What is Computer Architecture?

Architecture
• the interface between the hardware & lowest levels of the software
  • model of the hardware
  • contract between the hardware & software
• instruction set architecture
  • instructions:
    • operations
    • operands, addressing the operands
    • how instructions are encoded
• storage locations for data
  • registers: how many & what they are used for
  • memory: its size & how it is accessed
• I/O devices & how to access them
• software conventions:
  • subroutine calls: who saves the registers, which ones are saved
  • passing arguments: in registers? on the stack?

What is Computer Organization?

Organization (or Microarchitecture)
• basic components of a computer
  • on the CPU (ALU, registers, PC, etc.)
  • memory (levels of the cache hierarchy)
• how they operate
• how they are connected together

Organization is mostly invisible to the programmer
• today some components are considered part of the architecture
• why? because a programmer can get better performance if he/she knows the structure
• for example: the caches, the pipeline structure
Separate Architecture & its Organization

Why separate architecture & organization?
- many implementations for 1 architecture
  - family of implementations: sequences of machines that have the same ISA
    - MIPS R2000, R3000, R12000
    - Intel x86, Pentium series
    - IBM 360/85, 360/91, 370s

⇒ different points in the cost/performance curve
⇒ share software development costs
⇒ binary compatible: same software could run on all machines
⇒ open architecture: third party software

Different Architectures

Why have different architectures?
- different architecture philosophies & therefore different styles
  - support high level language operations: CISC
  - support basic primitive operations: RISC
- different application areas
  - example: multimedia instructions
- “ours is better” within the same style
Basic Architectural Design Principles

Design for the common case & make it fast

• common cases in hardware, uncommon cases in software
• make the common case hardware fast, even if it slows down the uncommon cases
• if a feature is not the common case, must have a good reason for adding it
• examples:
  • basic floating point operations in hardware
  • software library function for the cosine routine
  • memory access in hardware
  • trap to software for a page fault

Why does this principle work?

• executing in hardware is faster than emulating in software
• Amdahl’s Law: performance gain due to a hardware feature is limited by the fraction of time the feature is used

Smaller is faster

• examples:
  • memory hierarchy: registers, caches, main memory
  • distributed rather than centralized designs

Keep it simple

• simplicity leads to smaller, regular designs and shorter design & debug time
• example: RISC instructions are all 32 bits

Good design demands compromise

• trade-off in instruction format between
  • the size of the register file (how many bits are needed to specify a register) &
  • the number of operations (how many bits are needed to specify an instruction)
• trade-off between register (or cache) size & cycle time
Assembly Language

Symbolic form of computer machine language

• advantages for us
  • learn at the machine level what a computer does
  • thorough understanding through a hands-on experience
  • easier for humans to understand than patterns of 1’s & 0’s

• where assembly language is used in practice
  • things that aren’t expressible in a high-level language
    example: subroutine linkage
  • privileged tasks
    example: programs that need access to protected registers (I/O)
  • size-critical applications
    example: programs for embedded processors
  • time-critical applications
    example: real-time applications, OpenGL library

• why assembly language is not widely used
  • lower programmer productivity
    example: longer coding time, more debugging
  • optimizing compilers can produce almost the same quality code
  • not portable across architectures

Still Lower

Implementation

• design of organizational components or microarchitecture

Technology

• semiconductor material
  for example: silicon

• circuit technology (how build gates from transistors)
  for example: CMOS

• packaging
  for example: pin-grid array

• generation
  for example: vacuum tubes, VLSI