NYU | Center for Data Science

Week 01.2: Storage and computation

DS-GA 1004: Big Data

Instructor: Brian McFee

What are our resources?

- **Storage**
  - Where and how is data kept?
  - How much data can we keep?
- **Computation**
  - How quickly can we process data?
- **Communication**
  - How quickly can we move data between locations?

The cost of storage over time...

$3398
10MB

THE HARD DISK YOU'VE BEEN WAITING FOR

XCOMP introduces a complete micro-size disk subsystem with more...

- MORE STORAGE
- MORE SPEED
- MORE VALUE
- MORE SUPPORT

S100 users . . . The XCOMP subsystem is now available with 10 megabytes of storage; 5 megabytes also available at $2,898.00. Compare the price and features of any other 5¼-inch — or even 8-inch system, and you'll agree that XCOMP's value is unbeatable.

OUTPERFORMS OTHER HARD DISKS

Floppy disk and larger, more expensive hard disks are no match for this powerful little system. More data is available on every seek: 64K on 10MB and 32K on 5MB. Faster seek time too — an average of 70MS. It provides solid performance anywhere with only 20 watts of power. Data is protected in the sealed enclosure, and the landing zone for heads provides another margin of safety. The optional power board plugs directly into the S100 bus and provides power for the drive.

FAST CONTROLLER

The XCOMP controller is the key to this system's high efficiency operation. Speed-up features include interleave without table lookup, block-deblock with controller buffer, and read lookahead. OEMs worldwide have already proven the outstanding performance of the XCOMP controller.

MORE SOFTWARE

Included with the system is software for testing, formatting, I/O drivers for CP/M®, plus an automatic CP/M driver attach program. Support software and drivers for MP/M®, and Oasis® are also available. The sophisticated formatting program assigns alternate sectors for any weak sectors detected during formatting, assuring the lowest possible error rate — at least ten times better than floppies.

WARRANTY

The system has a full one-year warranty on parts and workmanship.

ALSO AVAILABLE FROM XCOMP

- General Purpose controllers (8 bit interface), with easy interface to microprocessor-based systems.
- GP controller adapter that plugs directly into most Z80 computers.
- ST/R GP controller for the 5MB and 10MB drive above, with ST506 type interface.
- SG/R GP controller for SA1000 interface.
- SM/R GP controller for storage module drives.
- ST/S, SG/S, and SM/S, same as above, for the S100 bus.

Quantity discounts available. Distributor, Dealer, and OEM inquiries invited.

See your local Dealer, or call:

XCOMP

XCOMP, Inc.
7566 Trade Street
San Diego, CA 92121
Tel. (714) 271-8730
Telex: 182786

Circle 405 on inquiry card.

= $10,442 in 2022

Byte Magazine, Vol. 6, No. 8 (1981/08)

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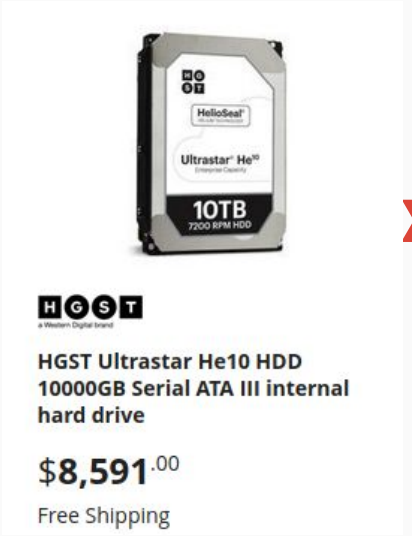


