Introduction to Computing Systems:

From Bits and Gates to C and Beyond

2nd Edition

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Lecture Goals

- Review course logistics
  - Assignments
  - Policies
  - Organization
  - Grading Criteria
- Introduce key concepts
  - Role of Abstraction
  - Software versus Hardware
  - Universal Computing Devices
  - Layered Model of Computing

Logistics

- Lectures: See syllabus
- Staff: See syllabus
- Recitations: See syllabus
- Help desks: See syllabus
- Office hours: See syllabus
- Materials on the website:
  - http://www.cs.colostate.edu/~cs270
- Piazza: access through Canvas

Assignments

Assignments are posted on website:

- Weekly assignments (mostly) alternate between written and programming assignments.
- Homework assignments: submission mode and deadline varies.
- Programming assignments are submitted in electronic form Sun. at 10pm.
- Late submission varies depending on the difficulty of the assignment.
- Regrading: through Piazza (see syllabus).

Policies

- Grading Criteria
  - Assignments (35%)
  - Recitations (10%)
  - Peer Instruction (5%)
  - Two Midterm Exams (15% each)
  - Final Exam (20%)
  - You must earn a passing grade (60% or higher) on each part – assignments and exams– in order to pass the class
- Late Policy
  - On-time = full points, late submission= 20% penalty
- Academic Integrity
  - http://www.cs.colostate.edu/~info/student-info.html
  - Do your own work
  - Be smart about Internet resources

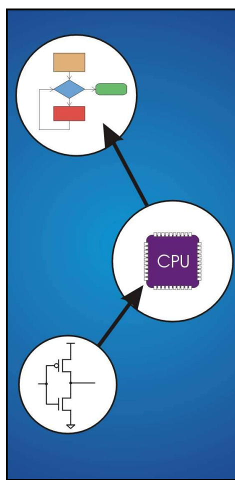
Organization

- 1/3 computer hardware: numbers and bits, transistors, gates, digital logic, state machines, von Neumann model, instruction sets, LC-3 architecture
- 1/3 assembly code: instruction formats, branching and control, LC-3 programming, subroutines, memory model (stack)
- 1/3 C programming: data types, language syntax, variables and operators, control structures, functions, pointers and arrays, memory model, recursion, I/O, data structures

Grading Criteria

How to be successful in this class:

1) Attend all classes and recitations, info will presented that you can't get anywhere else.
2) Do all the homework assignments, ask questions (early! (but not *too* early)) if you run into trouble.
3) Take advantage of lab sessions where help is available from instructors.
4) Read the textbook, work through the end of chapter problems.



Chapter 1 **Welcome Aboard**

Introduction to the World of Computing

- Computer: electronic genius?
  - NO! **Electronic idiot!**
  - Does exactly what we tell it to, nothing more.
- Goal of the course:
  - **You will be able to write programs in C**
  - **You will understand how a computer works (what's going on under the hood).**
- Textbook Approach:
  - From the bottom up (we will use mostly a top-down approach).
  - **Bits ➨ Transistors ➨ Gates ➨ Logic ➨ Processor ➨ Instructions ➨ Assembly Code ➨ C Programming**

Two Recurring Themes

- **Abstraction**
  - Productivity enhancer – don't need to worry about details…

    Can drive a car without knowing how the internal combustion engine works.
  - …until something goes wrong!

    Where's the dipstick?

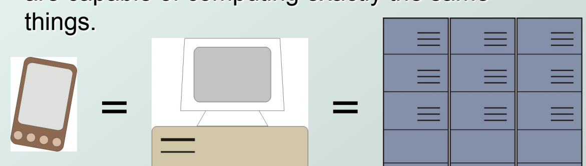
    What's a spark plug?
  - Important to understand the components and how they work together.

Two Recurring Themes

- **Hardware vs. Software**
  - It's not either/or – both are components of a computer system that cooperate.
  - Even if you specialize in one, you should understand capabilities and limitations of both.
  - The best programmers understand the computer systems which run their programs.
  - Computers are an entire ecosystem with multiple levels of abstraction.

Big Idea #1: Universal Computing Devices

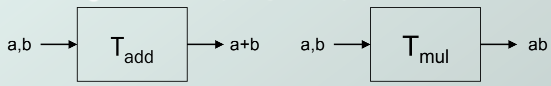
- All computers, given enough time and memory, are capable of computing exactly the same things.



