Computer Architecture and Logic Design

Introduction to the Computer Architecture

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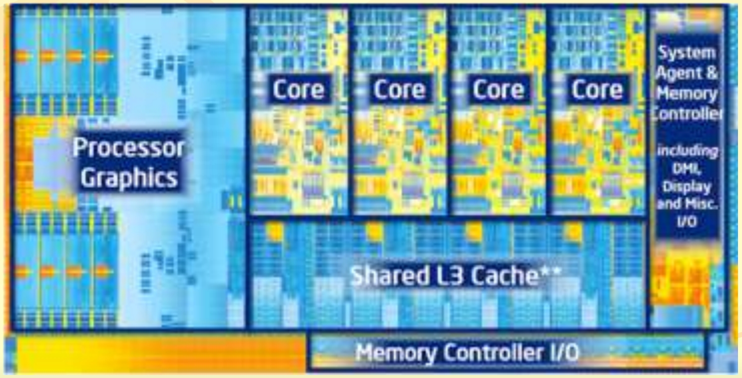
Learning Objectives

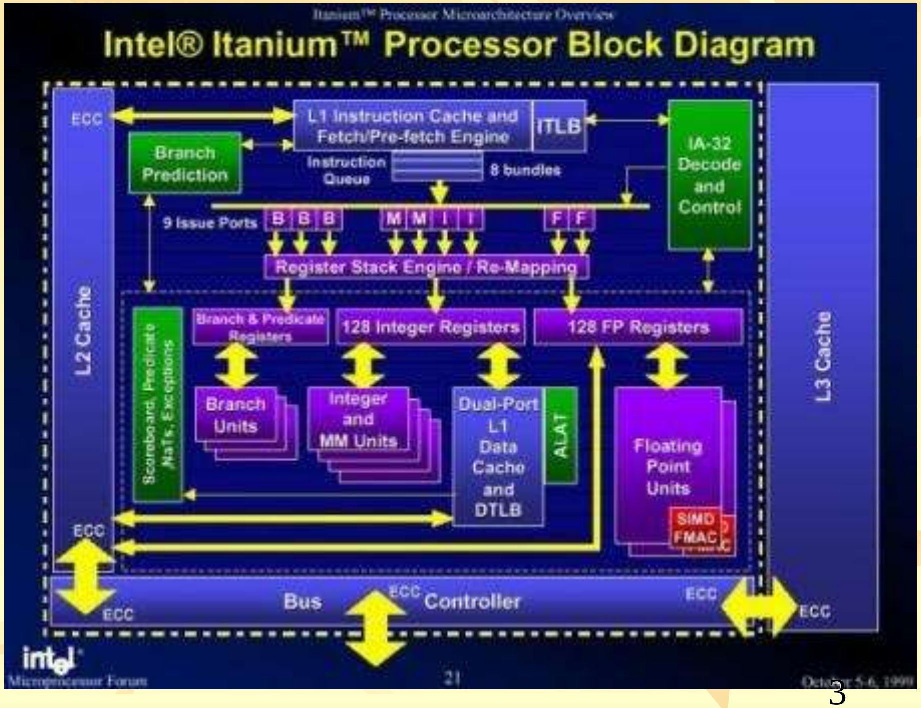
- Differentiate the term Computer Architecture and Computer Organisation
- Understand two important concepts of Abstraction and Hierarchy
- Which Books to read to gain deeper understanding of the Computer Architecture

Computer Architecture Goal

Get a deeper understanding of how computers work, analyze the performance. How the programs are translated to hardware, which help in writing optimized codes

160mm² die carrying 1.40 billion transistors





Computer Architecture?

- Computer architecture is the science and art of selecting and interconnecting hardware components to create computers that meet functional, performance, and cost goals.
- So computer architecture is not only a science, but also an art, implying that imaginative or technical skills are involved. Furthermore, it's about selecting the most appropriate hardware components and connecting them in the best way to build computers that can deliver a certain functionality with the highest performance and with the lowest cost possible.