HGST
a Western Digital brand

HGST Ultrastar He10 HDD 10000GB Serial ATA III internal hard drive

$8,591.00

Free Shipping

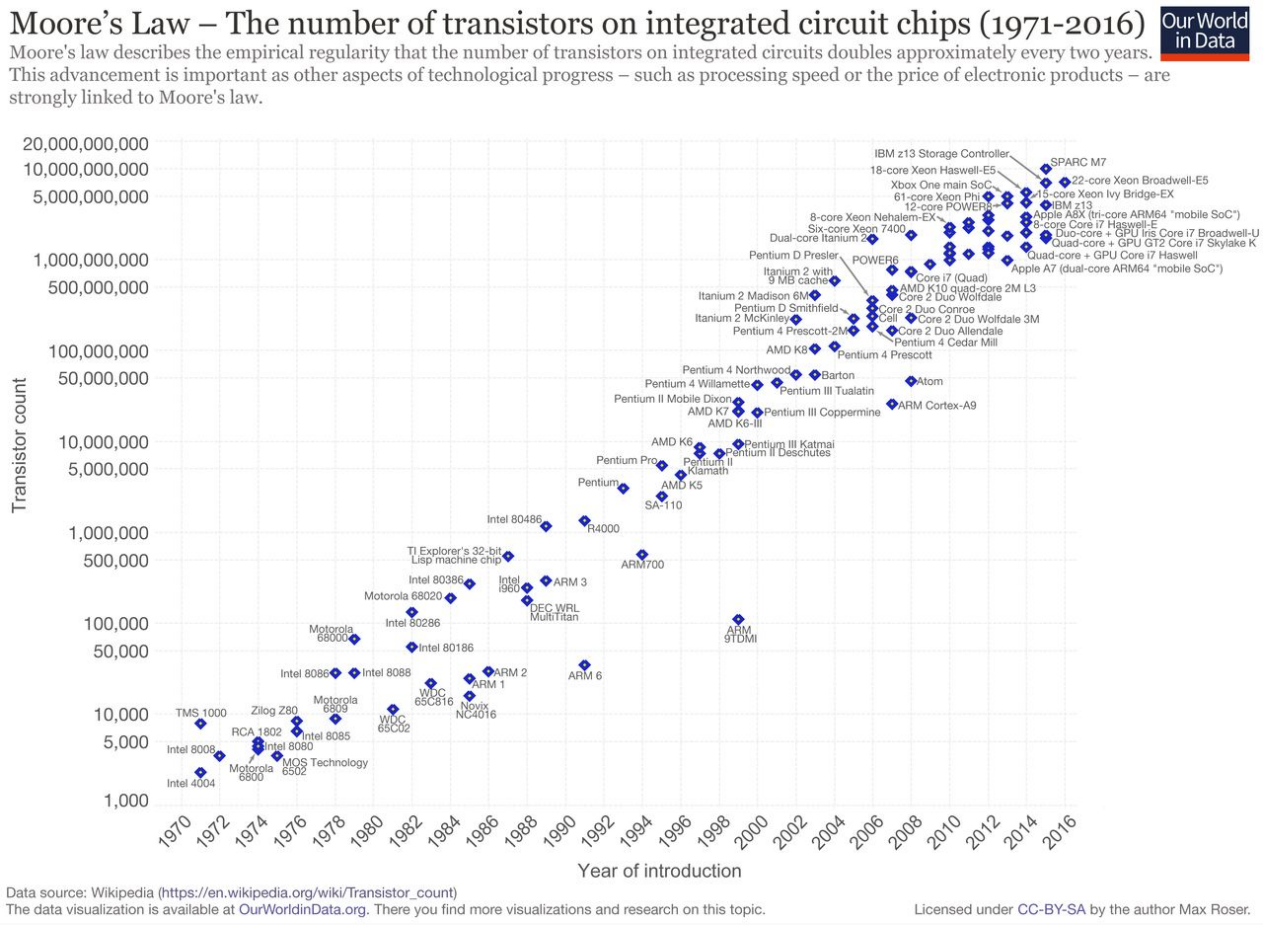
x20

Byte Magazine, Vol. 6, No. 8 (1981/08)

NewEgg.com (2022/01)

Volume and velocity

- (2019) Facebook generates 4 Petabytes (4e15 bytes) of new data per day
  https://research.fb.com/facebook-s-top-open-data-problems/
- (2019) YouTube collects 300 hours of HD video every minute
  http://www.businessofapps.com/data/youtube-statistics/
- (2017) Twitter stores >500PB of data
  https://blog.twitter.com/engineering/en_us/topics/infrastructure/2017/the-infrastructure-behind-twitter-scale.html
- (2017) CERN data center: > 200PB
  https://home.cern/news/news/computing/cern-data-centre-passes-200-petabyte-milestone

