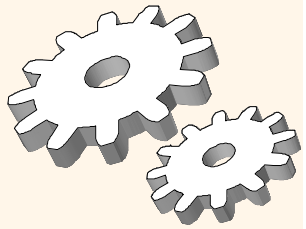
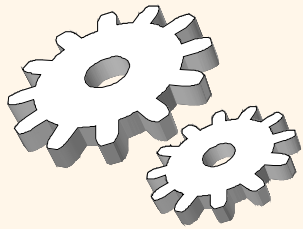


Transaction Management Overview

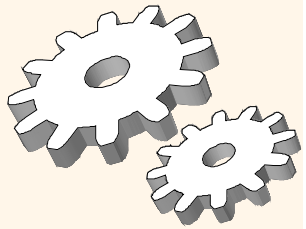
Chapter 16

Transactions



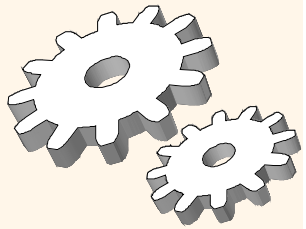
- Concurrent execution of user programs is essential for good DBMS performance.
  - Because disk accesses are frequent, and relatively slow, it is important to keep the cpu humming by working on several user programs concurrently.
- A user's program may carry out many operations on the data retrieved from the database, but the DBMS is only concerned about what data is read/written from/to the database.
- A *transaction* is the DBMS's abstract view of a user program: a sequence of reads and writes.

Concurrency in a DBMS



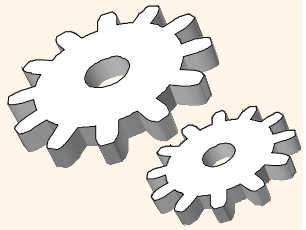
- Users submit transactions, and can think of each transaction as executing by itself.
  - Concurrency is achieved by the DBMS, which interleaves actions (reads/writes of DB objects) of various transactions.
  - Each transaction must leave the database in a consistent state if the DB is consistent when the transaction begins.
    - DBMS will enforce some ICs, depending on the ICs declared in CREATE TABLE statements.
    - Beyond this, the DBMS does not really understand the semantics of the data. (e.g., it does not understand how the interest on a bank account is computed).
- *Issues:* Effect of *interleaving* transactions, and *crashes*.

Atomicity of Transactions



- A transaction might *commit* after completing all its actions, or it could *abort* (or be aborted by the DBMS) after executing some actions.
- A very important property guaranteed by the DBMS for all transactions is that they are *atomic.* That is, a user can think of a Xact as always executing all its actions in one step, or not executing any actions at all.
  - DBMS *logs* all actions so that it can *undo* the actions of aborted transactions.

Example

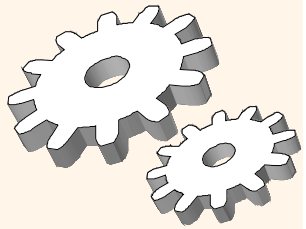


- Consider two transactions (*Xacts*):

```
T1:    BEGIN   A=A+100,   B=B-100   END
T2:    BEGIN   A=1.06*A,   B=1.06*B   END
```

- Intuitively, the first transaction is transferring $100 from B's account to A's account. The second is crediting both accounts with a 6% interest payment.
- There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together. However, the net effect *must* be equivalent to these two transactions running serially in some order.

Example (Contd.)



- Consider a possible interleaving (*schedule*):

T1:	A=A+100,		B=B-100
T2:		A=1.06*A,	B=1.06*B

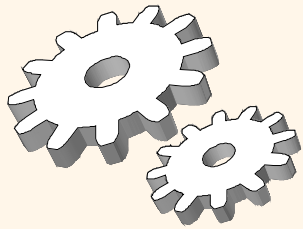
- This is OK. But what about:

T1:	A=A+100,		B=B-100
T2:		A=1.06*A, B=1.06*B	

- The DBMS's view of the second schedule:

T1:	R(A), W(A),		R(B), W(B)
T2:		R(A), W(A), R(B), W(B)	

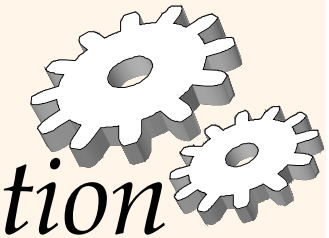
Scheduling Transactions



- *Serial schedule:* Schedule that does not interleave the actions of different transactions.
- *Equivalent schedules:* For any database state, the effect (on the set of objects in the database) of executing the first schedule is identical to the effect of executing the second schedule.
- *Serializable schedule:* A schedule that is equivalent to some serial execution of the transactions.

