CS422 Principles of Database Systems

Disk Access

Chengyu Sun
California State University, Los Angeles

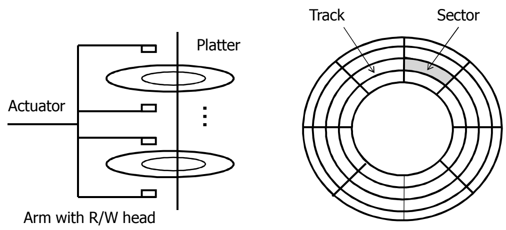
Why Study DBMS Internals

- To better use DBMS, e.g. query tuning
- To learn the design and implementation of a complex software system

Why Study Disk Access

- To understand data organization, external algorithms, query optimization, and File API

Disk Drive …



http://www.youtube.com/watch?v=PCipea9xEXE

… Disk Drive …

- Each disk drive contains a number of rotating platters
- Each platter has a number of tracks on which data is recorded
- Each track is divided into equal-sized (in bytes) sectors

… Disk Drive

- The tracks with the same track number on different platters form a cylinder
- Data can be accessed through read/write heads
- Read/write heads can move from one track to another controlled by an actuator

Access Data on Disk

1. Move the read/write head to the requested track
2. Rotate the platter so the first requested byte is beneath the r/w head
3. Continue to rotate the platter until all the requested data is transferred

Disk Access Time

- Seek time
- Rotational delay
- Transfer time

$$\text{Transfer Rate} = \frac{\text{Number of Bytes per Track}}{\text{Time for One Revolution of Platter}}$$

Measures of Disk Drive Performance

- Capacity
- Average seek time
- Rotation speed
- Transfer rate

Seagate ST3500410AS

- Capacity: 500G
- Bytes per sector: 512
- Number of sectors per track: 63
- Average seek time (read): <8.5ms
- Average seek time (write): <9.5ms
- RPM: 7200rpm
- Sustained transfer rate: 125Mb/s

Examples: Disk Access Time

- Use the specs of ST3500410AS to calculate the time for the following disk accesses
  - Read 1KB on one track
  - Read 4KB on one track
  - Read 4KB on four tracks

What We Learned from the Examples

- Reading more only costs little
- *Sequential access* is much more efficient than *random access*

Improve Disk Performance

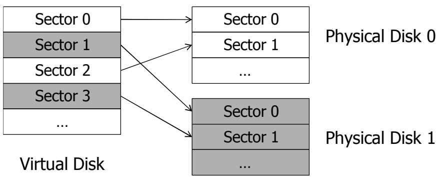
- Caching
- Striping
- Mirroring
- Storing parity

Caching

- Read more data than requested
  - Read one sector vs. read one track
- Transfer data from cache
  - No seek time
  - No rotational delay
  - Transfer rate 3Gb/s (SATA)

Striping

- Multiple small disks are faster than one large disk …
- … but only when the I/O requests are evenly distributed among the disks



Example: Striping

- Suppose we using `N` disks for striping, and each disk has `k` sectors. An access to virtual sector `x` is mapped to an access to which sector on which disk??

Mirroring

- Store the same data on two or more disks
- Improve reliability
- Do *not* improve speed
  - Same read speed
  - Slower write (*why??)*

Storing Parity …

- Let **S** be a set of bits. The parity of **S** is
  - 1 if **S** contains odd number of 1's
  - 0 if **S** contains even number of 1's

Disk 1	1	0	0	1	1	0
Disk 2	1	1	0	0	1	0
Disk 3	1	0	0	1	0	1
Parity Disk	1	1	0	0	??	??

… Storing Parity

- Backup any number of disks with one disk
- Can only recovery from single disk failure

Storing Parity without a Parity Disk

Disk 1	Disk 2	Disk 3	Disk 4
1	1	0	0
0	1	0	1
1	1	1	1
0	0	1	1
0	0	0	??
1	0	??	0
0	??	1	1
??	1	0	1

What's the benefit of distributing parity to all disks??

RAID …

- Redundant Array of Inexpensive Drives
- RAID 0 – striping
- RAID 1 – mirroring
- RAID 1+0 – mirroring + striping
- RAID 2 – striping (bit)
- RAID 3 – striping (byte) + parity
- RAID 4 – striping + parity

… RAID

- RAID 5 – striping + parity (no separate parity disk)
- RAID 6 – striping + 2*parity (no separate parity disk)

OS Disk Access API

- Block-level API
- File-level API

Block and Page …

- A block is similar to a sector except that the size is determined by the OS
  - E.g. NTFS default block size on Vista is 4KB
- A file always starts at the beginning of a block
  - *Tradeoff between large and small block sizes??*

… Block and Page

- A page is a block-sized area of main memory
- Each block/page is uniquely numbered by the OS

OS Block-Level API

- `read_block(n,p)` – read block `n` into page `p`
- `write_block(n,p)` – write page `p` to block `n`
- `allocate(n,k)` – allocate `k` continuous blocks; the new blocks should be as close to block `n` as possible
- `deallocate(n,k)` – mark `k` continuous blocks starting at block `n` as unused

OS File-Level API

- Similar to the API of `RandomAccessFile` in Java
  - http://java.sun.com/javase/6/docs/api/java/io/RandomAccessFile.html
  - Read and write various data types
  - `seek(long position)`

Example: RandomAccessFile

```
RandomAccessFile f =
        new RandomAccessFile("test", "rws");

f.seek( 8000 );
f.writeInt( 101 );

f.seek( 4000 );
int n = f.readInt();

f.close();
```

DBMS Disk Access API …

- Approach 1: use OS block-level API
  - Full control of disk access
    - Most efficient
    - Not constrained by OS limitations (e.g. file size)
  - Complex to implement
  - Disks must be mounted as *raw disk*
  - Difficult to administrate

… DBMS Disk Access API …

- Approach 2: use OS file-level API
  - Easy to implement
  - Easy to administrate
  - No block I/O
    - Much less efficient
    - No paging, which is required by DBMS buffer management

… DBMS Disk Access API

- Approach 3: build a block I/O API on top of OS's file I/O API
  - The approach taken by most DBMS

SimpleDB Disk Access API

- Package `simpledb.file`
  - `FileMgr`
  - `Block`
  - `Page`

Readings

- Chapter 12 of the textbook
- SimpleDB disk access API