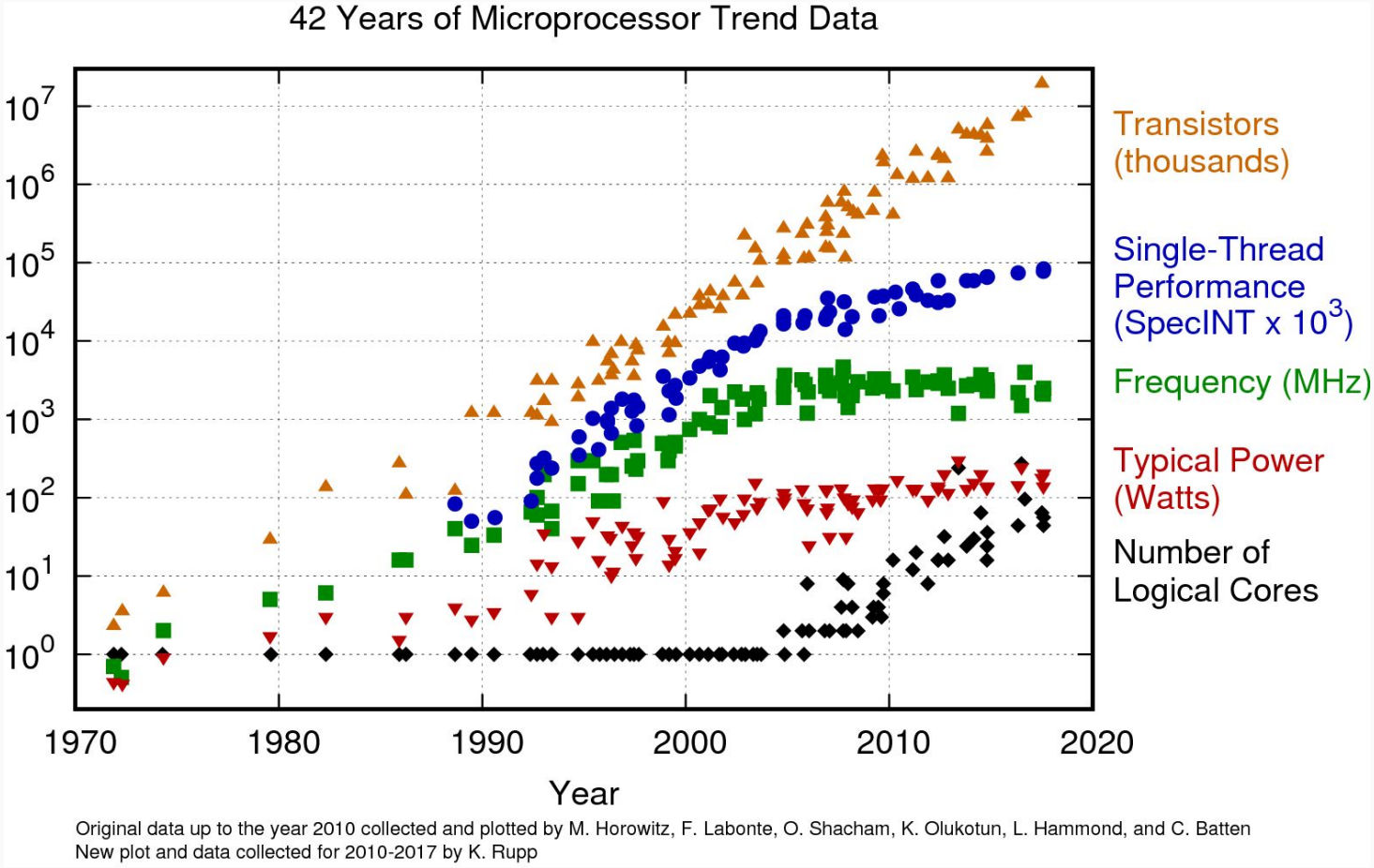


Note: transistor count ≠ speed!

Moore in 2015:

"I see Moore's law dying here in the next decade or so."

Gordon Moore (1965, 1975)



Gains now come from **parallelism** (multi-core), not **clock speed.**

https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/

What does this tell us?

- Storage capacity (per $) continues to increase
- Data velocity is increasing
- CPU speed is not keeping up

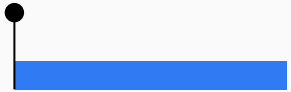
In pioneer days, they used oxen for heavy pulling, and when one ox couldn’t budge a log, they didn’t try to grow a bigger ox.

