SQL: Transactions

CPS 116
Introduction to Database Systems

Announcements (Thu. Sep. 25)

- Homework #2 due in a week!
- Graded Homework #1 should be available next Tuesday
- Project milestone #1 due in 3 weeks
  - I will start pitching project ideas in class
- Midterm in two weeks
  - Sample midterm will be available next Tuesday
  - Open book, open notes

Transactions

- A transaction is a sequence of database operations with the following properties (ACID):
  - Atomic: Operations of a transaction are executed all-or-nothing, and are never left “half-done”
  - Consistency: Assume all database constraints are satisfied at the start of a transaction, they should remain satisfied at the end of the transaction
  - Isolation: Transactions must behave as if they were executed in complete isolation from each other
  - Durability: If the DBMS crashes after a transaction commits, all effects of the transaction must remain in the database when DBMS comes back up
SQL transactions

- A transaction is automatically started when a user executes an SQL statement.
- Subsequent statements in the same session are executed as part of this transaction.
  - Statements see changes made by earlier ones in the same transaction.
  - Statements in other concurrently running transactions do not.
- COMMIT command commits the transaction.
  - Its effects are made final and visible to subsequent transactions.
- ROLLBACK command aborts the transaction.
  - Its effects are undone.

Fine prints

- Schema operations (e.g., CREATE TABLE) implicitly commit the current transaction.
  - Because it is often difficult to undo a schema operation.
- Many DBMS support an AUTOCOMMIT feature, which automatically commits every single statement.
  - You can turn it on/off through the API (e.g., JDBC).
  - Examples later in this lecture.
  - For DB2:
    - db2 command-line processor turns it on by default.
    - You can turn it off with option `-c`.

Atomicity

- Partial effects of a transaction must be undone when:
  - User explicitly aborts the transaction using ROLLBACK.
  - E.g., application asks for user confirmation in the last step and issues COMMIT or ROLLBACK depending on the response.
  - The DBMS crashes before a transaction commits.
- Partial effects of a modification statement must be undone when any constraint is violated.
  - However, only this statement is rolled back; the transaction continues.
- How is atomicity achieved?
  - Logging (to support undo).
Durability
- Effects of committed transactions must survive DBMS crashes
- How is durability achieved?
  - Forcing all changes to disk at the end of every transaction?
  - Logging (to support redo)

Consistency
- Consistency of the database is guaranteed by constraints and triggers declared in the database and/or transactions themselves
  - Whenever inconsistency arises, abort the statement or transaction, or (with deferred constraint checking or application-enforced constraints) fix the inconsistency within the transaction

Isolation
- Transactions must appear to be executed in a serial schedule (with no interleaving operations)
- For performance, DBMS executes transactions using a serializable schedule
  - In this schedule, operations from different transactions can interleave and execute concurrently
  - But the schedule is guaranteed to produce the same effects as a serial schedule
- How is isolation achieved?
  - Locking, multi-version concurrency control, etc.
SQL isolation levels

- Strongest isolation level: **SERIALIZABLE**
  - Complete isolation
  - SQL default
- Weaker isolation levels: **REPEATABLE READ, READ COMMITTED, READ UNCOMMITTED**
  - Increase performance by eliminating overhead and allowing higher degrees of concurrency
  - Trade-off: sometimes you get the "wrong" answer

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**READ UNCOMMITTED**

- Can read “dirty” data
  - A data item is dirty if it is written by an uncommitted transaction
- Problem:

  - Example:
    ```sql
    -- T1:  -- T2:
    UPDATE Student
    SET GPA = 3.0
    WHERE SID = 142;
    ROLLBACK;
    
    SELECT AVG(GPA)
    FROM Student;
    
    COMMIT;
    ```

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**READ COMMITTED**

- No dirty reads, but non-repeatable reads possible
  - Reading the same data item twice can produce different results
- Example: different averages

  ```sql
  -- T1:  -- T2:
  SELECT AVG(GPA)
  FROM Student;
  
  UPDATE Student
  SET GPA = 3.0
  WHERE SID = 142;
  COMMIT;

  SELECT AVG(GPA)
  FROM Student;
  COMMIT;
  ```
REPEATABLE READ

- Reads are repeatable, but may see phantoms
- Example: different average (still!)
  ```sql
  -- T1:
  INSERT INTO Student
  VALUES(789, 'Nelson', 10, 1.0);
  COMMIT;
  
  -- T2:
  SELECT AVG(GPA) FROM Student;
  
  SELECT AVG(GPA) FROM Student;
  COMMIT;
  ```

Summary of SQL isolation levels

<table>
<thead>
<tr>
<th>Isolation Level</th>
<th>Dirty reads</th>
<th>Non-repeatable reads</th>
<th>Phantoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>READ UNCOMMITTED</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>READ COMMITTED</td>
<td>Impossible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>REPEATABLE READ</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Possible</td>
</tr>
<tr>
<td>SERIALIZABLE</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Impossible</td>
</tr>
</tbody>
</table>

- Syntax: At the beginning of a transaction, set TRANSACTION ISOLATION LEVEL `isolation_level` (READ ONLY | READ WRITE);
  - READ UNCOMMITTED can only be READ ONLY

Transactions in programming (JDBC)

- Set isolation level for the current transaction
  - `con.setTransactionIsolationLevel(isolation_level);`
  - Where `isolation_level` is one of TRANSACTION_SERIALIZABLE (default), TRANSACTION_REPEATABLE_READ, TRANSACTION_READ_COMMITTED, and TRANSACTION_READ_UNCOMMITTED
- Set the transaction to be read-only or read/write (default)
  - `con.setReadOnly(true|false);`
- Turn on/off AUTOCOMMIT (commits every single statement)
  - `con.setAutoCommit(true|false);`
- Commit/rollback the current transaction (when AUTOCOMMIT is off)
  - `con.commit();`
  - `con.rollback();`
ANSI isolation levels are lock-based

- **READ UNCOMMITTED**
  - Short-duration locks: lock, access, release immediately

- **READ COMMITTED**
  - Long-duration write lock: do not release write locks until commit

- **REPEATABLE READ**
  - Long-duration locks on all data items accessed

- **SERIALIZABLE**
  - Lock ranges to prevent insertion as well

An isolation level not based on locks

- **Snapshot isolation**
  - Based on multiversion concurrency control
  - Available in Oracle, PostgreSQL, MS SQL Server, etc.
  - How it works
    - Transaction X performs its operations on a private snapshot of the database taken at the start of X
    - X can commit only if it does not write any data that has been also written by a transaction committed after the start of X
  - Avoids all ANSI anomalies
  - But is NOT equivalent to **SERIALIZABLE** because of write skew anomaly

Write skew example

- Constraint: combined balance \( A + B \geq 0 \)
- \( A = 100, B = 100 \)
- \( T_1 \) checks \( A + B - 200 \geq 0 \), and then proceeds to withdraw 200 from \( A \)
- \( T_2 \) checks \( A + B - 200 \geq 0 \), and then proceeds to withdraw 200 from \( B \)
- Possible under snapshot isolation because the writes (to \( A \) and to \( B \)) do not conflict
- But \( A + B = -200 < 0 \) afterwards!
Bottom line

- Group reads and dependant writes into a transaction in your applications
  - E.g., enrolling a class, booking a ticket

- Anything less than SERIALABLE is potentially very dangerous
  - Use only when performance is critical
  - READ ONLY makes weaker isolation levels a bit safer