CS2410: Computer Architecture

Principles of computer architecture & design

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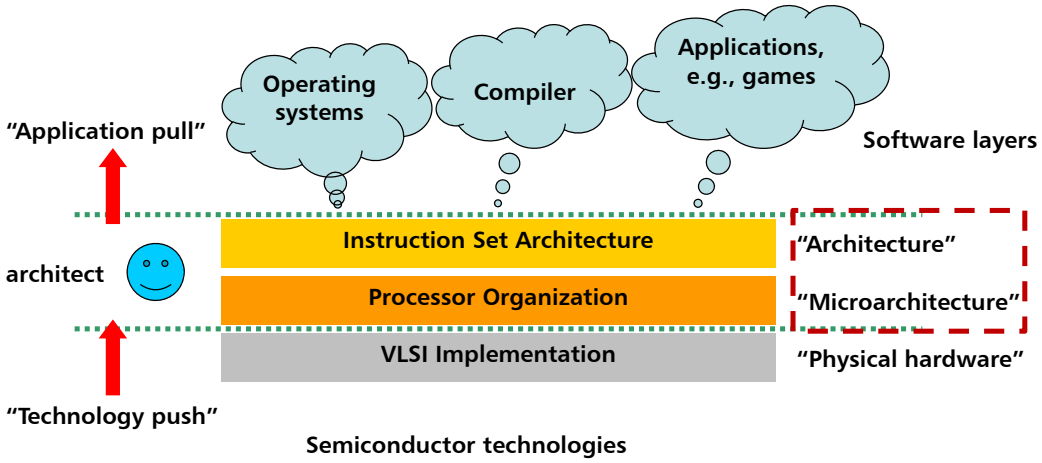
Dynamicity in computer architecture

- New technologies are developed and deployed continuously
  - Examples: cheaper & faster transistors (Moore's Law), storage class memory (best of DRAM and NAND flash), LCD and OLED displays, …
  - They expand the capabilities of a computer at a lower price
  - "Technology push"
- Need for new, more exciting applications call for higher computer performance and more capabilities
  - Examples: realistic 3D graphics based games, intelligent mining & management of large volumes of data (e.g., movies), …
  - "Application pull"
- Nonetheless, there are certain characteristics in computer design that appear to remain

Dynamicity in computer architecture



Asymmetry

- In a sense, computer architecture is all about how to overcome and/or exploit "asymmetry" present in computer hardware resources and software artifacts
- Can you give an example?

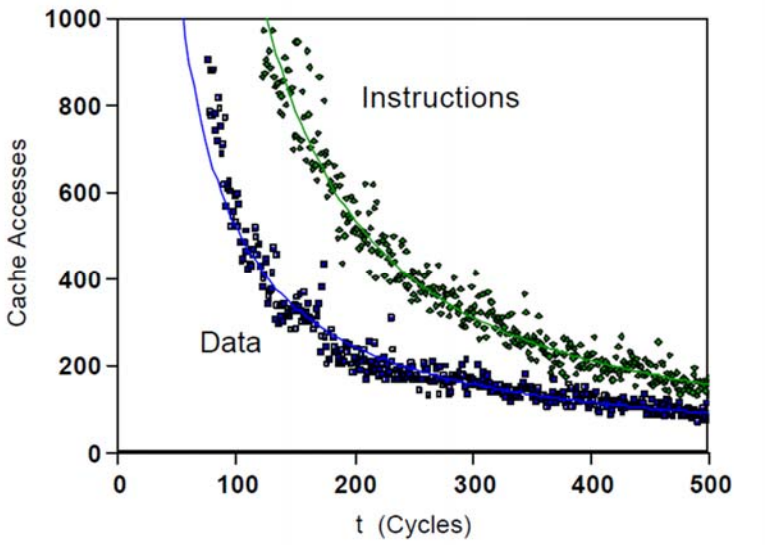
Asymmetry in hardware resources

- CPU operation latencies
  - ADD vs. DIV
- CPU speed vs. memory speed improvement rates
- Memory technology
  - SRAM latency vs. DRAM latency
- Main memory organization
  - Non-Uniform Memory Architecture (NUMA)
- On-chip shared L2 cache organization
  - Non-Uniform Cache Architecture (NUCA)
- Storage
  - Hard disk access (which block is read now and which block is next?)
  - SLC (single-level cell) vs. MLC (multi-level cell) NAND flash

Asymmetry in software behavior

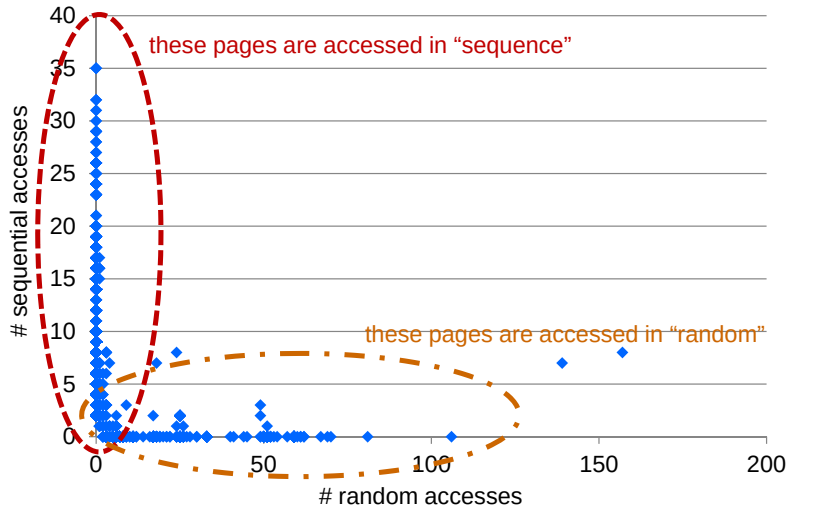
- 90/10 rule
  - Code repetition
- Memory access locality
  - Temporal
  - Spatial
- Working set & miss rate
- Storage access locality

Temporal locality example



Hartstein et al. JILP 2008

Sequential vs. random writes



“FINANCIAL1 TRACE”

Hashing

- Oftentimes, we need to collect & accumulate program execution information so that we can make informed decisions on resource usages
  - Branch prediction
  - Cache memory
- Information storage & retrieval mechanisms should be simple to enable efficient implementation
- What is hashing? ;-)
- Let's take a look at how "memory" is organized at this point

Parallelism

- The key enabler for performance improvement in computer architecture is to uncover and exploit parallelism
  - Draw of graph (V,E) where nodes represent a task and edges show dependences
- Examples
  - Pipelining
  - Multicore designs
  - Memory-level parallelism (superscalar processor)
  - Interleaved memory
  - Interleaved cache
  - RAID
  - Multiple channels in SSDs
  - …

Amdahl's law

- Optimization or parallelization usually applies to a portion
  - Places "limitation" of the scope of an optimization
  - Leads us to focus on "common cases"
  - "Make common case fast and rare case accurate"