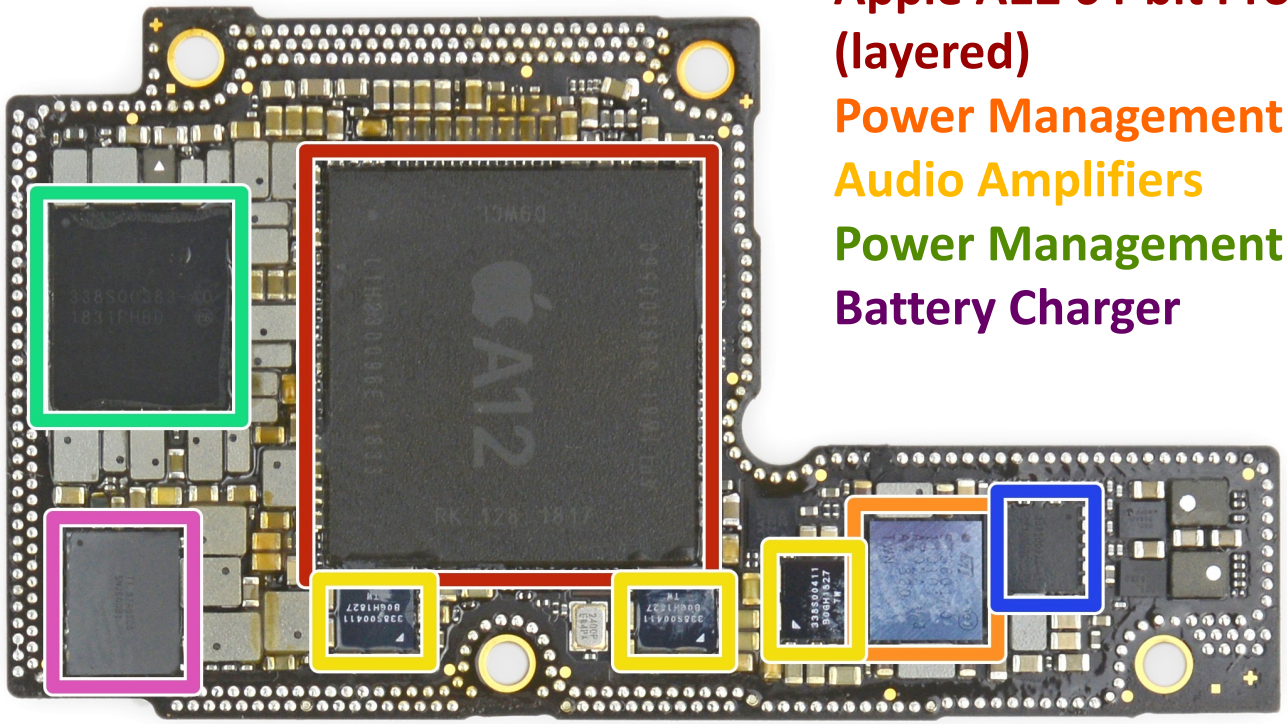
- These are programs that **build** other programs!
- Goal: Convert high-level languages into machine code that can be directly executed by hardware
- Examples
  - Apple Xcode
  - Microsoft Visual Studio
- **What's the difference between a compiler and interpreter?**



Hardware

https://www.ifixit.com/Teardown/iPhone+XS+and+XS+Max+Teardown/113021

Hardware



Apple A12 64-bit Processor + 4GB of RAM (layered)
Power Management
Audio Amplifiers
Power Management
Battery Charger

https://www.ifixit.com/Teardown/iPhone+XS+and+XS+Max+Teardown/113021

iPhone XS Processor

- Apple A12 Processor
  - Clock speed – 2.5GHz
  - 6 cores
  - 4GB RAM

  } What do these mean?

- **What does a processor do?**
  - Executes machine language instructions
    - **Machine language?**
  - **How does the processor execute the instructions?**

Microarchitecture

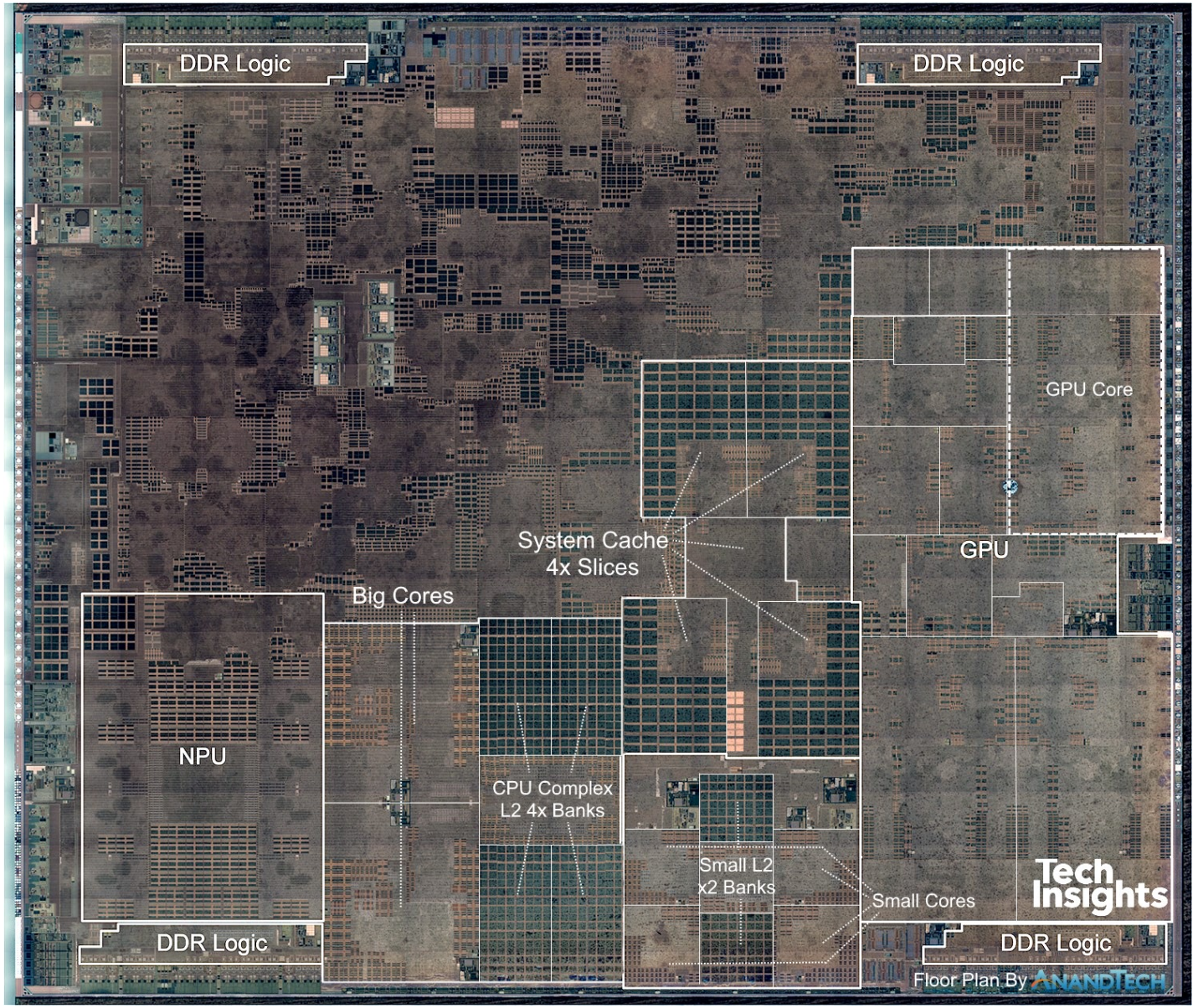
How Does It Work?