PDA = Workstation = Supercomputer

Turing Machine

- Mathematical model of a device that can perform any computation – Alan Turing (1937)
  - ability to read/write symbols on an infinite "tape"
  - state transitions, based on current state and symbol
- Every computation can be performed by some Turing machine. *(Turing's thesis)*



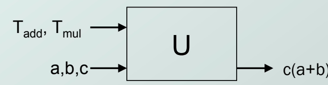
Turing machine that adds *Turing machine that multiplies*

For more info about Turing machines, see http://www.wikipedia.org/wiki/Turing_machine/

For more about Alan Turing, see http://www.turing.org.uk/turing/

Universal Turing Machine

- A machine that can implement all Turing machines – this is also a Turing machine!
  - inputs: data, description of computation (other TMs)



Universal Turing Machine

Universal machine is programmable – so is a computer!

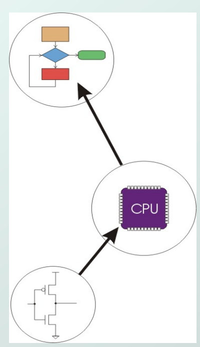
- **instructions are part of the input data**
- **a computer can emulate a Universal Turing Machine**

A computer is a universal computing device.

From Theory to Practice

- In theory, computer can ***compute*** anything that can possibly be computed
  - given enough *memory* and *time*
- In practice, ***solving problems*** involves computing under constraints.
  - time
    - weather forecast, next frame of animation, ...
  - cost
    - cell phone, automotive engine controller, ...
  - Power/energy
    - cell phone, handheld video game, ...

Big Idea #2: Transformations Between Layers



Problems

Algorithms

Language

Instruction Set Architecture

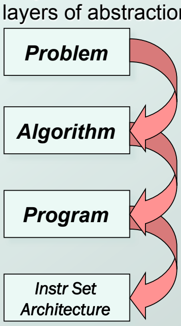
Microarchitecture

Circuits

Devices

How do we solve a problem using a computer?

- A systematic sequence of transformations between layers of abstraction.

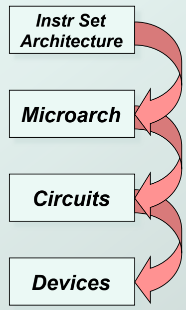


Software Design:
choose algorithms and data structures

Programming:
use language to express design

Compiling/Interpreting:
convert language to machine instructions

Deeper and Deeper…



Processor Design:
choose structures to implement ISA

Logic/Circuit Design:
gates and low-level circuits to implement components

Process Engineering & Fabrication:
develop and manufacture lowest-level components

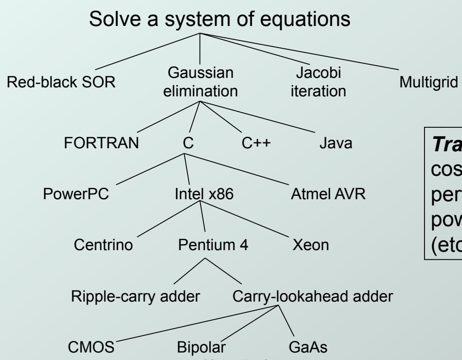
Descriptions of Each Level

- Problem Statement
  - stated using "natural language"
  - may be ambiguous, imprecise
- Algorithm
  - step-by-step procedure, guaranteed to finish
  - definiteness, effective computability, finiteness
- Program
  - express the algorithm using a computer language
  - high-level language, low-level language
- Instruction Set Architecture (ISA)
  - specifies the set of instructions the computer can perform
  - data types, addressing mode

Descriptions of Each Level (cont.)

- Microarchitecture
  - detailed organization of a processor implementation
  - different implementations of a single ISA
- Logic Circuits
  - combine basic operations to realize microarchitecture
  - many different ways to implement a single function (e.g., addition)
- Devices
  - properties of materials, manufacturability

Many Choices at Each Level



Tradeoffs:
cost
performance
power
(etc.)

Book Outline

- Bits and Bytes
  - How do we represent information using electrical signals?
- Digital Logic
  - How do we build circuits to process information?
- Processor and Instruction Set
  - How do we build a processor out of logic elements?
  - What operations (instructions) will we implement?
- Assembly Language Programming
  - How do we use processor instructions to implement algorithms?
  - How do we write modular, reusable code? (subroutines)
- I/O, Traps, and Interrupts
  - How does processor communicate with outside world?
- C Programming
  - How do we write programs in C?

Course Outline

- First, C programming (plus Bits/Bytes/Numbers)
  - Since you already have two semesters of Java
  - Learn the C memory model
  - How function parameters are passed (activation records, stack)
- Assembly Language Programming
  - How do we use processor instructions (three address instructions) to implement C programs (translation)?
  - How do we implement modular, reusable code? (subroutines)
  - How structured programs are broken down into “straight-line” code with (conditional) branches?
- Instruction set processor
  - Instructions and Data (the von Neumann model)?
- Digital circuits
  - Transistors and Gates, Memory and State machines
  - How the processor is built out of these (Register Transfer Notation)
- I/O, Traps, and Interrupts
  - How does processor communicate with outside world?