Memory Hierarchy: locality, and storage technologies

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April 1, 2021
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Announcements

Cache, memory, storage, and network hierarchy trends
- Static random-access memory (caches)
- Dynamic random-access memory (main memory)
- Solid state and hard disk drives (storage)

Locality: How to create illusion of fast access to capacious data
- Spatial locality
- Temporal locality
Looking ahead

Class plan

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Cache, memory, storage, and network hierarchy trends

- Assembly programming view of computer: CPU and memory.
- Full view of computer architecture and systems: +caches, +storage, +network

Figure: Memory hierarchy. Image credit CS:APP
Cache, memory, storage, and network hierarchy trends

Figure: Widening gap: CPU processing time vs. memory access time. Image credit CS:APP

Topic of this chapter:

- Technology trends that drive CPU-memory gap.
- How to create illusion of fast access to capacious data.
Static random-access memory (caches)

- SRAM is bistable logic
- Access time: 1 to 10 CPU clock cycles
- Implemented in the same transistor technology as CPUs, so improvement has matched pace.

Figure: SRAM operating principle. Image credit Wikimedia
Dynamic random-access memory (main memory)

- Needs refreshing every 10s of milliseconds
- 8GB typical in laptop; 1TB on each ilab machine
- Memory gap: DRAM technological improvement slower relative to CPU/SRAM.

Figure: DRAM operating principle. Image credit ocw.mit.edu
CPU / DRAM main memory interface

Figure: Memory Bus. Image credit CS:APP

- DDR4 bus standard supports 25.6GB/s transfer rate

Figure: Intel 2020 Gulftown die shot. Image credit AnandTech
Solid state and hard disk drives (storage)

Technology

- SSD: flash nonvolatile memory stores data as charge.
- HDD: magnetic orientation.

For in-depth on storage, file systems, and operating systems, take:

- CS214 Systems Programming
- CS416 Operating Systems Design

Over the summer, LCSR (admins of iLab) will be moving the storage systems that supports everyone’s home directories to SSD. [https://resources.cs.rutgers.edu/docs/file-storage/storage-technology-options/](https://resources.cs.rutgers.edu/docs/file-storage/storage-technology-options/)
I/O interfaces

Storage interfaces

- SATA 3.0 interface (6Gb/s transfer rate) typical
- PCIe (15.8 GB/s) becoming commonplace for SSD
- But interface data rate is rarely the bottleneck.

For in-depth on computer network layers, take:

- CS352 Internet Technology

Figure: I/O Bus. Image credit CS:APP
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  Spatial locality
  Temporal locality
Locality: How to create illusion of fast access to capacious data

From the perspective of memory hierarchy, locality is using the data in at any particular level more frequently than accessing storage at next slower level.

Well-written programs maximize locality

- Spatial locality
- Temporal locality
Spatial locality

Programs tend to access adjacent data.
Example: stride 1 memory access in a and b.
Temporal locality

Programs tend to access data over and over.

Example: \texttt{sum} gets accessed \texttt{N} times in iteration.