Difference between Computer Architecture and Organization

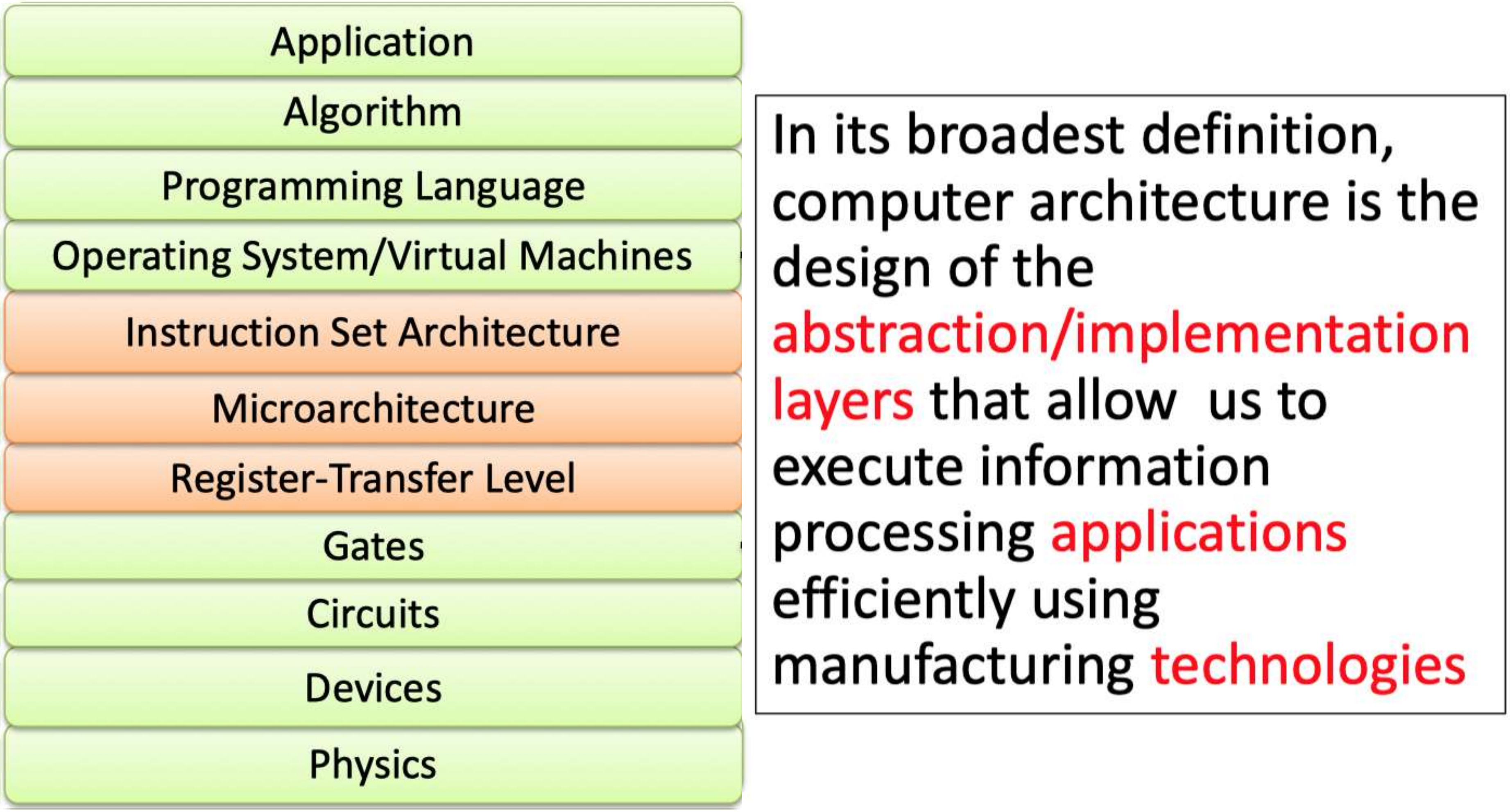
- Computer Architecture
  - Refer to those attributes of the system visible to a programmer or those attributes that have direct impact on the logical execution of a program
    - Examples : Instruction Set, number of bits for different data types, I/O mechanisms, techniques of memory addressing
- Computer Organization
  - Refer to operational units and their interconnections that realize their architectural specifications.
    - Examples : Hardware details transparent to programmers, such as control signals, interfaces between computer and peripherals, and memory technology used

Another Definition

- **Computer Architecture:** The science and art of designing, selecting, and interconnecting hardware components and designing the hardware/software interface to create a computing system that meets functional, performance, energy consumption, cost, and other specific goals.

- **Traditional definition:** “The term architecture is used here to describe the attributes of a system as seen by the programmer, i.e., the conceptual structure and functional behavior as distinct from the organization of the dataflow and controls, the logic design, and the physical implementation.” Gene Amdahl, IBM Journal of R&D, April 1964

What is Computer Architecture?