We shouldn’t be trying for bigger computers, but for more ***systems of computers***.

Grace Hopper (1906-1992)

File systems

Custom software for
each application / query



1960s

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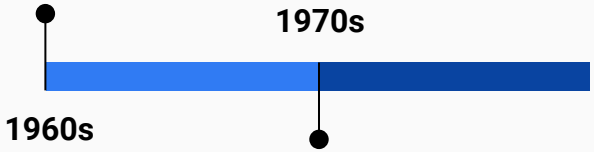

Relational model (Codd, 1970)

Tables are good!

Structured Query Language (SQL)

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RDBMS takes off

Databases for commodity computers

SQL standardizes

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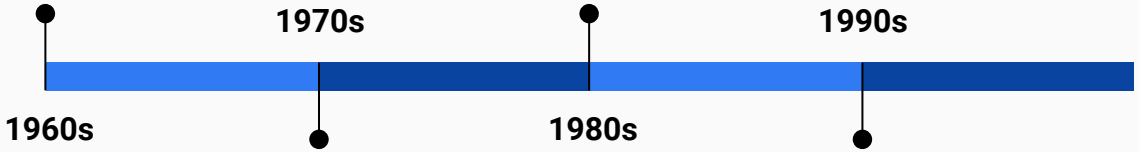

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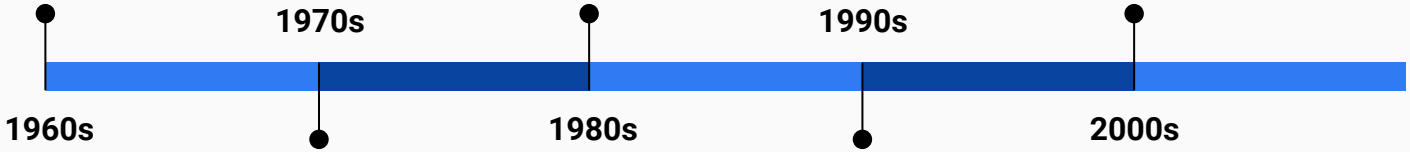
Simpler abstractions for distributed computation and storage



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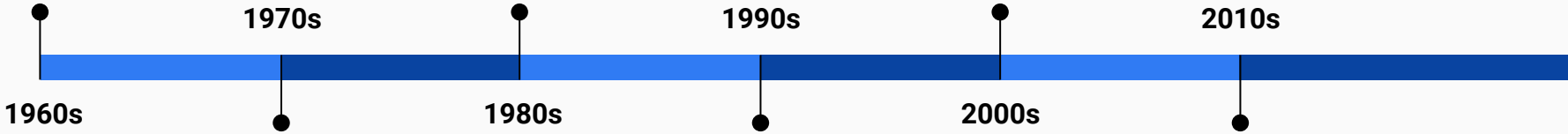

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THE CLOUD ERA

Flexible cluster management

High-level languages

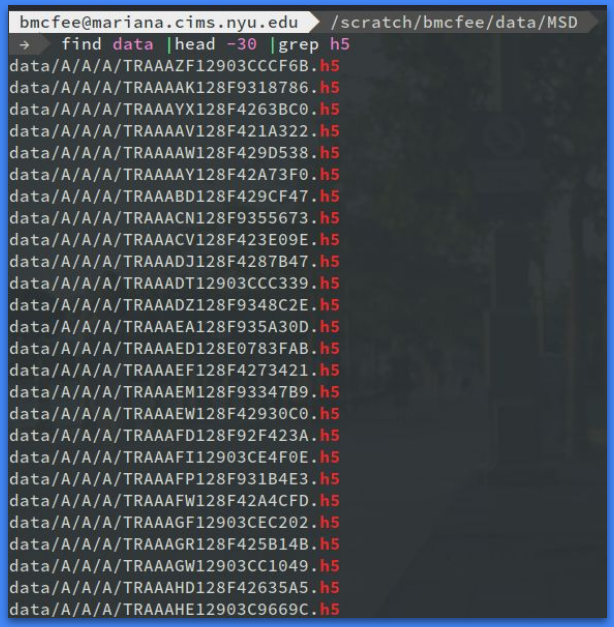
Focus on interactivity

Starting at the beginning

File systems!