- Apple won't tell us – trade secret!
- Experts can dissolve (with acid), burn, or grind off outer protective layers of chip and then peer inside:
  - Need a *really good* microscope!
  - *Reverse Engineering in the Semiconductor Industry:* http://www.scribd.com/doc/53742174/Reverse-Engineering

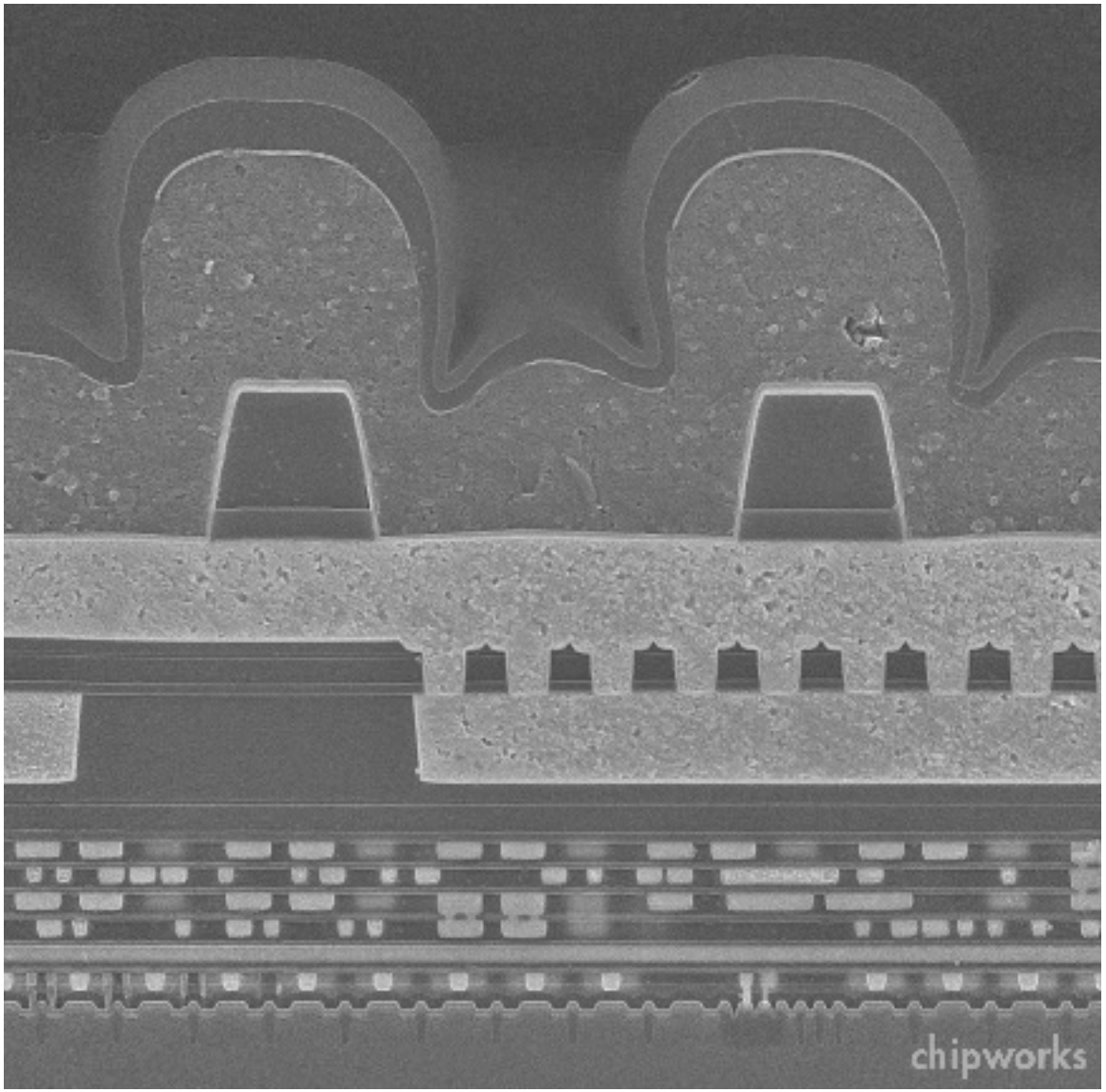
Can see this level of detail with your own eyes…

