Administrivia

Project 1 Part 3 due Monday!

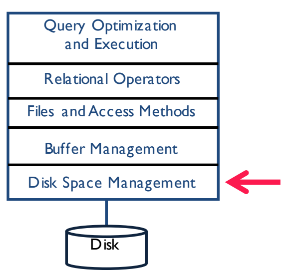
Sign up to meet with your staff members

L18

Query Performance 1:

Disk, Storage, and Indexing

Work from the bottom up



$ Matters

Why not store all in RAM?

- Costs too much
  - High-end Databases today ~Petabyte (1000TB) range.
  - ~60% cost of a production system is in the disks.
- Main memory not persistent
  - Obviously important if DB stops/crashes

Some systems are *main-memory* DBMSes, topic for advanced DB course

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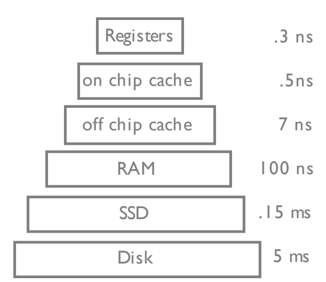
$ Matters

Newegg enterprise $1000
- RAM: 64-96 GB
- SSD: 400-1000
- Disk: 24000

RAM for active data

Disk for main database
- secondary storage

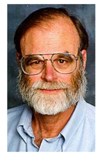
Tapes for archive

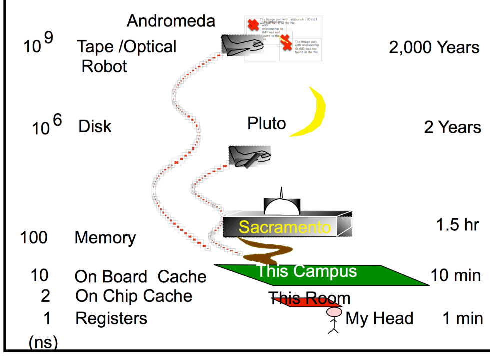


Interesting numbers
- compress 1k bytes: 3000 ns
- roundtrip in data center: .5 ms

https://gist.github.com/jboner/2841832

Jim Gray's Storage Latency Analogy: How Far Away is the Data?

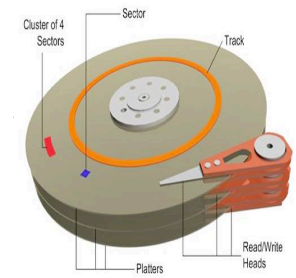




Jim Gray
Turing Award
B.S. Cal 1966
Ph.D. Cal 1969!

Spin speed: ~7200 RPM

Arm moved in/out to position head over a track



Time to access (read or write) a disk block
- seek time: 2-4 msec avg (arm movement)
- rotational delay: 2-4 msec (based on rotation speed)
- transfer time: 0.3 msec/64kb page
- transfer time: 4-8 msec/1MB of data

Throughput
- read: ~150 MB/sec
- write: ~50 MB/sec

Key: reduce seek and rotational delays
- HW & SW approaches

Pre-fetching

Next block concept (in order of speed)
- blocks on same track
- blocks on same cylinder
- blocks on adjacent cylinder

Sequentially arrange files
- minimize seek and rotation latency

When sequentially scanning: Pre-fetch
- >1 page/block at once

SSD versus Hard Drives

Disks are not dead!

	HDD WD Black 6 TB	SDD Samsung 850 Pro	SDD Factor
Sequential Throughput	214 MB/s	496 MB/s	2.3X
Random Throughput	0.5 MB/s	273 MB/s	546X
Random IO Latency	4800 us	8 us	600X
$/GB	$0.05	$0.46	0.1X

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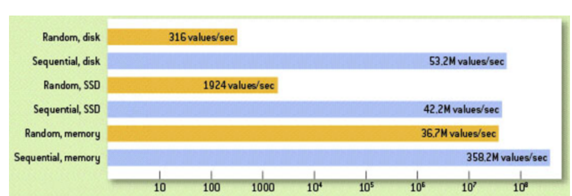
4 byte values read per second



5 orders of magnitude

Pragmatics of Databases

Most databases are pretty small
- All global daily weather since 1929: 20GB
- 2000 US Census: 200GB
- 2009 english wikipedia: 14GB

Data sizes grow faster than Moore's law:
- Record everything; storage is cheap?

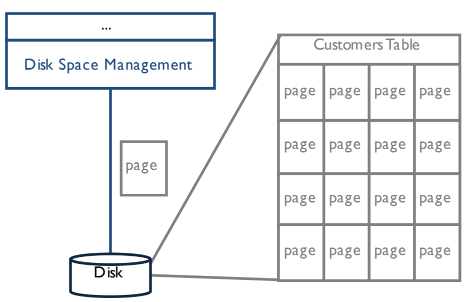
Disk Space Management

Small DB ⟷ VLDB

← Most Interesting Data → | Massive Companies

← Memory is good enough → | Disk Matters

Work from the bottom up



What is a page?

