Lecture 15:
Data Storage, Recovery

Monday, February 13, 2006

1

Outline

- Disks 11.3
  - Recommended reading: entire chapter 11
- Recovery using undo logging 17.2

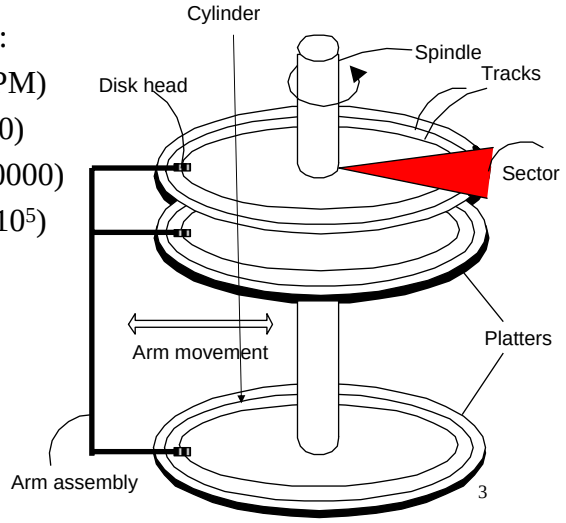
2

The Mechanics of Disk

Mechanical characteristics:

- Rotation speed (5400RPM)
- Number of platters (1-30)
- Number of tracks (<=10000)
- Number of bytes/track(10^5)

Unit of read or write:
disk block
Once in memory:
page
Typically: 4k or 8k or 16k



3

Disk Access Characteristics

- Disk latency = time between when command is issued and when data is in memory

- Disk latency = seek time + rotational latency
  - Seek time = time for the head to reach cylinder
    - 10ms – 40ms
  - Rotational latency = time for the sector to rotate
    - Rotation time = 10ms
    - Average latency = 10ms/2
- Transfer time = typically 40MB/s
- Disks read/write one block at a time

4

RAID

Several disks that work in parallel

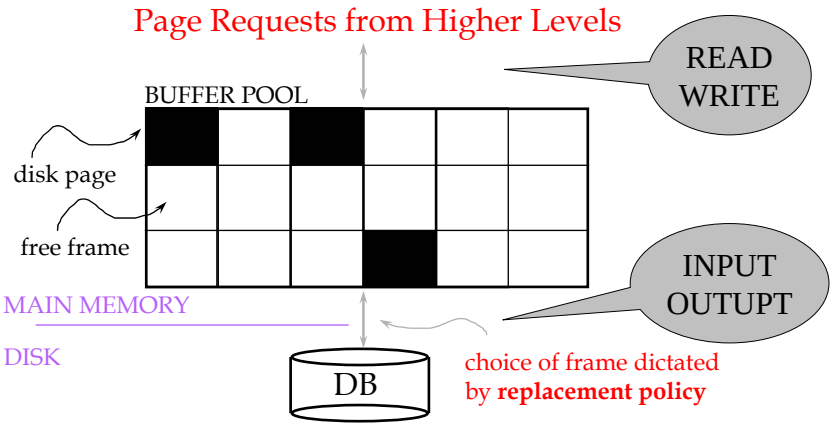
- Redundancy: use parity to recover from disk failure
- Speed: read from several disks at once

Various configurations (called *levels*):

- RAID 1 = mirror
- RAID 4 = n disks + 1 parity disk
- RAID 5 = n+1 disks, assign parity blocks round robin
- RAID 6 = “Hamming codes”

5

Buffer Management in a DBMS



- Data must be in RAM for DBMS to operate on it!
- Table of <frame#, pageid> pairs is maintained

6

Buffer Manager

Needs to decide on page replacement policy

- LRU
- Clock algorithm

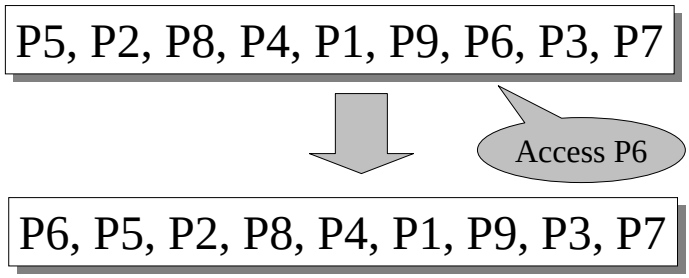
Both work well in OS, but not always in DB

Enables the higher levels of the DBMS to assume that the needed data is in main memory.