Divided into logic blocks with different functions:

- Processor
- Cache memory
- Memory Controller
- Video (GPU)



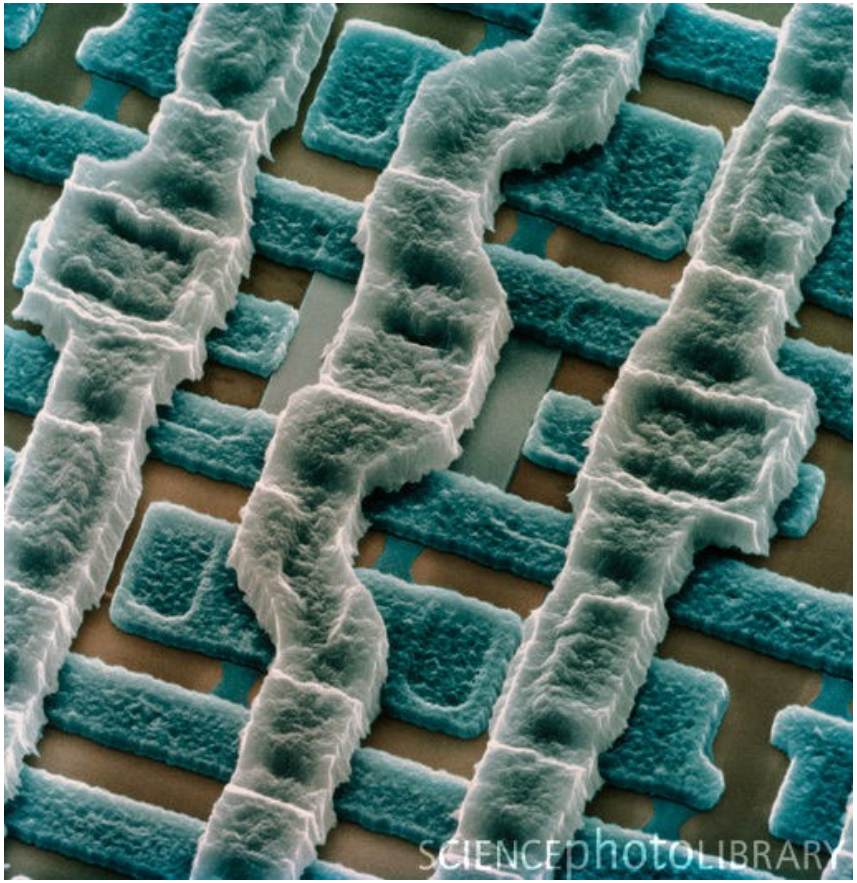
https://www.anandtech.com/show/13393/techinsights-publishes-apple-a12-die-shot-our-take



