Transactions and Recovery

Database Systems Lecture 15

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In This Lecture

- Transactions
- Recovery
  - System and Media Failures
- Concurrency
  - Concurrency problems
- For more information
  - Connolly and Begg chapter 20
  - Ullman and Widom 8.6

Transactions

- A transaction is an action, or a series of actions, carried out by a single user or an application program, which reads or updates the contents of a database.

Transactions

- A transaction is a 'logical unit of work' on a database
  - Each transaction does something in the database
  - No part of it alone achieves anything of use or interest
- Transactions are the unit of recovery, consistency, and integrity as well
- ACID properties
  - Atomicity
  - Consistency
  - Isolation
  - Durability

Atomicity and Consistency

- Atomicity
  - Transactions are atomic – they don't have parts (conceptually)
  - can't be executed partially; it should not be detectable that they interleave with another transaction
- Consistency
  - Transactions take the database from one consistent state into another
  - In the middle of a transaction the database might not be consistent

Isolation and Durability

- Isolation
  - The effects of a transaction are not visible to other transactions until it has completed
  - From outside the transaction has either happened or not
  - To me this actually sounds like a consequence of atomicity…
- Durability
  - Once a transaction has completed, its changes are made permanent
  - Even if the system crashes, the effects of a transaction must remain in place

Example of transaction

- Transfer £50 from account A to account B

```
Read(A)      \
A = A - 50    |
Write(A)      |
Read(B)        > transaction
B = B+50      |
Write(B)     /
```

Atomicity - shouldn't take money from A without giving it to B

Consistency - money isn't lost or gained

Isolation - other queries shouldn't see A or B change until completion

Durability - the money does not go back to A

The Transaction Manager

- The transaction manager enforces the ACID properties
  - It schedules the operations of transactions
  - COMMIT and ROLLBACK are used to ensure atomicity
  - Locks or timestamps are used to ensure consistency and isolation for concurrent transactions (next lectures)
  - A log is kept to ensure durability in the event of system failure (this lecture)

COMMIT and ROLLBACK

- COMMIT signals the successful end of a transaction
  - Any changes made by the transaction should be saved
  - These changes are now visible to other transactions
- ROLLBACK signals the unsuccessful end of a transaction
  - Any changes made by the transaction should be undone
  - It is now as if the transaction never existed

Recovery

- Transactions should be durable, but we cannot prevent all sorts of failures:
  - System crashes
  - Power failures
  - Disk crashes
  - User mistakes
  - Sabotage
  - Natural disasters
- Prevention is better than cure
  - Reliable OS
  - Security
  - UPS and surge protectors
  - RAID arrays
- Can't protect against everything though

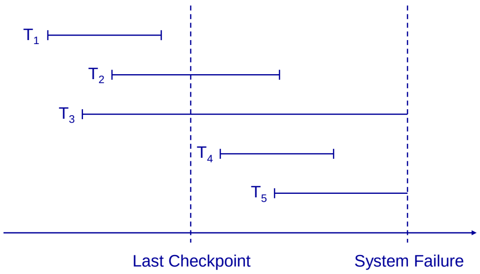
The Transaction Log

- The transaction log records the details of all transactions
  - Any changes the transaction makes to the database
  - How to undo these changes
  - When transactions complete and how
- The log is stored on disk, not in memory
  - If the system crashes it is preserved
- Write ahead log rule
  - The entry in the log must be made before COMMIT processing can complete

System Failures

- A system failure means all running transactions are affected
  - Software crashes
  - Power failures
- The physical media (disks) are not damaged
- At various times a DBMS takes a checkpoint
  - All committed transactions are written to disk
  - A record is made (on disk) of the transactions that are currently running

Types of Transactions



System Recovery

- Any transaction that was running at the time of failure needs to be undone and restarted
- Any transactions that committed since the last checkpoint need to be redone
- Transactions of type T_1 need no recovery
- Transactions of type T_3 or T_5 need to be undone and restarted
- Transactions of type T_2 or T_4 need to be redone

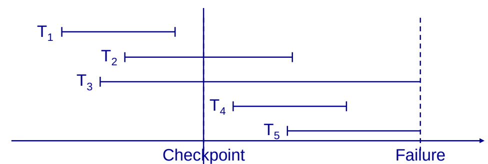
Transaction Recovery

UNDO and REDO: lists of transactions

UNDO = all transactions running at the last checkpoint
REDO = empty

For each entry in the log, starting at the last checkpoint
    If a BEGIN TRANSACTION entry is found for T
        Add T to UNDO
    If a COMMIT entry is found for T
        Move T from UNDO to REDO