7

Least Recently Used (LRU)

- Order pages by the time of last accessed
- Always replace the least recently accessed



LRU is expensive (why ?); the clock algorithm is good approx 8

Buffer Manager

Why not use the Operating System for the task??

- DBMS may be able to anticipate access patterns
- Hence, may also be able to perform prefetching
-DBMS needs the ability to force pages to disk, for recovery purposes
- need fine grained control for transactions

9

Transaction Management

Two parts:

- Recovery from crashes: ACID
- Concurrency control: ACID

Both operate on the buffer pool

10

Recovery

From which of the events below can a database actually recover ?

- Wrong data entry
- Disk failure
- Fire / earthquake / bankrupcy / ….
- Systems crashes

11

Recovery

Type of Crash	Prevention
Wrong data entry	Constraints and Data cleaning
Disk crashes	Redundancy: e.g. RAID, archive
Fire, theft, bankruptcy…	Buy insurance, Change jobs…
System failures: e.g. power	DATABASE RECOVERY

Most frequent

12

System Failures

- Each transaction has *internal state*
- When system crashes, internal state is lost
  - Don't know which parts executed and which didn't
- Remedy: use a **log**
  - A file that records every single action of the transaction

13

Transactions

- Assumption: the database is composed of ***elements***
  - Usually 1 element = 1 block
  - Can be smaller (=1 record) or larger (=1 relation)
- Assumption: each transaction reads/writes some elements

14

Primitive Operations of Transactions

- READ(X,t)
  - copy element X to transaction local variable t
- WRITE(X,t)
  - copy transaction local variable t to element X

- INPUT(X)
  - read element X to memory buffer
- OUTPUT(X)
  - write element X to disk

15

Example

```
START TRANSACTION
READ(A,t);
t := t*2;
WRITE(A,t);
READ(B,t);
t := t*2;
WRITE(B,t)
COMMIT;
```

Atomicity:
BOTH A and B
are multiplied by 2

16

READ(A,t); t := t*2; WRITE(A,t);
READ(B,t); t := t*2; WRITE(B,t)

	Transaction	Buffer pool		Disk	
Action	t	Mem A	Mem B	Disk A	Disk B
INPUT(A)		8		8	8
READ(A,t)	8	8		8	8
t:=t*2	16	8		8	8
WRITE(A,t)	16	16		8	8
INPUT(B)	16	16	8	8	8
READ(B,t)	8	16	8	8	8
t:=t*2	16	16	8	8	8
WRITE(B,t)	16	16	16	8	8
OUTPUT(A)	16	16	16	16	8
OUTPUT(B)	16	16	16	16	16

17

Action	t	Mem A	Mem B	Disk A	Disk B
INPUT(A)		8		8	8
READ(A,t)	8	8		8	8
t:=t*2	16	8		8	8
WRITE(A,t)	16	16		8	8
INPUT(B)	16	16	8	8	8
READ(B,t)	8	16	8	8	8
t:=t*2	16	16	8	8	8
WRITE(B,t)	16	16	16	8	8
OUTPUT(A)	16	16	16	16	
OUTPUT(B)	16	16	16	16	

Crash occurs after OUTPUT(A), before OUTPUT(B)
We lose atomicity

18

The Log

- An append-only file containing log records
- Note: multiple transactions run concurrently, log records are interleaved
- After a system crash, use log to:
  - Redo some transaction that didn't commit
  - Undo other transactions that didn't commit
- Three kinds of logs: undo, redo, undo/redo

19

Undo Logging

Log records

- <START T>
  - transaction T has begun
- <COMMIT T>
  - T has committed
- <ABORT T>
  - T has aborted
- <T,X,v>
  - T has updated element X, and its *old* value was v

20

Action	T	Mem A	Mem B	Disk A	Disk B	Log
						<START T>
INPUT(A)		8		8	8	
READ(A,t)	8	8		8	8	
t:=t*2	16	8		8	8	
WRITE(A,t)	16	16		8	8	<T,A,8>
INPUT(B)	16	16	8	8	8	
READ(B,t)	8	16	8	8	8	
t:=t*2	16	16	8	8	8	
WRITE(B,t)	16	16	16	8	8	<T,B,8>
OUTPUT(A)	16	16	16	16	8	
OUTPUT(B)	16	16	16	16	16	
COMMIT						<COMMIT T>

21

Action	T	Mem A	Mem B	Disk A	Disk B	Log
						<START T>
INPUT(A)		8		8	8	
READ(A,t)	8	8		8	8	
t:=t*2	16	8		8	8	
WRITE(A,t)	16	16		8	8	<T,A,8>
INPUT(B)	16	16	8	8	8	
READ(B,t)	8	16	8	8	8	
t:=t*2	16	16	8	8	8	
WRITE(B,t)	16	16	16	8	8	<T,B,8>
OUTPUT(A)	16	16	16	16	8	
OUTPUT(B)	16	16	16	16	16	
COMMIT						<COMMIT T>

Crash !