- To understand modern tools, it helps to understand the previous generation.
- What problems did people face in designing:
  - Relational databases?
  - Map-reduce?
  - Spark?
  - Dask?

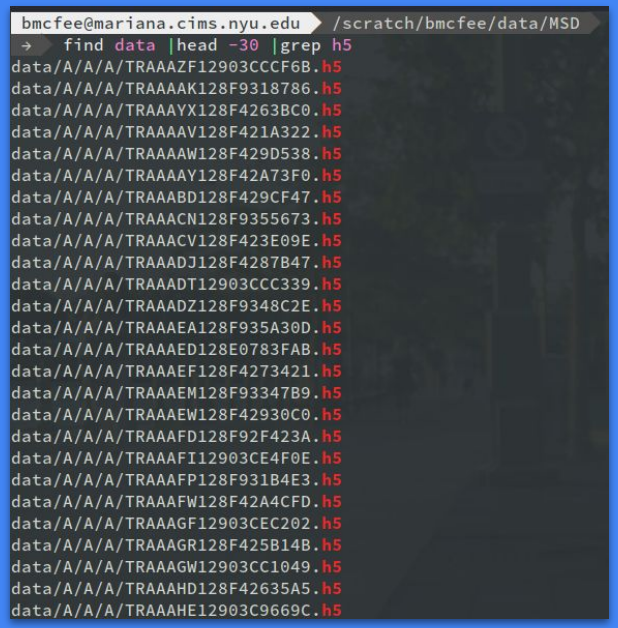
File systems



- Use directories to organize your data
- Structured data can be stored as files

  ⇒ data persists across application runs

File systems



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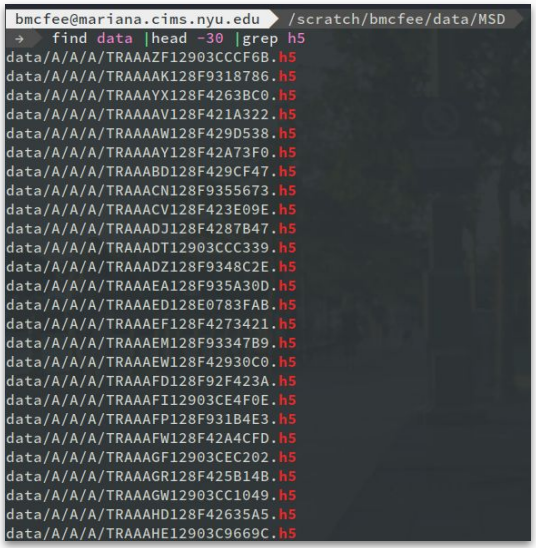
  ⇒ data persists across application runs
- Some great properties:
  - **Easy** to implement
  - **Portable** across systems
  - Network file systems (NFS) enable **limited distributed processing**

File systems can be awesome!

- If the data doesn't have obvious structure to index
  - Or if your data is naturally organized by the file system (**name** and **time**)
  - E.g., system logs
- **Or** if indexing isn't worth the cost
  - E.g., one-off jobs
- **Or** if you want maximum portability across platforms

Reasons not to rely (only) on file systems

- Does not expose or exploit the structure of data
  - What if I want to search by file contents?
    Better options than brute force?
- Each query / analysis required writing a new program
  - Little re-usability between similar analyses
  - Or the same analysis with slightly different data structures
- Directory hierarchies may be too restrictive
- Practical limitations of filesystems (inode count, etc)



When are file systems not awesome?

- When your data is structured along multiple axes
- When data have complex interactions
- When your analyses are complex
- When the benefits of indexing outweigh the costs
  - E.g., finding items in sub-linear time
- **Relational databases to the rescue!**

Databases did not replace file systems

- File archives are still the most common way to share large datasets
  - But we usually include some metadata/indexing structure as well
- As we'll see soon, **Hadoop** relies on a distributed file system
  - DB abstractions can be built on top
  - But this comes with restrictions on file contents
- Key differences now:
  - Standardized (restricted) file formats ("CSV", Parquet, HDF5, NPY, etc.)

Next week

Relational databases

- Structure can be a very good thing!
- Relational model and SQL
- Databases as a service