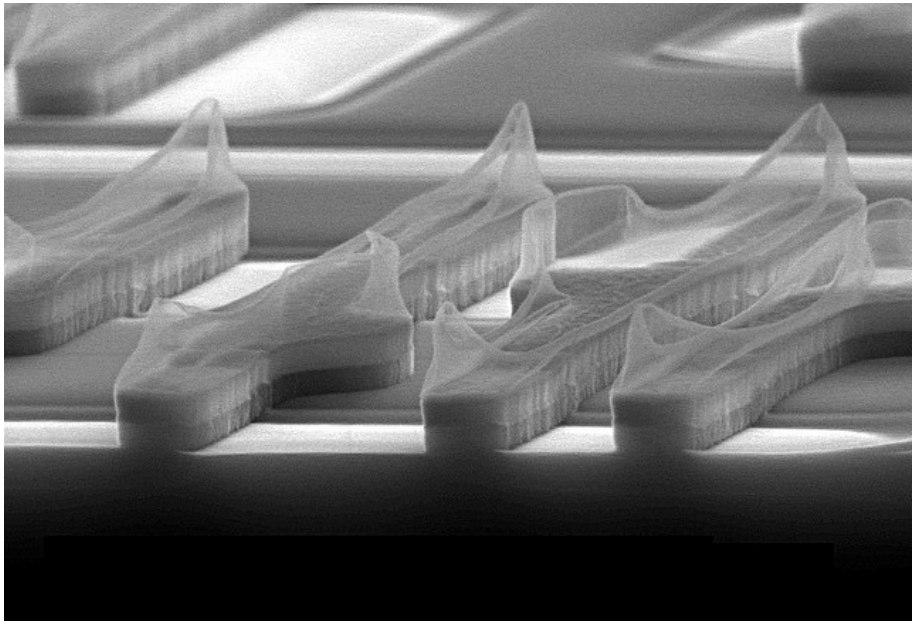
SEM Cross-Section of (older) Apple A5

Digital Logic

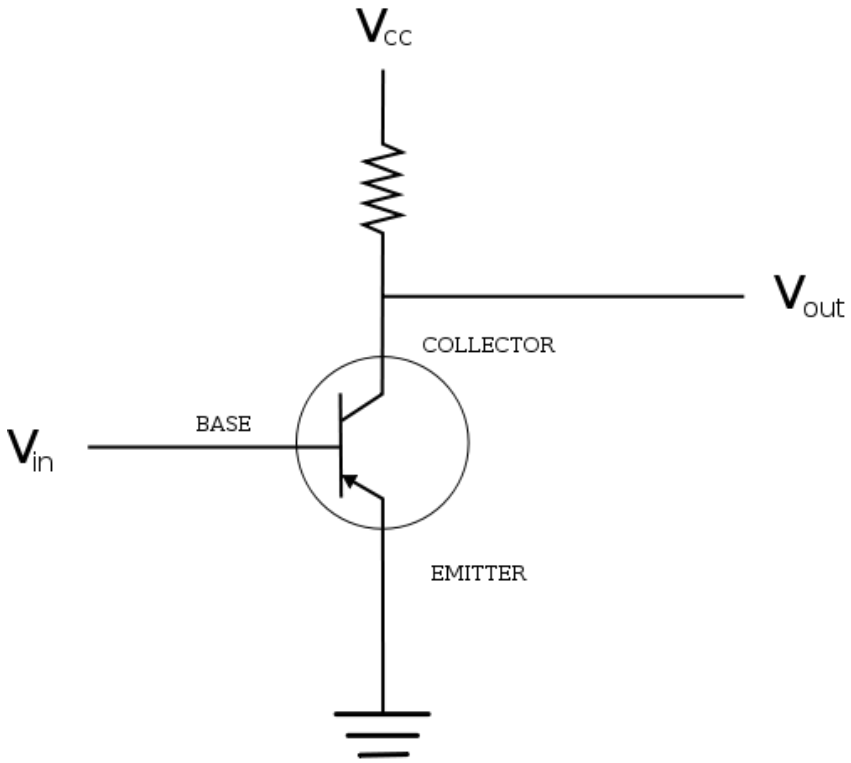
Memory cell



Transistor

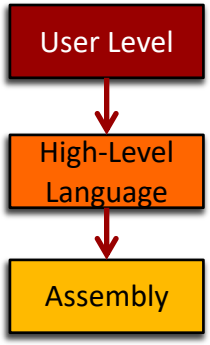


Transistors



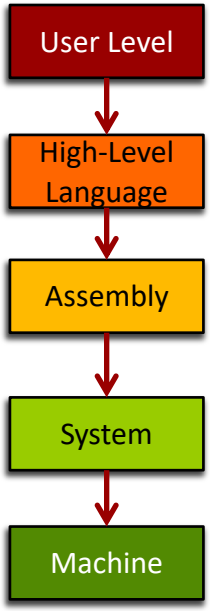
- You can still make assumptions at this level that the transistor is either “on” (1) or “off” (0)
- But below this are **analog circuits**

The Computer Level Hierarchy



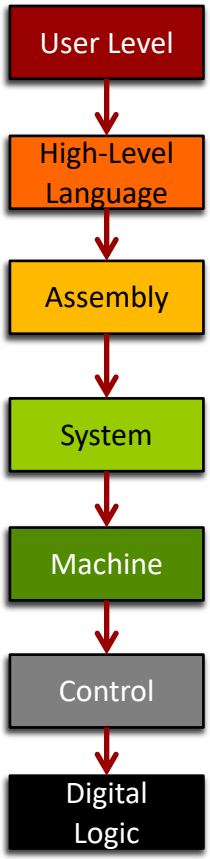
- Level 6: The **User Level** – "Pokemon Go"
  - Program execution and **user interface** level
- Level 5: **High-Level Language Level** – "Objective C"
  - Programming languages like C++, Java, Python, …
- Level 4: **Assembly Language Level** – "ARM Assembly"
  - Program directly at this level, or …
  - **Use a compiler/interpreter** to process/convert high-level code

The Computer Level Hierarchy



- Level 3: **System Software Level** - "iOS"
  - Controls active programs and manages system resources
  - Assembly language instructions often pass through Level 3 without modification
- Level 2: **Machine Level**
  - Instruction Set Architecture (ISA) Level
  - Instructions are particular to the architecture of the specific machine (i.e. Intel processors, ARM processors, IBM processors…)