(Note: If each transaction preserves consistency, every serializable schedule preserves consistency.)

Anomalies with Interleaved Execution



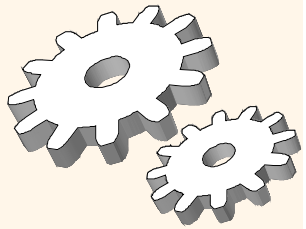
- Reading Uncommitted Data (WR Conflicts, "dirty reads"):

```
T1:    R(A), W(A),                          R(B), W(B), Abort
T2:                  R(A), W(A), C
```

- Unrepeatable Reads (RW Conflicts):

```
T1:    R(A),                          R(A), W(A), C
T2:           R(A), W(A), C
```

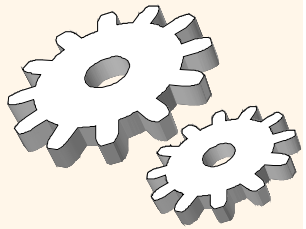
Anomalies (Continued)



- Overwriting Uncommitted Data (WW Conflicts):

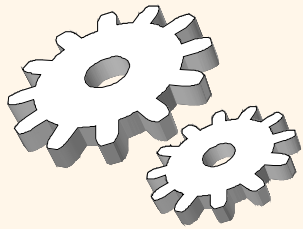
T1:	W(A),		W(B), C
T2:		W(A), W(B), C	

Lock-Based Concurrency Control



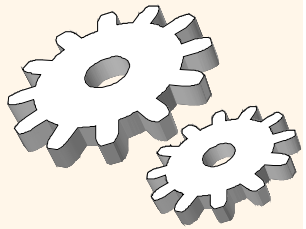
- *Strict Two-phase Locking (Strict 2PL) Protocol*:
  - Each Xact must obtain a S (*shared*) lock on object before reading, and an X (*exclusive*) lock on object before writing.
  - All locks held by a transaction are released when the transaction completes
    - (Non-strict) 2PL Variant: Release locks anytime, but cannot acquire locks after releasing any lock.
  - If an Xact holds an X lock on an object, no other Xact can get a lock (S or X) on that object.
- Strict 2PL allows only serializable schedules.
  - Additionally, it simplifies transaction aborts
  - (Non-strict) 2PL also allows only serializable schedules, but involves more complex abort processing

Aborting a Transaction



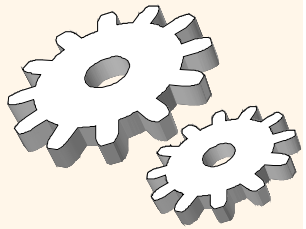
- If a transaction *Ti* is aborted, all its actions have to be undone. Not only that, if *Tj* reads an object last written by *Ti*, *Tj* must be aborted as well!
- Most systems avoid such *cascading aborts* by releasing a transaction's locks only at commit time.
  - If *Ti* writes an object, *Tj* can read this only after *Ti* commits.
- In order to *undo* the actions of an aborted transaction, the DBMS maintains a *log* in which every write is recorded. This mechanism is also used to recover from system crashes: all active Xacts at the time of the crash are aborted when the system comes back up.

The Log



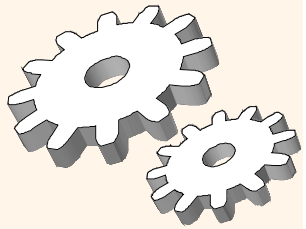
- The following actions are recorded in the log:
  - *Ti writes an object*: the old value and the new value.
    - Log record must go to disk *before* the changed page!
  - *Ti commits/aborts*: a log record indicating this action.
- Log records are chained together by Xact id, so it's easy to undo a specific Xact.
- Log is often *duplexed* and *archived* on stable storage.
- All log related activities (and in fact, all CC related activities such as lock/unlock, dealing with deadlocks etc.) are handled transparently by the DBMS.

