CSE 240 -- Principles of Computer Architecture

Fall Quarter, 1998

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UCSD

Computer Architecture is... ???

Computer Architecture is... ???

- Computer Architect (building architect)
  - high-level design
  - organization
  - functionality
  - performance
- Hardware Designer (builder, construction engineer)
  - materials
  - implementation details

Computer Architecture is... ???

- the first computer science discipline
- Eckert and Mauchly, the first computer scientists, were computer architects, as was John von Neumann and Maurice Wilkes

Computer Architecture is... ???

- Instruction Set Design
- Computer Organization

Computer Architecture is... ???

- That part of the machine that is visible to the user (programmer/compiler-writer/OS writer/user)
  - the software interface (Instruction Set Design)
  - performance (Computer Organization)

Computer Architecture is... ???

PERFORMANCE!!!!!

Why do I care?

- **You may actually do computer architecture someday**
- **You may actually care about software performance someday**
  - The ability of application programs, compilers, operating systems, etc. to deliver performance depends critically on an understanding of the underlying computer organization.
  - That becomes more true every year.
  - Computer architectures become more difficult to understand every year.

Which is faster?

```
for (i=0; i<N; i=i+1)
  for (j=0; j<N; j=j+1) {
   r = 0;
    for (k=0; k<N; k=k+1)
      r = r + y[i][k] * z[k][j];
   x[i][j] = r;
    }
```

```
for (jj=0; jj<N; jj=jj+B)
for (kk=0; kk<N; kk=kk+B)
for (i=0; i<N; i=i+1) {
  for (j=jj; j<min(jj+B-1,N); j=j+1)
    r = 0;
     for (k=kk; k<min(kk+B-1,N); k=k+1)
       r = r + y[i][k] * z[k][j];
    x[i][j] = x[i][j] + r;
     }
```


Which is faster?

```
load R1, addr1
store R1, addr2
add R0, R2 -> R3
subtract R4, R3 -> R5
add R0, R6 ->R7
store R7, addr3
```

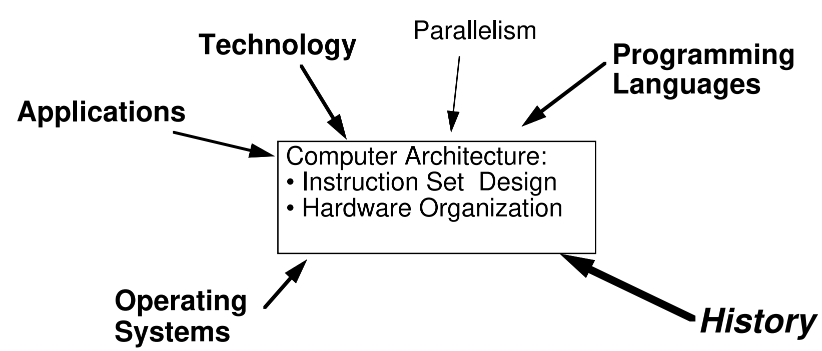
```
load R1, addr1
add R0, R2 -> R3
add R0, R6 -> R7
store R1, addr2
subtract R4, R3 -> R5
store R7, addr3
```


Which is faster?

```
loop1:  add ...
        load ...
        add ...
        bne R1, loop1
loop2:  add ...
        load ...
        bne R2, loop2
```

```
loop1:  add ...
        load ...
        add ...
        bne R1, loop1
        nop
        nop
loop2:  add ...
        load ...
        bne R2, loop2
```


The Forces on Computer Architecture



Administration

- Who are you?
- Who am I?   Instructor -- Dr. Dean Tullsen
- syllabus, other details

What is Computer Architecture?

Computer Architecture =
Machine Organization +
Instruction Set Architecture

What the machine looks like

How you talk to the machine

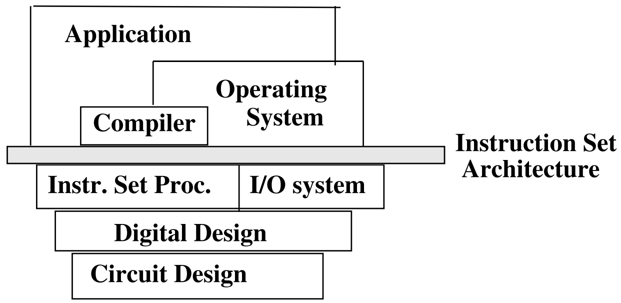
The Instruction Set Architecture

- that part of the architecture that is visible to the programmer
  - opcodes (available instructions)
  - number and types of registers
  - instruction formats
  - storage access, addressing modes
  - exceptional conditions

Examples of ISAs

- Alpha AXP
- 80x86/pentium
- VAX
- MIPS
- SPARC
- IBM 360
- ...