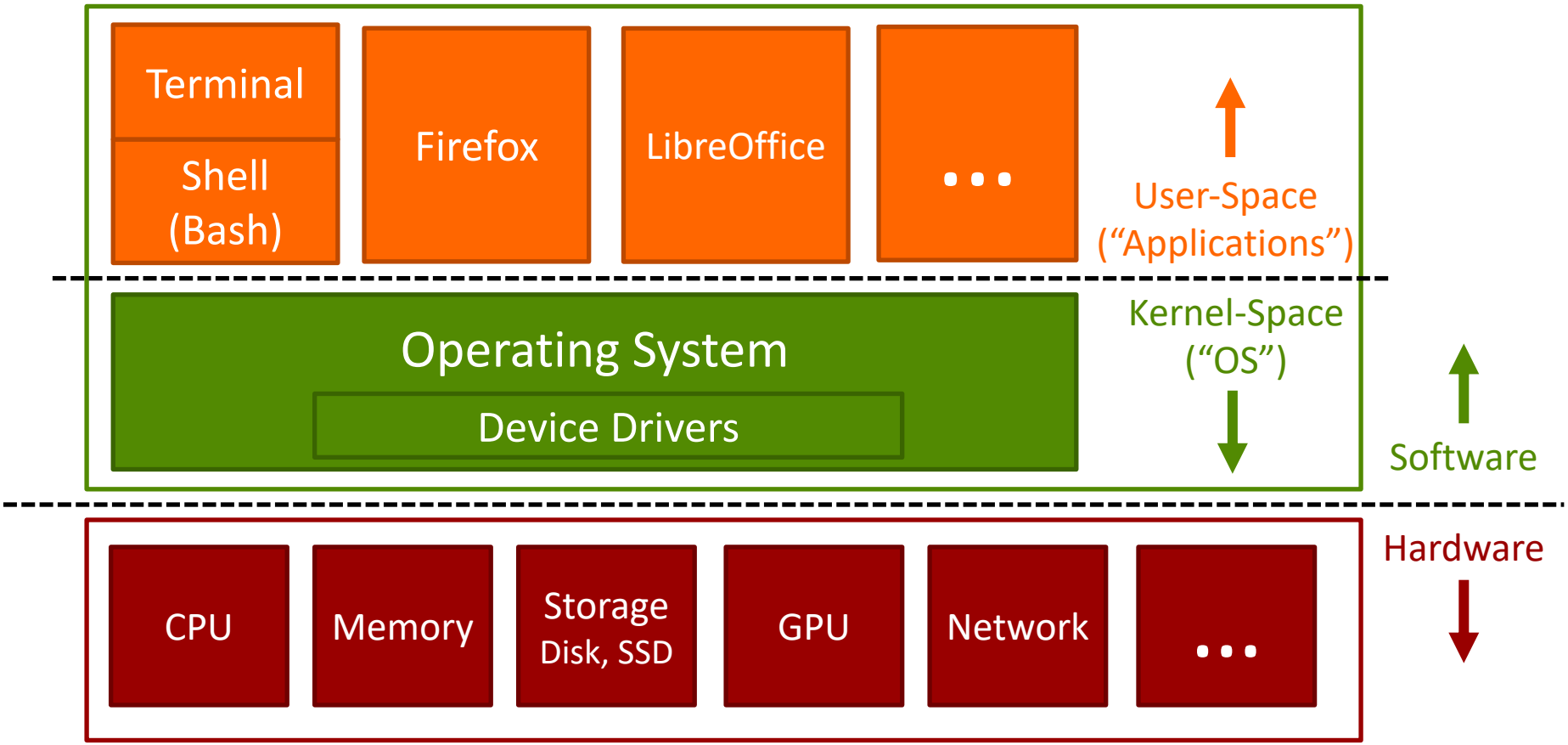
The Computer Level Hierarchy



These levels are too hardware-oriented for ECPE 170…

- Level 1: **Control Level**
  - Decodes and executes instructions and moves data through the system
  - **ECPE 173 – Computer Organization & Architecture**
- Level 0: **Digital Logic Level**
  - Digital circuits, gates and wires implement the mathematical logic of all other levels
  - **ECPE 71 – Digital Design**
    ECPE 174 – Advanced Digital Design

Hardware / Software "Stack"



Course Overview

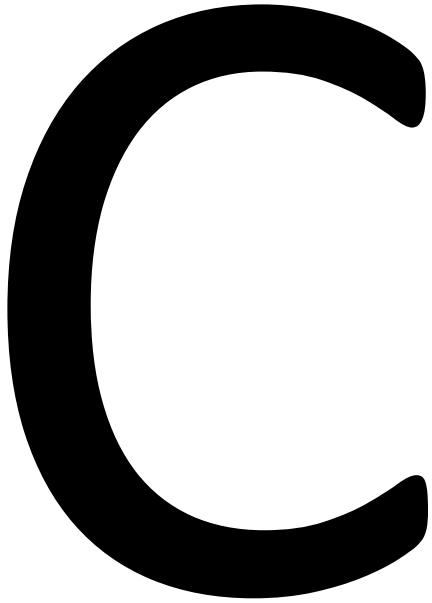
Motivating Question

- **What do you, as a programmer, need to know about the underlying system (software *and* hardware) to write more efficient code?**
  - Role of the tools
    - Compiler, assembler, linker, profiler
  - Role of the operating system and its efficient usage
  - Assembly programming (using the CPU efficiently)
  - Memory hierarchy and its impact on performance

Course Goals

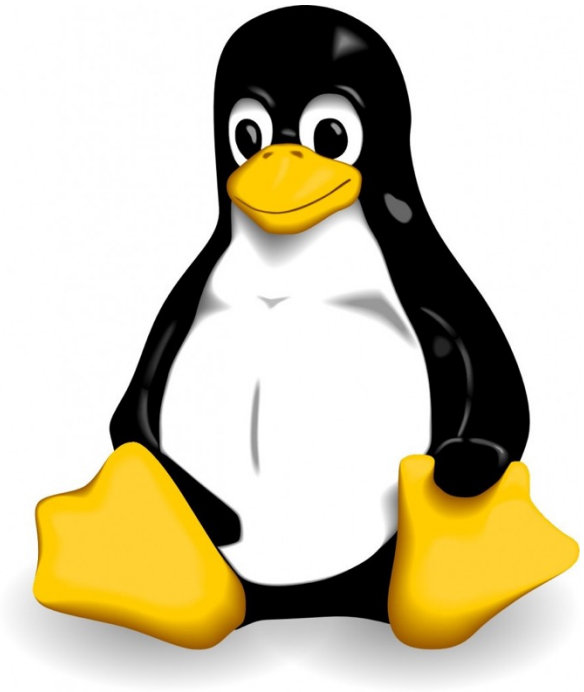
- Present a complete view of how computer systems are constructed
  - From the CPU assembly programming level to the user application level
- Understand the relationship between computer software and hardware
- Lay the foundation for future courses
  - Advanced Digital design / VLSI
  - Operating systems
  - Computer networking
  - Application development

C Programming Language



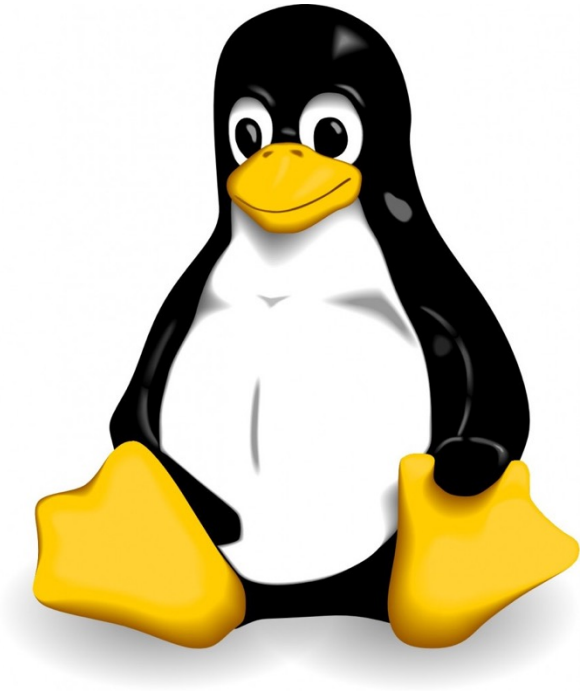
- **Why not Python, Java, Ruby, Perl, PHP, …?**
- High-level languages (especially interpreted, managed code…) try to *hide* the underlying machine from you
- ECPE 170 wants to *reveal* the underlying machine to you!
- Industry demand for systems programmers

Linux



- **Course will be taught 100% in Linux**
- *Did you* have *to choose Linux for ECPE 170?*
- No, not really, but…
  - Too many Pacific graduates were *escaping* without a working knowledge!
  - **Feedback from co-op employers and graduates: "More Linux/Unix skills please!"**