Application

Algorithm

Programming Language

Operating System/Virtual Machines

Instruction Set Architecture

Microarchitecture

Register-Transfer Level

Gates

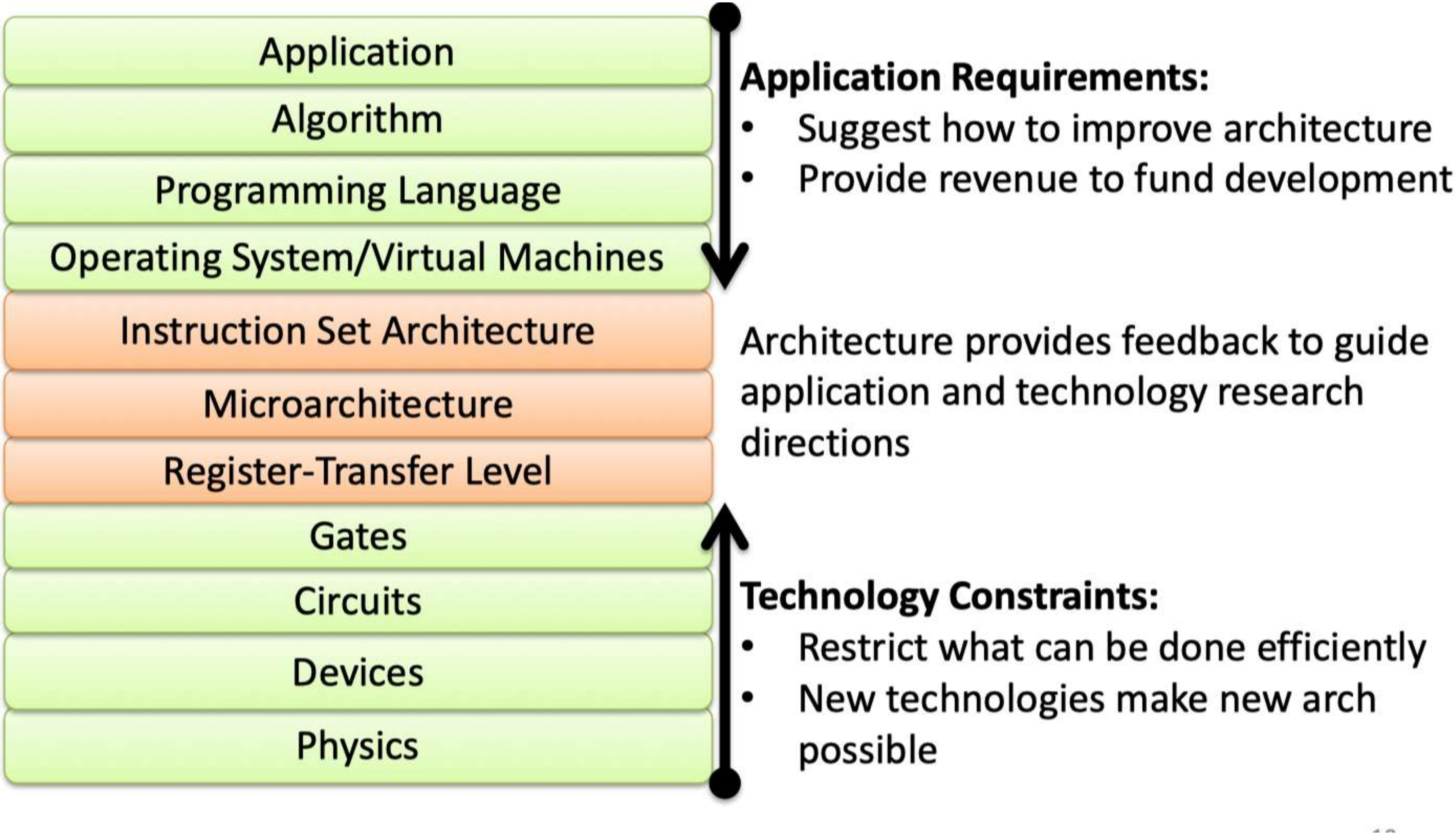
Circuits

Devices

Physics

In its broadest definition, computer architecture is the design of the abstraction/implementation layers that allow us to execute information processing applications efficiently using manufacturing technologies

Computer Architecture is Constantly Changing



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Application Requirements:

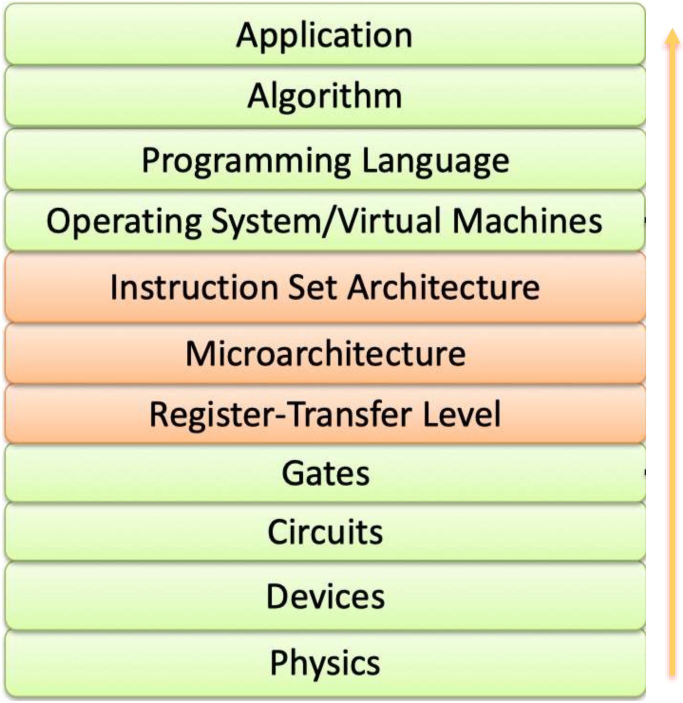
- Suggest how to improve architecture
- Provide revenue to fund development

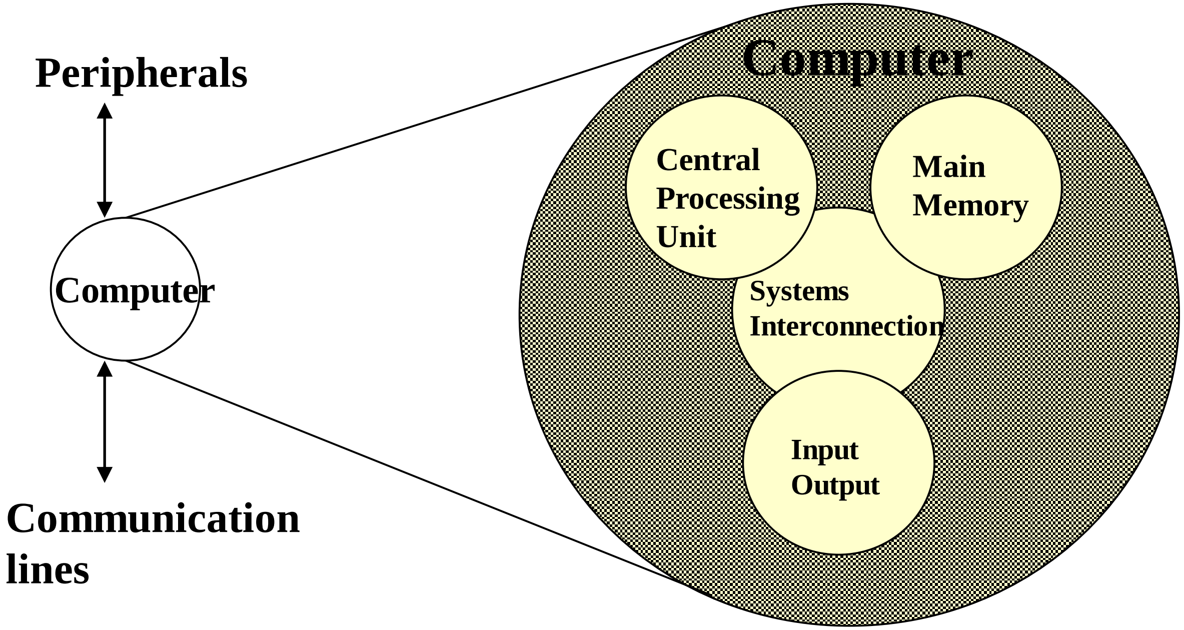
Architecture provides feedback to guide application and technology research directions

Technology Constraints:

- Restrict what can be done efficiently
- New technologies make new arch possible

