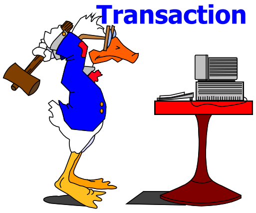
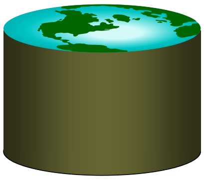
Transaction Management Overview



R & G Chapter 16

There are three side effects of acid. Enhanced long term memory, decreased short term memory, and I forget the third.
- Timothy Leary



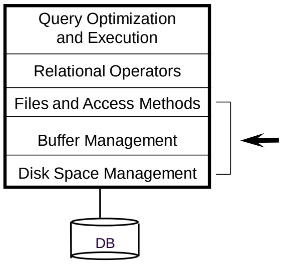
Concurrency Control & Recovery

- Concurrency Control
  - Provide correct and highly available data access in the presence of concurrent access by many users
- Recovery
  - Ensures database is fault tolerant, and not corrupted by software, system or media failure
  - 24x7 access to mission critical data
- A boon to application authors!
  - Existence of CC&R allows applications be be written without explicit concern for concurrency and fault tolerance

Roadmap

- Overview (Today)
- Concurrency Control (1-2 lectures)
- Recovery (1-2 lectures)

Structure of a DBMS



These layers must consider concurrency control and recovery (Transaction, Lock, Recovery Managers)

Transactions and Concurrent Execution

- Transaction ("xact")- DBMS's abstract view of a user program (or activity):
  - A sequence of reads and writes of database objects.
  - Unit of work that must commit or abort as an atomic unit
- Transaction Manager controls the execution of transactions.
- User's program logic is invisible to DBMS!
  - Arbitrary computation possible on data fetched from the DB
  - The DBMS only sees data read/written from/to the DB.
- Challenge: provide atomic transactions to concurrent users!
  - Given only the read/write interface.

Concurrency: Why bother?

- The *latency* argument
- The *throughput* argument
- Both are critical!

ACID properties of Transaction Executions

- **A** tomicity: All actions in the Xact happen, or none happen.
- **C** onsistency: If each Xact is consistent, and the DB starts consistent, it ends up consistent.
- **I** solation: Execution of one Xact is isolated from that of other Xacts.
- **D** urability: If a Xact commits, its effects persist.

A.C.I.D.

Atomicity and Durability

- A transaction ends in one of two ways:
  - *commit* after completing all its actions
    - "commit" is a contract with the caller of the DB
  - *abort* (or be aborted by the DBMS) after executing some actions.
    - Or *system crash* while the xact is in progress; treat as abort.
- Two important properties for a transaction:
  - *Atomicity* : Either execute all its actions, or none of them
  - *Durability* : The effects of a committed xact must survive failures.
- DBMS ensures the above by *logging* all actions:
  - *Undo* the actions of aborted/failed transactions.
  - *Redo* actions of committed transactions not yet propagated to disk when system crashes.

Transaction Consistency

A.C.I.D.

- Transactions preserve DB *consistency*
  - Given a consistent DB state, produce another consistent DB state
- DB Consistency expressed as a set of declarative Integrity Constraints
  - CREATE TABLE/ASSERTION statements
    - E.g. Each CS186 student can only register in one project group. Each group must have 2 students.
  - Application-level
    - E.g. Bank account total of each customer must stay the same during a "transfer" from savings to checking account
- Transactions that violate ICs are aborted
  - That's all the DBMS can automatically check!

Isolation (Concurrency)

A.C.I.D.

