Introduction to Database Systems
CSE 444

Lecture 8: Transactions in SQL

Where We Are

- What we have already learned
  - Relational model of data
  - Data manipulation language: SQL
  - Views and constraints
  - Database design (E/R diagrams & normalization)
- But what if I want to update my data?
- Today: transactions in SQL (Sec. 6.6)
  - Old edition: Sec. 8.6

Transactions

- Problem: An application must perform *several* writes and reads to the database, as a unit
- Solution: multiple actions of the application are bundled into one unit called *Transaction*
- Very powerful concept
  - *Database transactions* (that's where they started)
  - *Transaction monitors*
  - *Transactional memory*

Turing Awards to Database Researchers

- Charles Bachman 1973 for CODASYL
- Edgar Codd 1981 for relational databases
- Jim Gray 1998 for transactions

The World Without Transactions

- Just write applications that talk to databases

- Rely on operating systems for scheduling, and for concurrency control

- What can go wrong ?
  - Several famous anomalies
  - Other anomalies are possible (but not famous)

Lost Updates

Client 1:

```
UPDATE Customer
SET rentals= rentals + 1
WHERE cname= ‘Fred’
```

Client 2:

```
UPDATE Customer
SET rentals= rentals + 1
WHERE cname= ‘Fred’
```

Two people attempt to rent two movies for Fred, from two different terminals. What happens ?

Unrepeatable Read

```
Client 1: rent-a-movie
x = SELECT rentals FROM Cust
      WHERE cname= 'Fred'

if (x < 5)
  { UPDATE Cust
     SET rentals= rentals + 1
     WHERE cname= 'Fred' }
else println("Denied !")
```

```
Client 2: rent-a-movie
x = SELECT rentals FROM Cust
      WHERE cname= 'Fred'

if (x < 5)
  { UPDATE Cust
     SET rentals= rentals + 1
     WHERE cname= 'Fred' }
else println("Denied !")
```

What's wrong ?

Inconsistent Read

Client 1: move from gizmo→gadget

```
UPDATE Products
SET quantity = quantity + 5
WHERE product = ‘gizmo’



UPDATE Products
SET quantity = quantity - 5
WHERE product = ‘gadget’
```

Client 2: inventory….

```
SELECT sum(quantity)
FROM Product
```

What’s wrong ?

Inconsistent Read

```
Client 1: rent-two-movies
x = SELECT rentals FROM Cust
     WHERE cname= ‘Fred’

if (x < 4) { /* movie 1…*/
    UPDATE Cust
    SET rentals= rentals + 1
    WHERE cname= ‘Fred’

   /* ….and movie 2 */
    UPDATE Cust
    SET rentals= rentals + 1
    WHERE cname= ‘Fred’
}
else println(“Denied !”)
```

```
Client 2: rent-a-movie
x = SELECT rentals FROM Cust
     WHERE cname= ‘Fred’

if (x < 5)
  { UPDATE Cust
    SET rentals= rentals + 1
    WHERE cname= ‘Fred’ }
else println(“Denied !”)
```

What’s wrong ?

Dirty Reads

```
Client 1: transfer $100  acc1→ acc2
X = Account1.balance
Account2.balance += 100

If (X>=100) Account1.balance -=100
else { /* rollback ! */
        account2.balance -= 100
        println(“Denied !”)
```

```
Client 1: transfer $100  acc2 → acc3
Y = Account2.balance
Account3.balance += 100

If (Y>=100) Account2.balance -=100
else { /* rollback ! */
        account3.balance -= 100
        println(“Denied !”)
```

What’s wrong ?

Some Famous anomalies

- Dirty read (Write-Read conflict)
  - T reads data written by T' while T' has not committed
  - What can go wrong: T' writes more data (which T has already read) or T' aborts
  - Inconsistent read: T sees some but not all changes made by T'
- Unrepeatable read (Read-Write conflict)
  - T reads the same value twice and gets two different results
- Lost update (Write-Write conflict)
  - Two tasks T and T' both modify the same data
  - T and T' both commit
  - Final state shows effects of only T, but not of T'

Protection against crashes

Client 1:

```
UPDATE Accounts
SET balance= balance - 500
WHERE name= ‘Fred’
```

Crash !

```
UPDATE Accounts
SET balance = balance + 500
WHERE name= ‘Joe’
```

What’s wrong ?

