

SQL: Transactions

CPS 116
Introduction to Database Systems

Announcements (October 27) ²

- ❖ Homework #2 due today!
- ❖ Project milestone #2 due next Thursday

Transactions ³

- ❖ 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

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- ❖ 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

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- ❖ 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

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- ❖ 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

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- ❖ 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

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- ❖ 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

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- ❖ 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

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- ❖ 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

READ UNCOMMITTED

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- ❖ 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 Student
SET GPA = 3.0
WHERE SID = 142;

ROLLBACK;
 - -- T2:

SELECT AVG(GPA)
FROM Student;

COMMIT;

READ COMMITTED

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- ❖ No dirty reads, but non-repeatable reads possible
 - Reading the same data item twice can produce different results
- ❖ Example: different averages
 - -- T1:

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

SELECT AVG(GPA)
FROM Student;
COMMIT;

REPEATABLE READ 13

❖ Reads are repeatable, but may see phantoms

❖ Example: different average (still!)

```
-- 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 14

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`

Transactions in programming (JDBC) 15

❖ Set isolation level for the current transaction

- `con.setTransactionIsolationLevel(l);`
- Where *l* 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 ¹⁶

- ❖ 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 ¹⁷

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 ¹⁸

- ❖ 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

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

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