CS315: Database Systems
Transactions and Recovery Systems

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ACID Properties

- A transaction is a logical unit of a program
- To preserve data integrity, a database must follow four properties
  1. Atomicity: Either all operations of a transaction are reflected or none are reflected
  2. Consistency: If a database is consistent before the execution of the transaction, it must be consistent after it
  3. Isolation: Although multiple transactions may execute concurrently, each transaction must be unaware of others, i.e., to a transaction, it must seem that either any other transaction has completed execution or has not started execution at all
  4. Durability: After a transaction finishes successfully, the changes must be permanent in the database despite subsequent failures
- Together, these four properties are called the ACID properties

Transaction Model

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  - RAW: read-after-write
  - WAR: write-after-read
  - WAW: write-after-write

Example

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- Durability: If *b* is notified of credit, it must persist even if the database crashes

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- Incorrect summary: One transaction is updating values while other is computing an aggregate on them

Causes of Transaction Failures

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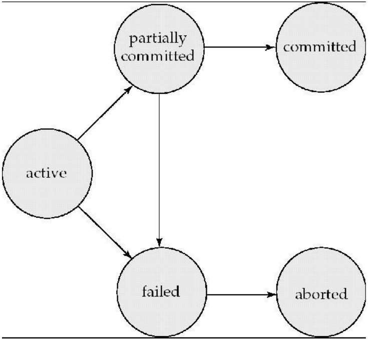
- System crash
  - Memory is lost
- System error
  - Divide by zero
- Exceptions
  - Insufficient account balance
- Concurrency enforcement
  - Deadlock detection
- Disk crash
  - Persistency fails
- Physical problems
  - Power failure, fire

States of a Transaction

- Active: transaction is executing
- Partially committed: after last statement has been executed
- Failed: when execution cannot proceed
- Committed: after successful completion
- Aborted: transaction has been rolled back and it has been ensured that there is no effect of the transaction



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- Before a transaction reaches its commit point, any portion of the log not yet written to disk must be flushed – this is called force-writing of the log
  - Ensures that redo operations can be done successfully

Concurrency

- Multiple transactions should be able to run concurrently
- Advantages
  - Increased processor and disk utilization leading to better *throughput*: one is using CPU, other is doing disk I/O
  - Reduced average response time: short transactions finish earlier and do not wait behind long ones
- Concurrency control schemes achieve isolation
- Must ensure correctness of concurrent executions
- Serializability imposes notion of correctness

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- Recovery algorithms have two main parts
  1. Action taken *during normal execution* to ensure that enough information is collected to recover from failures
  2. Action taken *after a failure* that utilizes information collected so far to recover the database contents and maintain atomicity and durability
- Assume that transactions run serially, i.e., one after another

Log-Based Recovery

- Log or journal is maintained on *stable storage*
  - Stable storage: data is *never* lost
- Log records for every operation of a transaction are recorded
- When transaction T starts, (start, T) record is logged
- *Before* read or write, the corresponding log record is written
  - (write, T, x, old, new)
  - (read, T, x, val)
- When T finishes successfully, (commit, T) is logged
- If T fails, (abort, T) is logged
- Two approaches of recovery based on logs
  1. Deferred database modification
  2. Immediate database modification

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  - Otherwise, value of *A* will be wrong

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- If found, redo all operations
  - If (commit, T) record is deferred till all writes are performed on the database, redo is not required
- Both undo and redo operations *must* be idempotent
  - Crash may occur multiple times
- Also called a undo/redo (or undo/no-redo) recovery scheme
- Undos must be done in the *reverse* order of serial transactions
- Redos must be done in the *forward* order of serial transactions
- Undos must be done *before* redos

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  - Value of A is set correctly to 7

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- Any T_i with no (commit, T_i) is *undone*

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- Undos done in *reverse* order
- Redos done in *forward* order
- Undos done *before* redos
- Only operations after checkpoint need to be undone or redone

Example

- (start, T1); (write, T1, B, 2, 3); (start, T2); (commit, T1); (write, T2, C, 5, 7); (checkpoint, $\{$T2$\}$); (start, T3); (write, T3, A, 1, 9); (commit, T3); (start, T4); (write, T4, C, 7, 2);

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- Undo-list: T4, T2
- Redo-list:

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- Undo-list: T4, T2
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- Order:

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- Undo-list: T4, T2
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- Order of operations:
  - T4: Revert value of C to 7
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  - T3:

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- Order of operations:
  - T4: Revert value of C to 7
  - T2: No operation
  - T3: Re-write value of A to 9
- Operations again restarted from checkpoint position

Log Record Buffering

- Log records are buffered in memory before a block is output to the stable storage
- Records are flushed in the order of appearance in the log
- Force-writing is used to flush log records to stable storage before a transaction enters the commit point
- (commit, T) entry is also flushed
- Before a block of data is written to the database, all log records pertaining to it are flushed to the stable storage
- This is called write-ahead logging (WAL) rule

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  - No overhead of writing log records