Recovering From a Crash



- There are 3 phases in the *Aries* recovery algorithm:
  - *Analysis*: Scan the log forward (from the most recent *checkpoint*) to identify all Xacts that were active, and all dirty pages in the buffer pool at the time of the crash.
  - *Redo*: Redoes all updates to dirty pages in the buffer pool, as needed, to ensure that all logged updates are in fact carried out and written to disk.
  - *Undo*: The writes of all Xacts that were active at the crash are undone (by restoring the *before value* of the update, which is in the log record for the update), working backwards in the log. (Some care must be taken to handle the case of a crash occurring during the recovery process!)

Summary



- Concurrency control and recovery are among the most important functions provided by a DBMS.
- Users need not worry about concurrency.
  - System automatically inserts lock/unlock requests and schedules actions of different Xacts in such a way as to ensure that the resulting execution is equivalent to executing the Xacts one after the other in some order.
- Write-ahead logging (WAL) is used to undo the actions of aborted transactions and to restore the system to a consistent state after a crash.
  - *Consistent state*: Only the effects of commited Xacts seen.

Read committed

The lowest isolation level in which SQL allows transactions to do updates is `READ COMMITTED` (Oracle's default isolation level).

SQL statements of transactions running at this isolation level make no dirty reads or writes. In particular, they see other transactions as atomic, in the sense that either:

- No changes made by a transaction are seen, or
- all changes made by a transaction are seen.

However, different statements in the transaction may see the database in different states (i.e., some transactions may commit in between).

This is sometimes referred to as the **phantom phenomenon**.

Problem session (5 minutes)

In the same setting as before, assume that transactions run at isolation level `READ COMMITTED`. Consider the following sequence of statements.

A	B
`INSERT INTO Primes VALUES (2);`	
	`SELECT * FROM A.Primes;`
	`INSERT INTO A.Primes VALUES (2003);`
	`SELECT * FROM A.Primes;`
`COMMIT;`	
	`SELECT * FROM A.Primes;`
`SELECT * FROM Primes;`	
	`COMMIT;`
`SELECT * FROM Primes;`	

What output is possible for each `SELECT` statement?

The SERIALIZABLE isolation level

The highest isolation level in SQL is SERIALIZABLE, which makes sure that transactions always execute in a serial schedule.

A slightly weaker guarantee, ANOMALY SERIALIZABLE, gives the following guarantee in addition to that of READ COMMITTED:

- No value read or written by the transaction is changed before the transaction is committed.
- In particular, there is no phantom phenomenon.

Oracle defines the SERIALIZABLE isolation level, but the actual behavior is not always serializable (see exercises today). It seems to be at least ANOMALY SERIALIZABLE, though.

SQL isolation levels

The SQL standard defines four isolation levels in total:

- `SERIALIZABLE` (not really implemented in Oracle). Ideal, serializable transactions.
- `REPEATABLE READ`. Allows the result of a query to change during the transaction, in the sense that more tuples may be added.
- `READ COMMITTED` (Oracle default). The result of any statement reflects some set of committed transactions.
- `READ UNCOMMITTED`. Allow dirty reads. (Not recommended!)

Nonstandard isolation levels

Several DBMSs (DB2, SQL Server) have isolation levels that are not in the SQL standard:

- `CURSOR STABILITY`. Like `READ COMMITTED`, but additionally prevents "lost updates" (consider, for example, two transactions that simultaneously try to increase the balance of a bank account).
- `SNAPSHOT ISOLATION`. Transactions are guaranteed to only see data as it is "at the time they are started".

A thorough description of these and the SQL isolation levels is provided in the paper *A Critique of ANSI SQL Isolation Levels*, found in the course schedule.

Most important points in this lecture

As a minimum, you should after this week:

- Know and understand the ACID properties of transactions.
- Know how to create transactions in SQL.
- Be able to predict possible transaction behavior at isolation levels `SERIALIZABLE` and `READ COMMITTED`.