- DBMS interleaves actions of many xacts concurrently
  - Actions = reads/writes of DB objects
- DBMS ensures xacts do not "step onto" one another.
- Each xact executes as if it were running by itself.
  - Concurrent accesses have no effect on a Transaction's behavior
  - Net effect *must be* identical to executing all transactions for *some* serial order.
  - Users & programmers think about transactions in isolation
    - Without considering effects of other concurrent 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

- 1st xact transfers $100 from B's account to A's
- 2nd credits both accounts with 6% interest.
- Assume at first A and B each have $1000. What are the legal outcomes of running T1 and T2?
  - T1 ; T2 (**A=1166,B=954)**
  - T2 ; T1 (**A=1160,B=960)**
  - In either case, A+B = $2000 *1.06 = $2120
  - There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together.

Example (Contd.)

- Consider a possible interleaved *schedule*:

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

- This is OK (same as T1;T2). But what about:

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

- **Result: A=1166, B=960; A+B = 2126, bank loses $6 !**
- **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: Definitions

- *Serial schedule:* no concurrency
  - Does not interleave the actions of different transactions.
- *Equivalent schedules*: same result on any DB state
  - 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*: equivalent to a serial 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

- A simple mechanism to allow concurrency but avoid the anomalies just described…
- *Two-phase Locking (2PL) Protocol*:
  - Always obtain a S (*shared*) lock on object before reading
  - Always obtain an X (*exclusive*) lock on object before writing.
  - If an Xact holds an X lock on an object, no other Xact can get a lock (S or X) on that object.
  - DBMS internally *enforces* the above locking protocol
  - Two phases: acquiring locks, and releasing them
    - No lock is ever acquired after one has been released
    - "Growing phase" followed by "shrinking phase".
- Lock Manager tracks lock requests, grants locks on database objects when they become available.

Strict 2PL

- **2PL allows only serializable schedules but is subjected to cascading aborts.**
- **Example: rollback of T1 requires rollback of T2!**

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

- **To avoid Cascading aborts, use Strict 2PL**
- **Strict Two-phase Locking (Strict 2PL) Protocol:**
  - Same as 2PL, except:
  - A transaction releases no locks until it completes

Introduction to Crash Recovery

- Recovery Manager
  - Upon recovery from crash:
    - Must bring DB to a consistent transactional state
  - Ensures transaction Atomicity and Durability
  - *Undoes* actions of transactions that do not commit
  - *Redoes* lost actions of committed transactions
    - lost during system failures or media failures
- Recovery Manager maintains *log* information during normal execution of transactions for use during crash recovery

The Log

- Log consists of "records" that are written sequentially.
  - Stored on a separate disk from the DB
  - Typically chained together by Xact id
  - Log is often *duplexed* and *archived* on stable storage.
- Log stores modifications to the database
  - *if Ti writes an object*, write a log record with:
    - If UNDO required need "before image"
    - IF REDO required need "after image".
  - *Ti commits/aborts*: a log record indicating this action.
- Need for UNDO/REDO depend on Buffer Mgr (!!)
  - UNDO required if uncommitted data can overwrite stable version of committed data (STEAL buffer management).
  - REDO required if xact can commit before all its updates are on disk (NO FORCE buffer management).

Logging Continued

- Write Ahead Logging (WAL) protocol
  - Log record must go to disk *before* the changed page!
    - implemented via a handshake between log manager and the buffer manager.
  - All log records for a transaction (including its commit record) must be written to disk before the transaction is considered "Committed".
- All log related activities are handled transparently by the DBMS.
  - As was true of CC-related activities such as lock/unlock, dealing with deadlocks, etc.

ARIES Recovery

- There are 3 phases in ARIES recovery protocol:
  - *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, as found in the log), working backwards in the log.
- At the end --- all committed updates and only those updates are reflected in the database.
- 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.
- Concurrency control (Isolation) is automatic.
  - DBMS issues proper Two-Phase Locking (2PL) requests
  - Enforces lock discipline (S & X)
  - End result promised to be "serializable": equivalent to some serial schedule
- Atomicity and Durability ensured by Write-Ahead Logging (WAL) and recovery protocol
  - used to *undo* the actions of aborted transactions (no subatomic stuff visible after recovery!)
  - used to *redo* the lost actions of committed transactions