Introduction to Computer Engineering

CS/ECE 252
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Chapter 1
Welcome Aboard

Slides based on set prepared by
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Computer System: Layers of Abstraction

Software

Hardware

Application Program

Algorithms

Language

Instruction Set Architecture

(and I/O Interfaces)

Microarchitecture

Circuits

Devices
Big Idea #1: Universal Computing Device

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)

\[ T_{\text{add}} \quad a,b \quad \rightarrow \quad a+b \]

\[ T_{\text{mul}} \quad a,b \quad \rightarrow \quad ab \]

Turing machine that adds
Turing machine that multiplies
Universal Turing Machine

Turing described a Turing machine that could implement all other Turing machines.

- inputs: data, plus a description of computation (Turing machine)

\[ T_{\text{add}}, T_{\text{mul}} \rightarrow U \rightarrow c(a+b) \]

Therefore, a computer is a universal computing device!
From Theory to Practice

In theory, computer can *compute* anything that’s possible to compute
- 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*
  - cell phone, handheld video game, ...
Big Idea #2: Transformations Between Layers

How do we solve a problem using a computer?
A systematic sequence of transformations between layers of abstraction.

- **Problem**
  - Software Design: choose algorithms and data structures

- **Algorithm**
  - Programming: use language to express design

- **Program**
  - Compiling/Interpreting: convert language to machine instructions

- **Instr Set Architecture**
Deeper and Deeper…

- **Instr Set Architecture**

- **Microarch**

- **Circuits**

- **Devices**

**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

Solve a system of equations

Red-black SOR

Gaussian elimination

Jacobi iteration

Multigrid

FORTRAN

C

C++

Java

Sun SPARC

Intel x86

Compaq Alpha

Pentium II

Pentium III

AMD Athlon

Ripple-carry adder

Carry-lookahead adder

CMOS

Bipolar

GaAs

Tradeoffs:
cost
performance
power
(etc.)
What’s Next

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?