Linux



- **Who here has used a Linux desktop/laptop/server before?**
- **Who here has used a Linux "device" before?**
  - *I'd be surprised if it isn't everyone…*
  - Android runs a Linux kernel
  - Amazon Kindle runs a Linux kernel
  - TiVO runs a Linux kernel

Discussion

- What is open-source?
- What is an operating system *kernel*?
  - Is the kernel everything you need from an OS?
- What is Linux?
- What is Ubuntu Linux? (RedHat? Debian? …)

Virtual Machine

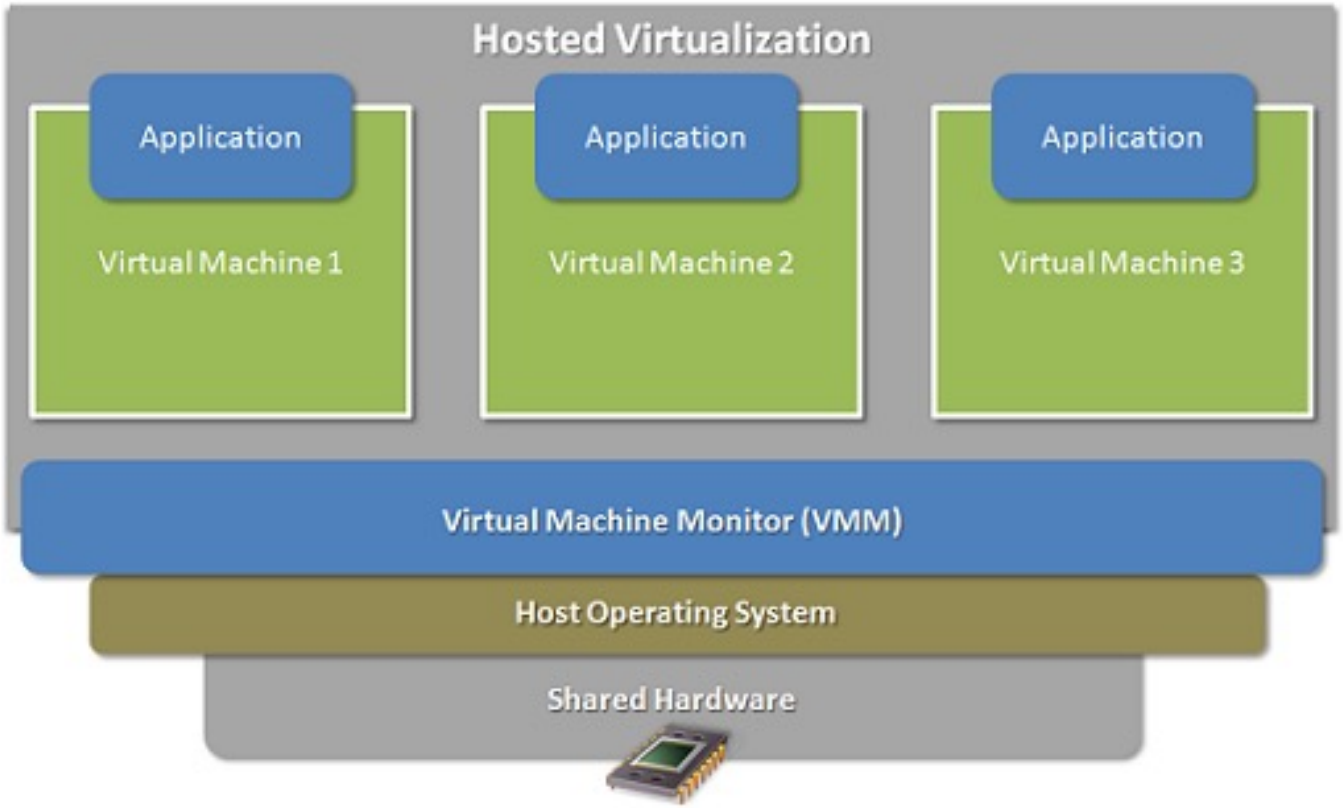
- **Course will be taught 100% from a virtual machine booting Linux that *you* install!**
- *Couldn't you just give us remote access to a server someplace that is already configured?*
- Yes, but…
  - By installing it yourself you will have the skills to use it again in the future

Discussion

- **What is a Virtual Machine?**
- **How is it different from dual booting?**
- **Which comes first, the virtual machine, or the OS?**
  - Answer: It depends!
  - Typical desktop install: hosted virtualization
  - Typical server install: bare-metal virtualization