Transaction Recovery



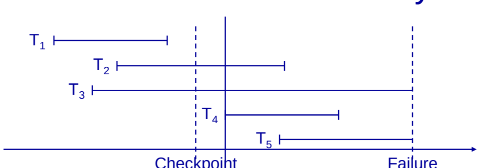
UNDO: T_2, T_3

REDO:

Last Checkpoint

Active transactions: T_2, T_3

Transaction Recovery



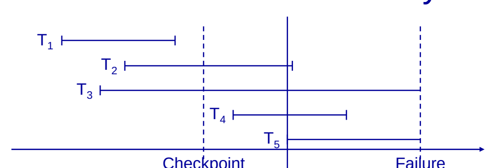
UNDO: T_2, T_3, T_4

REDO:

T4 Begins

Add T_4 to UNDO

Transaction Recovery



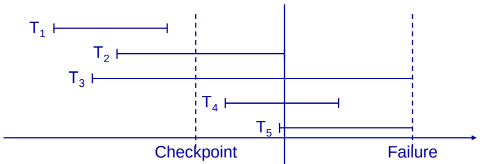
UNDO: T_2, T_3, T_4, T_5

REDO:

T_5 begins

Add T_5 to UNDO

Transaction Recovery



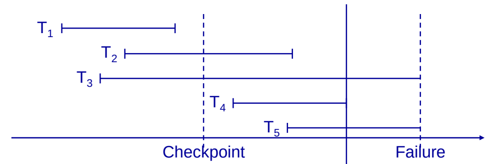
UNDO: T_3, T_4, T_5

REDO: T_2

T_2 Commits

Move T_2 to REDO

Transaction Recovery



UNDO: T_3, T_5

REDO: T_2, T_4

T_4 Commits

Move T_4 to REDO

Forwards and Backwards

- Backwards recovery
  - We need to undo some transactions
  - Working backwards through the log we undo any operation by a transaction on the UNDO list
  - This returns the database to a consistent state
- Forwards recovery
  - Some transactions need to be redone
  - Working forwards through the log we redo any operation by a transaction on the REDO list
  - This brings the database up to date

Media Failures

- System failures are not too severe
  - Only information since the last checkpoint is affected
  - This can be recovered from the transaction log
- Media failures (disk crashes etc) are more serious
  - The data stored to disk is damaged
  - The transaction log itself may be damaged

Backups

- Backups are needed to recover from media failure
  - The transaction log and entire contents of the database is written to secondary storage (often tape)
  - Time consuming, and often requires down time
- Backups frequency
  - Frequent enough that little information is lost
  - Not so frequent as to cause problems
  - Every day (night) is common
- Backup storage

Recovery from Media Failure

- Restore the database from the last backup
- Use the transaction log to redo any changes made since the last backup
- If the transaction log is damaged you can't do step 2
  - Store the log on a separate physical device to the database
  - The risk of losing both is then reduced

Concurrency

- Large databases are used by many people
  - Many transactions to be run on the database
  - It is desirable to let them run at the same time as each other
  - Need to preserve isolation
- If we don't allow for concurrency then transactions are run sequentially
  - Have a queue of transactions
  - Long transactions (eg backups) will make others wait for long periods

Concurrency Problems

- In order to run transactions concurrently we interleave their operations
- Each transaction gets a share of the computing time
- This leads to several sorts of problems
  - Lost updates
  - Uncommitted updates
  - Incorrect analysis
- All arise because isolation is broken

Lost Update

T1	T2
Read(X)	
X = X - 5	
	Read(X)
	X = X + 5
Write(X)	
	Write(X)
COMMIT	
	COMMIT

- T1 and T2 read X, both modify it, then both write it out
  - The net effect of T1 and T2 should be no change on X
  - Only T2's change is seen, however, so the final value of X has increased by 5

Uncommitted Update

T1	T2
Read(X)	
X = X - 5	
Write(X)	
	Read(X)
	X = X + 5
	Write(X)
ROLLBACK	
	COMMIT

- T2 sees the change to X made by T1, but T1 is rolled back
  - The change made by T1 is undone on rollback
  - It should be as if that change never happened

Inconsistent analysis

T1	T2
Read(X)	
X = X - 5	
Write(X)	
	Read(X)
	Read(Y)
	Sum = X+Y
Read(Y)	
Y = Y + 5	
Write(Y)	

- T1 doesn't change the sum of X and Y, but T2 sees a change
  - T1 consists of two parts – take 5 from X and then add 5 to Y
  - T2 sees the effect of the first, but not the second

Next Lecture

- Concurrency
  - Locks and resources
  - Deadlock
- Serialisability
  - Schedules of transactions
  - Serial & serialisable schedules
- For more information
  - Connolly and Begg chapter 20
  - Ullman and Widom 8.6