Unit of transfer between storage and database
Typically fixed size
Small enough for one I/O to be fast
Big enough to not be wasteful

Usually a multiple of 4 kB
- Intel virtual memory hardware page size
- Modern disk sector size (minimum I/O size)

Default pages sizes in DBs

SQLite:	1 kB
IBM DB2:	4 kB
Postgres:	8 kB
SQL Server:	8 kB
MySQL:	16 kB
MongoDB (Wired Tiger):	32 kB

Disk Space Management

Manages space on disk, IO, and caching

Sequential performance desirable
- hidden from rest of DBMS
- some algorithms assume sequential performance

Example Disk Space Interface

DiskInterface:
- readPage(page_id): data
- writePage(page_id, data)
- newPage(): page_id
- freePage(page_id)

Record, Page and File Abstractions

Record: "application" storage unit
- e.g. a row in a table

Page: Collection of records

File: Collection of pages
- insert/delete/modify record
- get(record_id) a record
- scan all records

May be in multiple OS files spanning multiple disks

Units that we'll care about

Ignore CPU cost
Ignore RAM cost

B # *data* pages on disk for relation
R # records per data page
D avg time to read/write data page to/from disk

Simplifies life when computing costs
Very rough approximation, but OK for now
- ignores prefetching, bulk writes/reads, CPU/RAM

Different Ways to Store a Table

Criteria
- Accessing Data
- Deleting Data
- Inserting Data

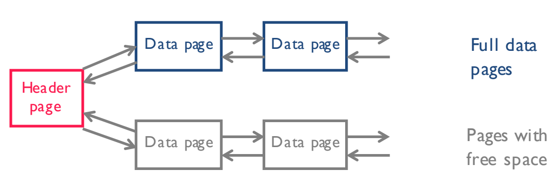
Unordered Heap Files

Unordered collection of records

Pages allocated as collection grows

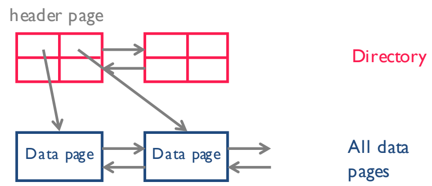
Need to track:
- pages in file
- free space on pages
- records on page

Potential Heap File Implementation



Header page location? Typically in the "catalog"
Data page = 2 pointers + data

Alternative: Use a directory



Directory entries track #free bytes on data pages
Directory is collection of pages

Indexes

"If I had eight hours to chop down a tree,
I'd spend six sharpening my ax."

Abraham Lincoln

Indexes

Heap files can get data by sequential scan

Queries use *qualifications* (predicates)
- find students in "CS"
- find students from CA

Indexes
- file structures for value-based queries
- B+-tree index (~1970s)
- Hash index

Overview! Details in 4112

Indexes

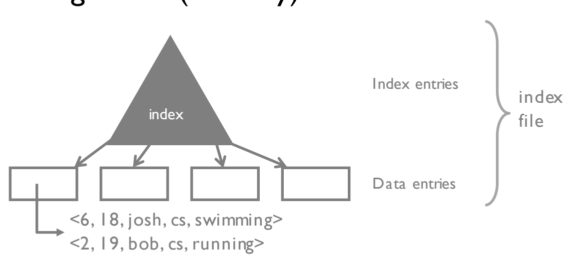
Defined wrt a *search key*
- different than a candidate key!

Faster access for WHERE clauses w/ search key

```
CREATE INDEX idx1 ON users USING btree (sid)
CREATE INDEX idx2 ON users USING hash  (sid)
CREATE INDEX idx3 ON users USING btree (age,name)
```

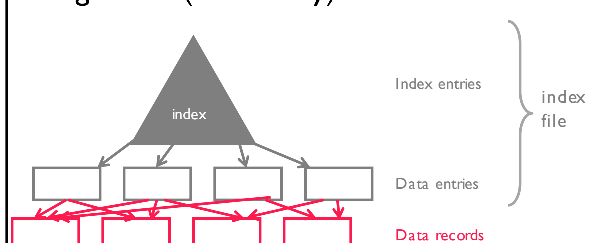
You will play around with indexes in HW4

High level (Primary) index structure



What is a data entry?
- actual data record

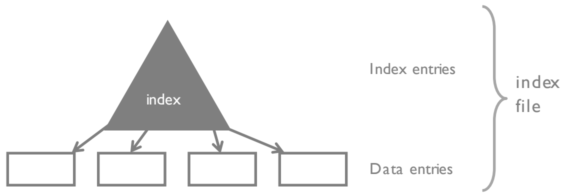
High level (Secondary) index structure



What is a data entry?
- actual data record
- <search key value, rid>

Tradeoffs
- directly access tuple.
- compact, fixed size entries

High level index structure



What is a data entry?

- actual data record
- <search key value, rid>

Tradeoffs

- directly access tuple.
- compact, fixed size entries