Recommended technique for ECPE 170

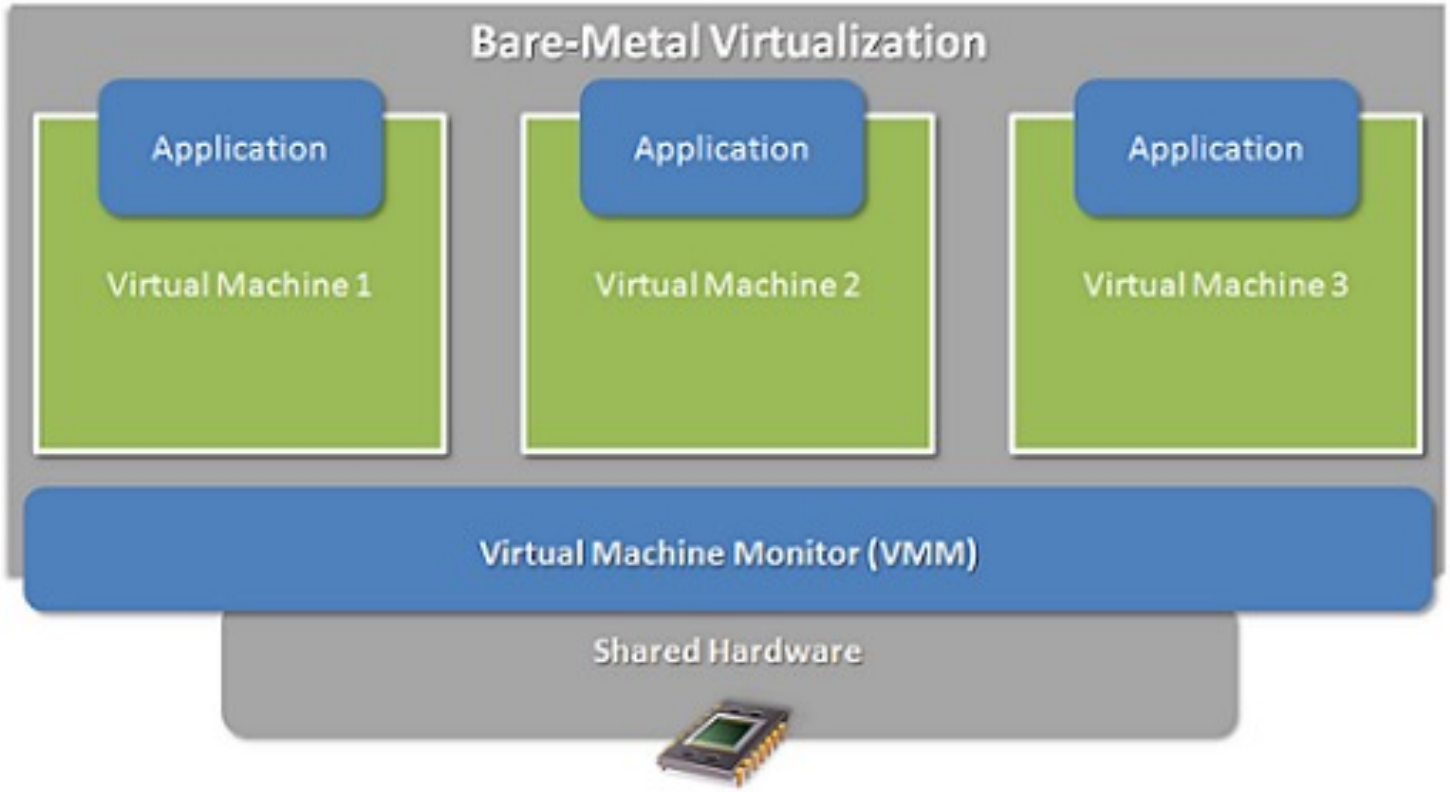
Hosted Virtualization



Bare-Metal Virtualization

More efficient, but not as easy to install.

The virtual machine monitor acts like an operating system itself!



Version Control

- **Course will use version control!**
  - Only way to get lab code or turn in assignments
- *Did you* have *to mandate VCS for ECPE 170?*
- No, not really, but…
  - Too many Pacific graduates were *avoiding* learning this on their own!
  - **Feedback from co-op employers and graduates: "Only n00bs work without version control!"**
  - Used everywhere: Source code of all kinds! (C++, Python, Matlab, VHDL/Verilog, …)

Version Control

- **Who here has used a *version control system* before?**
  - What system?
  - Where at?
  - What purpose?

Questions?

- Questions?
- Concerns?

Course Mechanics

Websites

Main website (syllabus, schedule)

- http://ecs-network.serv.pacific.edu/ecpe-170

Canvas website (gradebook)

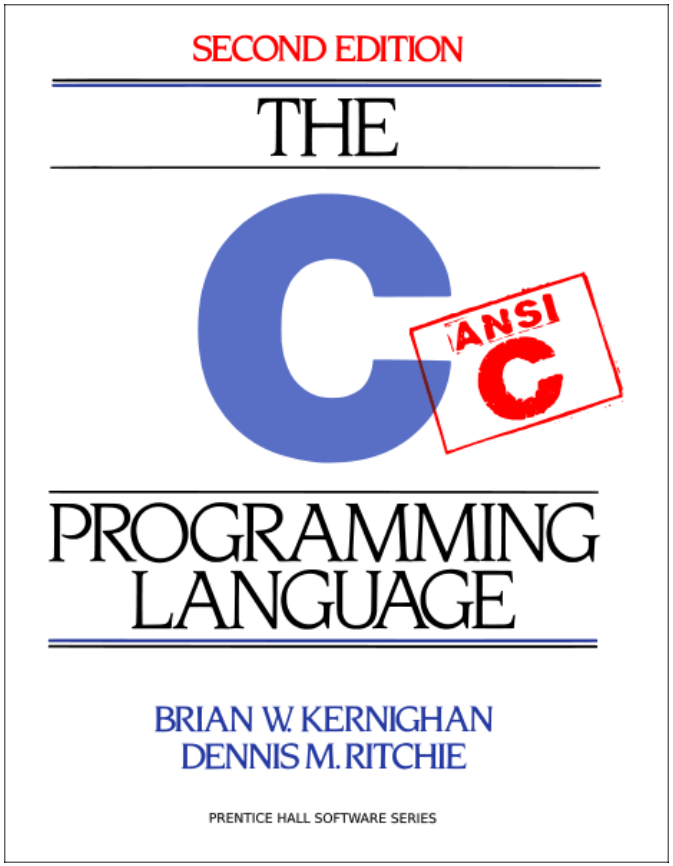
- http://canvas.pacific.edu

Bitbucket.org (version control)

- http://bitbucket.org

Textbook

- **No official textbook**
- Optional reference books (useful for this class and beyond)
  - The C Programming Language, 2nd Edition
- **Please suggest useful online or print references throughout the semester**



Grading

- **70% - Labs**
  - Points assigned to each lab will vary based on complexity
  - Each lab *begins* as an in-class activity
    - Unfinished work becomes homework/project
    - **Labs are large – assume "the usual" amount of homework/projects for a 4-credit class**
  - **Tip: The best students last semester *started* the labs outside of class, and finished them as an in-class activity**
- **15% - Video Presentation (1)**
  - Perform a sequence of technical activities or solve a problem
  - Explain in your own words *how* and *why* you solved the problem
- **15% - Final Exam**
  - In-class during the scheduled exam day

Class Attendance

- **See class schedule on website**
- *Strong* – Class will have significant new lecture content or in-class participation problem
- *Moderate* – Class will have significant lab activity
- *Recommended* – Students have the option of performing their work outside of the class, as long as they are confident in performing the required task on their own

Honor Code

- **All assignments are submitted individually**
- **Encouraged Activities**
  - Collaborating with your classmates (asking questions, solving problems together)
  - Searching for solutions online
    - Provided code copied does not exceed 25% of total assignment length
    - Provided you clearly **document this copy** in your source code and lab report
      - What did you copy? Where did it come from?