The Instruction Set Architecture



•ISA provides a *level of abstraction* for both the hardware and the software

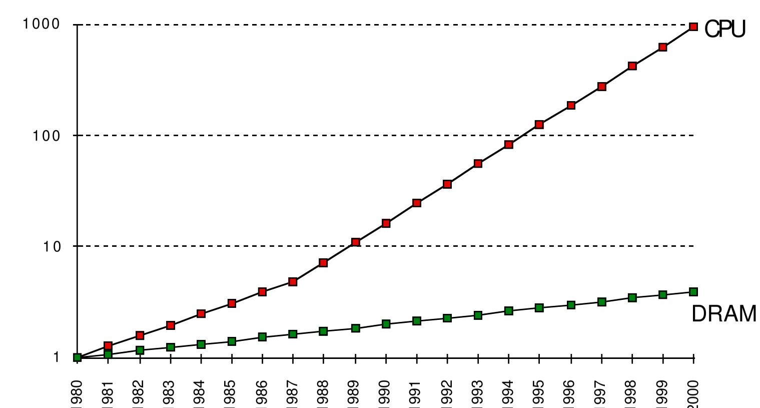
Computer Organization

- Once you have decided on an ISA, you must decide how to design the hardware to execute those programs written in the ISA as fast as possible.
- This must be done every time a new implementation of the architecture is released, with typically very different technological constraints.

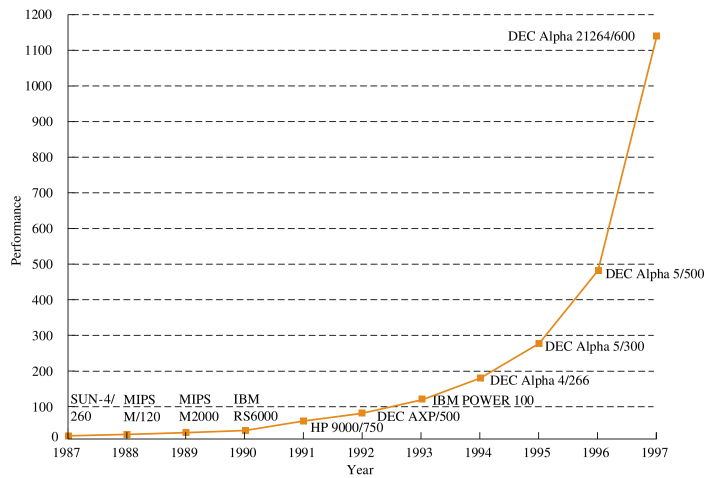
The Challenge of Computer Architecture

- This industry changes faster than any other.
- The ground rules change every year.
  - new problems
  - new opportunities
  - different tradeoffs
- It's all about making programs run faster than the next guy's machine.

Performance Trends



Processor Performance



A Workstation Architecture

MIPS R10000 CPU

MIPS R10000 CPU

PowerPC 604e

Course Outline

I. Introduction
II. Computer System Performance
III. Instruction Set Architecture
IV. Pipelining
V. Instruction-Level Parallelism
VI. The Memory/Cache Hierarchy
VII. Parallel Machines

What you can expect to get out of this class

- to become conversant with computer architecture terms and concepts.
- to understand fundamental concepts in computer architecture and how they impact computer and application performance.
- to be able to read and evaluate architectural descriptions of even today's most complex processors.
- to learn experimental techniques used to evaluate advanced architectural ideas. In other words, to do architecture research!

Key Points

- Computer Architecture defines the software-visible machine description (ISA) and the overall machine organization.
- High-performance software requires a deep understanding of the underlying machine organization.
- The instruction set architecture defines how software is allowed to use the processor. Multiple computers with vastly different organizations and performance can share an ISA.
- We can't improve performance unless we can quantify it, model it, and argue about it.