

SQL: Transactions

Introduction to Databases

CompSci 316 Fall 2019



DUKE
COMPUTER SCIENCE

Announcements (Wed., Oct. 9)

- Gradiance SQL recursion exercise due tonight
- Project Milestone 1 due tonight!
 - Only one member of the group submit (as a group)
 - Be sure to include `members.txt` in your submission
 - Stay tuned for instructions on how to post weekly updates on Piazza
- Midterm grading almost done
 - Sample solution already posted on Sakai
- Homework 2 grades released
 - Sample solution already posted on Sakai

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 **AUTO COMMIT** feature, which automatically commits every single statement
 - You can turn it on/off through the API
 - For PostgreSQL:
 - `psql` command-line processor turns it on by default
 - You can turn it off at the `psql` prompt by typing:
`\set AUTOCOMMIT 'off'`

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
 - Some systems roll back only this statement and let the transaction continue; others roll back the whole transaction
- How is atomicity achieved?
 - Logging (to support undo)

Durability

- DBMS accesses data on stable storage by bringing data into memory
- Effects of committed transactions must survive DBMS crashes
- How is durability achieved?
 - Forcing all changes to disk at the end of every transaction?
 - Too expensive
 - 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
- 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

READ UNCOMMITTED

- Can read “dirty” data
 - A data item is dirty if it is written by an uncommitted transaction
- Problem: What if the transaction that wrote the dirty data eventually aborts?
- Example: wrong average

- -- T1:
UPDATE User
SET pop = 0.99
WHERE uid = 142;

ROLLBACK;

- -- T2:

SELECT AVG(pop)
FROM User;

COMMIT;

READ COMMITTED

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

- -- T1:

```
UPDATE User
SET pop = 0.99
WHERE uid = 142;
COMMIT;
```

- -- T2:

```
SELECT AVG(pop)
FROM User;
```

```
SELECT AVG(pop)
FROM User;
COMMIT;
```

REPEATABLE READ

- Reads are repeatable, but may see **phantoms**
- Example: different average (still!)

- -- T1:

```
INSERT INTO User  
VALUES(789, 'Nelson',  
      10, 0.1);  
COMMIT;
```

- -- T2:

```
SELECT AVG(pop)  
FROM User;
```

```
SELECT AVG(pop)  
FROM User;  
COMMIT;
```

Summary of SQL isolation levels

Isolation level/anomaly	Dirty reads	Non-repeatable reads	Phantoms
READ UNCOMMITTED	Possible	Possible	Possible
READ COMMITTED	Impossible	Possible	Possible
REPEATABLE READ	Impossible	Impossible	Possible
SERIALIZABLE	Impossible	Impossible	Impossible

- Syntax: At the beginning of a transaction,
SET TRANSACTION ISOLATION LEVEL
isolation_level [**READ ONLY** | **READ WRITE**];
 - READ UNCOMMITTED can only be READ ONLY
- PostgreSQL defaults to **READ COMMITTED**

Transactions in programming

Using psycopg2 as an example:

```
conn = psycopg2.connect(dbname='beers')  
conn.set_session(isolation_level='SERIALIZABLE',  
                 read_only=False,  
                 autocommit=True)
```

- `isolation_level` defaults to `READ COMMITTED`
- `read_only` defaults to `False`
- `autocommit` defaults to `False`
- When `autocommit` is `False`, commit/abort current transaction as follows:

```
conn.commit()
```

```
conn.rollback()
```

ANSI isolation levels are lock-based

- READ UNCOMMITTED
 - Short-duration locks: lock, access, release immediately
- READ COMMITTED
 - Long-duration write locks: 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

Isolation levels not based on locks?

Snapshot isolation in Oracle

- Based on **multiversion concurrency control**
 - Used 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!

👉 To avoid write skew, when committing, ensure the transaction didn't *read* any object others wrote and committed after this transaction started

Bottom line

- Group reads and dependent 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