Computer Architecture : Abstractions Vs Hierarchy





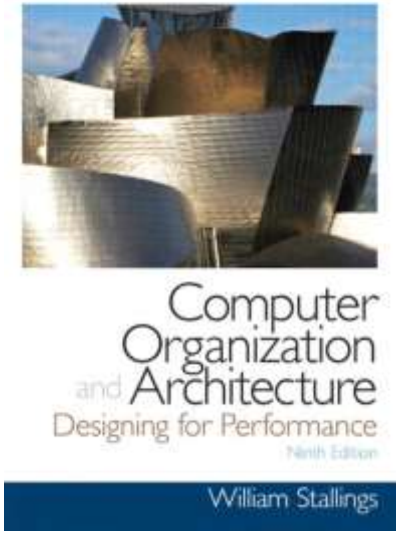
Abstractions Levels

Hierarchy Levels

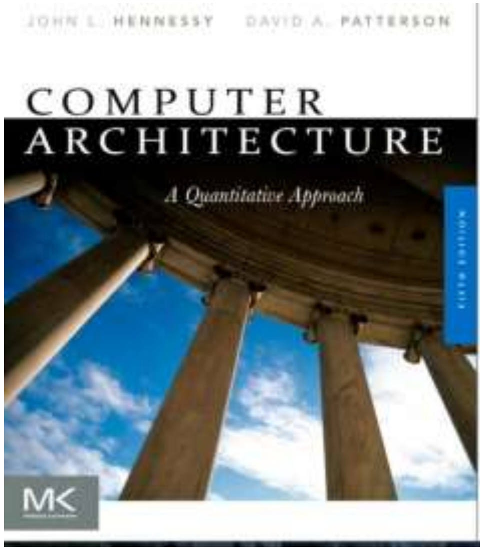
Reference Books

Text Books

COMPUTER ORGANIZATION AND DESIGN
THE HARDWARE/SOFTWARE INTERFACE
RISC-V EDITION
DAVID A. PATTERSON
JOHN L. HENNESSY
MK


Computer Organization and Architecture
Designing for Performance
Ninth Edition
William Stallings

Reference Books



Learning Objectives feedback

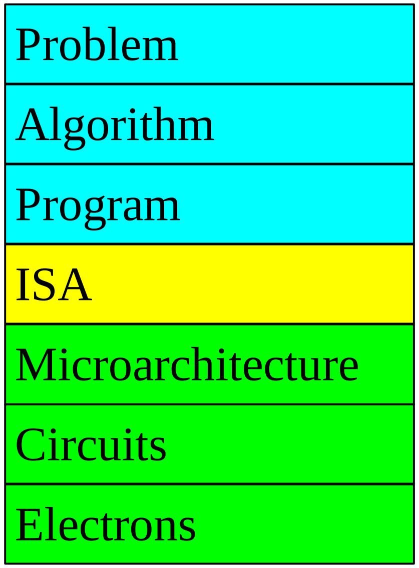
- Differentiate the term Computer Architecture and Computer Organisation
- Understand two important concepts of Abstraction and Hierarchy

Lecture Review

- The Goal?
  - Get a deeper understanding of how computers work, analyse the performance. How the programs are translated to hardware, which help in writing optimised codes
- Computer architecture?
  - It is the science and art of selecting and interconnecting hardware components to create computers that meet functional, performance, and cost goals.
- Abstraction?
  - Higher Abstraction means hiding details

ISA vs. Microarchitecture

- ISA (Instruction Set Architecture)
  - Agreed upon interface between software and hardware
    - SW/compiler assumes, HW promises
  - What the software writer needs to know to write and debug system/user programs
- Microarchitecture
  - Specific implementation of an ISA
  - Not visible to the software
- Microprocessor
  - **ISA, uarch**, circuits
  - "Architecture" = ISA + microarchitecture



Problem

Algorithm

Program

ISA

Microarchitecture

Circuits

Electrons

A Note on Hardware vs. Software

- However, you will be much more capable if you master both hardware and software (and the interface between them)

  - Can develop better software if you understand the underlying hardware
  - Can design better hardware if you understand what software it will execute
  - Can design a better computing system if you understand both

- Computer Architecture covers the HW/SW interface and microarchitecture

Why Study Computer Architecture?

- Enable better systems: make computers faster, cheaper, smaller, more reliable, …
    - By exploiting advances and changes in underlying technology/circuits

- Enable new applications
    - Life-like 3D visualization 20 years ago?
    - Virtual reality?
    - Personalized genomics? Personalized medicine?

- Enable better solutions to problems
    - Software innovation is built into trends and changes in computer architecture
        - > 50% performance improvement per year has enabled this innovation

- Understand why computers work the way they do

Computer Architecture Today

- Today is a very exciting time to study computer architecture

- Industry is in a large paradigm shift (to multi-core and beyond) – many different potential system designs possible

- Many difficult problems motivating and caused by the shift
  - Power/energy constraints → multi-core?
  - Complexity of design → multi-core?
  - Difficulties in technology scaling → new technologies?
  - Memory wall/gap
  - Reliability wall/issues
  - Programmability wall/problem
  - Huge hunger for data and new data-intensive applications

- No clear, definitive answers to these problems

Related Courses

- Digital Logic and Design
- Digital System Design
- Computer Architecture and Organization
- Microprocessor Based Systems
- Embedded Systems
  - Controls
  - Communications
  - Electronics/Power Electronics
  - Multimedia Processing
  - Any other Simple or Complex system
- Compilers and Operating Systems
- High Performance Computing

I Hope you enjoy the Study of Computer Architecture

THE END