Honor Code

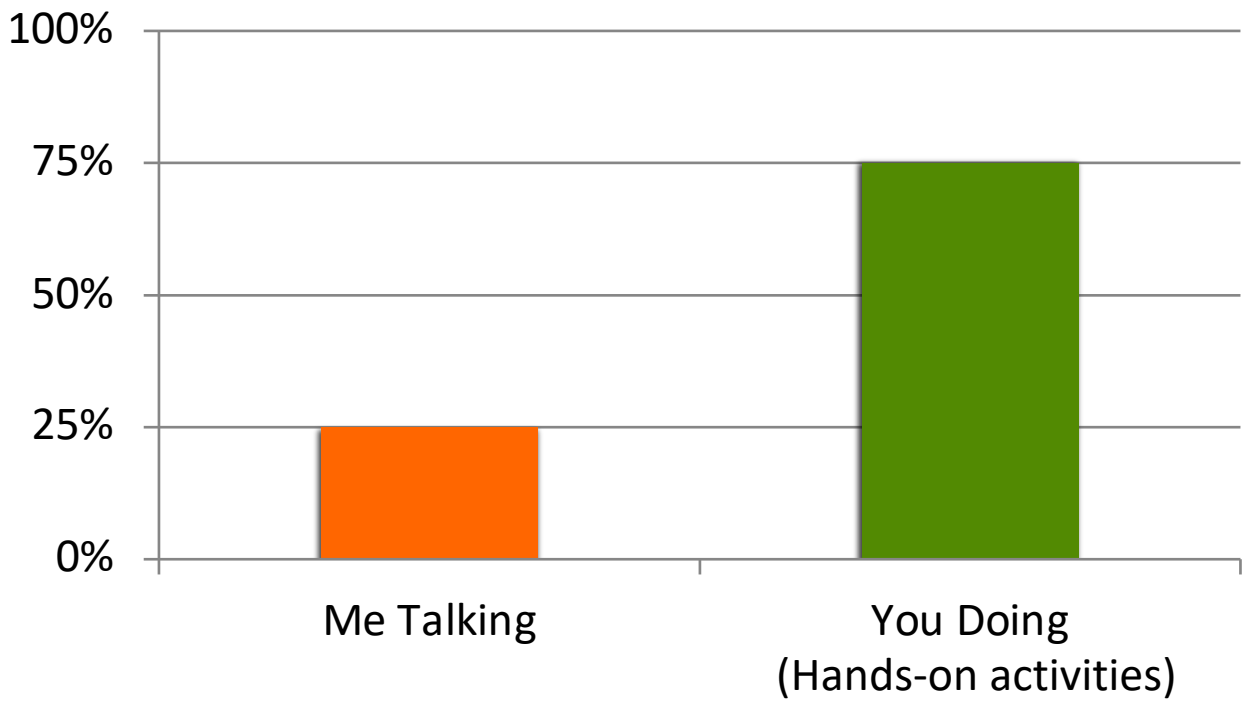
- **Risky Activities**
  - Having your classmates type on your computer or assignment file
  - Posting solutions to Discord
- **Forbidden Activities**
  - Copying someone's work verbatim (classmate or otherwise)
  - Copying someone's work and obfuscating its source
- Your code will be checked for similarity with other submissions with an automated tool. More than a 30% match on non-trivial code is a red flag.

Lab Topics

1. Linux
2. Version Control
3. C Programming
4. C Programming Project
5. Performance Measurement
6. Performance Optimization (compiler and programmer techniques)
7. Performance Optimization (Memory systems)
8. Network Programming 1 (Python)
9. Network Programming 2
10. Assembly Programming 1 (MIPS)
11. Assembly Programming 2
12. Assembly Programming 3

Class Time

- The goal* in designing this course:



* Actual time in any specific class may vary

Lab 1 - Linux

Homework

- **Before the next class**
  1. **Skim "Virtual Machine Setup" tutorial instructions on website**
     - http://ecs-network.serv.pacific.edu/ecpe-170/tutorials/vm_setup
  2. **Decide on what computer system you want to use for this class**
  3. **Download all software**
     - Virtual machine installer (VMware Player)
     - Linux .iso image (installer) – 64-bit version

Next Class - Linux Installfest

- Tutorial Day
- Objectives
  - Follow the “Virtual Machine Setup” tutorial from website to install Linux
  - Debug individual problems if needed
  - Verify OS works
  - **Submit screenshot to “Pre-Lab 1” assignment on Canvas as proof of success**

Next Class - Linux Installfest

- **I want you to be comfortable as professionals working independently to solve problems**
- If you complete the "Virtual Machine Setup" tutorial independently (**and submit to Canvas a screenshot by Thursday morning**), you don't need to attend Thursday's class.
- I will still be here to answer all questions and solve problems

Next Class - Linux Installfest

- **Warning: Don't skip class Thursday, and then tell me next Tuesday at Lab #1 that your OS doesn't work!**

Lab 1 - Linux

- **The first lab is next Tuesday**
  - Topic: Linux
  - Crash course in command-line usage
- **Lab 1: Pre-Lab**
  - Submit to Canvas the screenshot of your working command prompt in Linux. Hopefully you will have this done by end-of-class Thursday
  - **Pre-Lab is due at the start of the lab**

Bring Laptop!

Every class – bring your laptop

Bring Laptop!

Every class – bring your laptop!!

Just assume we'll do significant lab activity in class unless it's been made crystal clear in advance that a day will be all lecture/discussion instead…

Questions?

- Questions?
- Concerns?