Enter Transactions

- Concurrency control
  - The famous anomalies and more…

- Recovery

Definition

- **A transaction** = one or more operations, which reflect a single real-world transition
  - Happens completely or not at all
- Examples
  - Transfer money between accounts
  - Rent a movie; return a rented movie
  - Purchase a group of products
  - Register for a class (either waitlisted or allocated)
- By using transactions, all previous problems disappear

Transactions in Applications

START TRANSACTION

May be omitted: first SQL query starts txn

[SQL statements]

COMMIT or ROLLBACK (=ABORT)

Transactions in Ad-hoc SQL

- Default: each statement = one transaction

Revised Code

Client 1: rent-a-movie

```
START TRANSACTION
x = SELECT rentals
      FROM Cust
      WHERE cname= ‘Fred’


if (x < 5)
  { UPDATE Cust
     SET rentals= rentals + 1
     WHERE cname= ‘Fred’ }
else println(“Denied !”)
COMMIT
```

Client 2: rent-a-movie

```
START TRANSACTION
x = SELECT rentals
      FROM Cust
      WHERE cname= ‘Fred’


if (x < 5)
  { UPDATE Cust
     SET rentals= rentals + 1
     WHERE cname= ‘Fred’ }
else println(“Denied !”)
COMMIT
```

Now it works like a charm

Revised Code

```
Client 1: transfer $100  acc1→ acc2
START TRANSACTION
X = Account1.balance;    Account2.balance += 100

If (X>=100) { Account1.balance -=100;  COMMIT }
else {println("Denied !"; ROLLBACK)
```

```
Client 1: transfer $100  acc2→ acc3
START TRANSACTION
X = Account2.balance;    Account3.balance += 100

If (X>=100) { Account2.balance -=100;  COMMIT }
else {println("Denied !"; ROLLBACK)
```

Using Transactions

Very easy to use:

- START TRANSACTION
- COMMIT
- ROLLBACK

But what EXACTLY do they mean ?

- Popular culture: ACID
- Underlying theory: serializability

Transaction Properties ACID

- Atomic
  - State shows either all the effects of txn, or none of them
- Consistent
  - Txn moves from a state where integrity holds, to another where integrity holds
- Isolated
  - Effect of txns is the same as txns running one after another (ie looks like batch mode)
- Durable
  - Once a txn has committed, its effects remain in the database

ACID: Atomicity

- Two possible outcomes for a transaction
  - It *commits*: all the changes are made
  - It *aborts*: no changes are made

- That is, transaction's activities are all or nothing

ACID: Consistency

- The state of the tables is restricted by integrity constraints
  - Account number is unique
  - Stock amount can’t be negative
  - Sum of *debits* and of *credits* is 0
- Constraints may be explicit or implicit
- How consistency is achieved:
  - Programmer makes sure a txn takes a consistent state to a consistent state
  - The system makes sure that the tnx is atomic

ACID: Isolation

- A transaction executes concurrently with other transaction
- Isolation: the effect is as if each transaction executes in isolation of the others

ACID: Durability

- The effect of a transaction must continue to exists after the transaction, or the whole program has terminated
- Means: write data to disk

ROLLBACK

- If the app gets to a place where it can’t complete the transaction successfully, it can execute ROLLBACK
- This causes the system to “abort” the transaction
  - The database returns to the state without any of the previous changes made by activity of the transaction

Reasons for Rollback

- User changes their mind (“ctl-C”/cancel)
- Explicit in program, when app program finds a problem
  - E.g. when the # of rented movies > max # allowed
  - Use it freely in Project 2 !!
- System-initiated abort
  - System crash
  - Housekeeping, e.g. due to timeouts