22

WHAT DO WE DO ?

Action	T	Mem A	Mem B	Disk A	Disk B	Log
						<START T>
INPUT(A)		8		8	8	
READ(A,t)	8	8		8	8	
t:=t*2	16	8		8	8	
WRITE(A,t)	16	16		8	8	<T,A,8>
INPUT(B)	16	16	8	8	8	
READ(B,t)	8	16	8	8	8	
t:=t*2	16	16	8	8	8	
WRITE(B,t)	16	16	16	8	8	<T,B,8>
OUTPUT(A)	16	16	16	16	8	
OUTPUT(B)	16	16	16	16	16	
COMMIT						<COMMIT T>

Crash !

WHAT DO WE DO ?

After Crash

- In the first example:
  - We UNDO both changes: A=8, B=8
  - The transaction is atomic, since none of its actions has been executed
- In the second example
  - We don't undo anything
  - The transaction is atomic, since both it's actions have been executed

24

Undo-Logging Rules

U1: If T modifies X, then <T,X,v> must be written to disk before OUTPUT(X)

U2: If T commits, then OUTPUT(X) must be written to disk before <COMMIT T>

- Hence: OUTPUTs are done *early*, before the transaction commits

25

Action	T	Mem A	Mem B	Disk A	Disk B	Log
						<START T>
INPUT(A)		8		8	8	
READ(A,t)	8	8		8	8	
t:=t*2	16	8		8	8	
WRITE(A,t)	16	16		8	8	<T,A,8>
INPUT(B)	16	16	8	8	8	
READ(B,t)	8	16	8	8	8	
t:=t*2	16	16	8	8	8	
WRITE(B,t)	16	16	16	8	8	<T,B,8>
OUTPUT(A)	16	16	16	16	8	
OUTPUT(B)	16	16	16	16	16	
COMMIT						<COMMIT T>

26

Recovery with Undo Log

After system's crash, run recovery manager

- Idea 1. Decide for each transaction T whether it is completed or not
  - <START T>….<COMMIT T>…. = yes
  - <START T>….<ABORT T>……. = yes
  - <START T>…… = no
- Idea 2. Undo all modifications by incomplete transactions

27

Recovery with Undo Log

Recovery manager:

- Read log <u>from the end</u>; cases:

  <COMMIT T>: mark T as completed

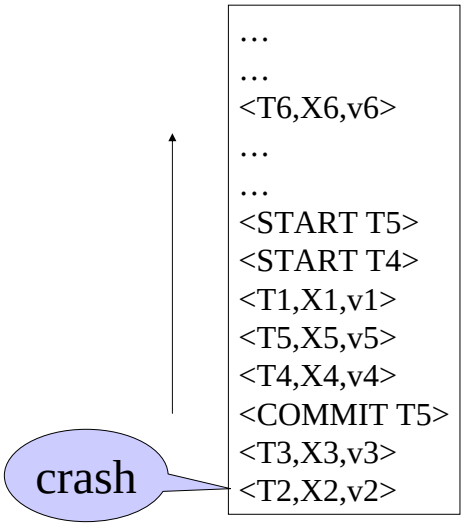
  <ABORT T>: mark T as completed

  <T,X,v>: if T is not completed
  then write X=v to disk
  else ignore

  <START T>: ignore

28

Recovery with Undo Log



Question1 in class:
Which updates are undone ?

Question 2 in class:
How far back do we need to read in the log ?

29

Recovery with Undo Log

- Note: all undo commands are *idempotent*
  - If we perform them a second time, no harm is done
  - E.g. if there is a system crash during recovery, simply restart recovery from scratch

30

Recovery with Undo Log

When do we stop reading the log ?

- We cannot stop until we reach the beginning of the log file
- This is impractical

Instead: use checkpointing

31