Introduction to Database Systems CSE 444

Lecture 14: Transactions in SQL

October 26, 2007

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Transactions

- Major component of database systems
- Critical for most applications; arguably more so than SQL
- Turing awards to database researchers:
  - Charles Bachman 1973
  - Edgar Codd 1981 for inventing relational dbs
  - Jim Gray 1998 for inventing transactions

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Why Do We Need Transactions

- Concurrency control
- Recovery

In the following examples, think of a *transaction* as meaning a procedure.
A transaction *commits* when it ends successfully.
A transaction *rolls back* when it aborts.

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Concurrency control: Three Famous anomalies

- Dirty read
  - T reads data written by T' while T' has not committed
  - What can go wrong: T' write more data (which T has already read), or T' aborts
- Lost update
  - 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'
- Inconsistent read
  - One task T sees some but not all changes made by T'

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Dirty Reads

```
Client 1:
/* transfer $100  from account 1 to account 2 */

If Account1.balance > 100
  then Account1.balance = Account1.balance - 100

       Account2.balance = Account2.balance + 100
       COMMIT
  else ROLLBACK
```

```
Client 2:
/* Compute total amount */

X = Account1.balance;
Y = Account2.balance;

Z = X + Y;
Print(Z);
COMMIT
```

What goes wrong ?

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Dirty Reads

```
Client 1:
/* transfer $100  from account 1 to account 2 */

/* tentatively move money into account 2 */
Account2.balance = Account2.balance + 100

If Account1.balance > 100
  then Account1.balance = Account1.balance - 100
       COMMIT
  else /* oops: remove $100 from Account 2 */
       Account2.balance = Account2.balance - 100
       ROLLBACK
```

Not needed (done by ROLLBACK)

```
Client 2:
/* withdraw $100 */

If Account2.balance > 100
  then Account2.balance =
            Account2.balance - 100;
       DISPENSE MONEY
       COMMIT
  else ROLLBACK
```

What goes wrong ?

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Lost Updates

Client 1:
UPDATE Product
SET Price = Price – 1.99
WHERE pname = 'Gizmo'

Client 2:
UPDATE Product
SET Price = Price*0.5
WHERE pname='Gizmo'

Two different users attempt to apply a discount.
Will it work ?

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Inconsistent Read

Client 1:

UPDATE Products
SET quantity = quantity + 5
WHERE product = 'gizmo'

UPDATE Products
SET quantity = quantity - 5
WHERE product = 'gadget'

Client 2:

SELECT sum(quantity)
FROM Product

Note: this is a form of *dirty read*

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Protection against crashes

Client 1:

UPDATE Products
SET quantity = quantity + 5
WHERE product = 'gizmo'

Crash !

UPDATE Products
SET quantity = quantity - 5
WHERE product = 'gadget'

What's wrong ?

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Definition

- **A transaction** = one or more operations, which reflects a single real-world transition
  - In the real world, this happened completely or not at all
- Examples
  - Transfer money between accounts
  - Purchase a group of products
  - Register for a class (either waitlist or allocated)
- If grouped in transactions, all problems in previous slides disappear

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Transactions in SQL

- In "ad-hoc" SQL:
  - Default: each statement = one transaction
- In a program:

START TRANSACTION

May be omitted: first SQL query starts txn

[SQL statements]

COMMIT or ROLLBACK (=ABORT)

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Revised Code

Client 1: START TRANSACTION
UPDATE Product
SET Price = Price – 1.99
WHERE pname = 'Gizmo'
COMMIT

Client 2: START TRANSACTION
UPDATE Product
SET Price = Price*0.5
WHERE pname='Gizmo'
COMMIT

Now it works like a charm

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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

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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

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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 txn is atomic

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ACID: Isolation

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

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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 (stable storage)

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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

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Reasons for Rollback

- User changes their mind ("ctl-C"/cancel)
- Explicit in program, when app program finds a problem
  - e.g. when qty on hand < qty being sold
- System-initiated abort
  - System crash
  - Housekeeping
    - e.g. due to timeouts

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READ-ONLY Transactions

```
Client 1: START TRANSACTION
          INSERT INTO SmallProduct(name, price)
                SELECT pname, price
                FROM Product
                WHERE price <= 0.99

          DELETE Product
                WHERE price <=0.99
          COMMIT

Client 2: SET TRANSACTION READ ONLY
          START TRANSACTION
          SELECT count(*)
          FROM Product

          SELECT count(*)
          FROM SmallProduct
          COMMIT
```

Makes it faster

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Isolation Levels in SQL

1. "Dirty reads"
   SET TRANSACTION ISOLATION LEVEL READ UNCOMMITTED
2. "Committed reads"
   SET TRANSACTION ISOLATION LEVEL READ COMMITTED
3. "Repeatable reads"
   SET TRANSACTION ISOLATION LEVEL REPEATABLE READ
4. Serializable transactions (default):
   SET TRANSACTION ISOLATION LEVEL SERIALIZABLE

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Isolation Level: Dirty Reads

Plane seat allocation

What can go wrong ?

What can go wrong if only the function AllocateSeat modifies Seat ?

```
function AllocateSeat( %request)

SET ISOLATION LEVEL READ UNCOMMITED

START TRANSACTION

Let x =     SELECT Seat.occupied
            FROM Seat
            WHERE Seat.number = %request

If (x == 1)  /* occupied */   ROLLBACK

            UPDATE Seat
            SET occupied = 1
            WHERE Seat.number = %request

COMMIT
```

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Are dirty reads OK here ?

What if we switch the two updates ?

```
function TransferMoney( %amount, %acc1, %acc2)

START TRANSACTION

Let x =     SELECT Account.balance
            FROM Account
            WHERE Account.number = %acc1

If (x < %amount)  ROLLBACK

            UPDATE Account
            SET balance = balance+%amount
            WHERE Account.number = %acc2

            UPDATE Account
            SET balance = balance-%amount
            WHERE Account.number = %acc1

COMMIT
```

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Isolation Level: Read Committed

Stronger than READ UNCOMMITTED

It is possible to read twice, and get different values

```
SET ISOLATION LEVEL READ COMMITED

Let x =     SELECT Seat.occupied
            FROM Seat
            WHERE Seat.number = %request

/* . . . . . More stuff here . . . . */

Let y =     SELECT Seat.occupied
            FROM Seat
            WHERE Seat.number = %request

/* we may have x ≠ y   ! */
```

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Isolation Level: Repeatable Read

Stronger than
READ COMMITTED

May see incompatible values:

another txn transfers from acc. 55555 to 77777

```
SET ISOLATION LEVEL REPEATABLE READ

Let x =   SELECT Account.amount
          FROM Account
          WHERE Account.number = '555555'

/* . . . . . More stuff here . . . . */

Let y =   SELECT Account.amount
          FROM Account
          WHERE Account.number = '777777'

/* we may have a wrong x+y  ! */
```


Isolation Level: Serializable

Strongest level

Default

```
SET ISOLATION LEVEL SERIALIZABLE

. . . .
```

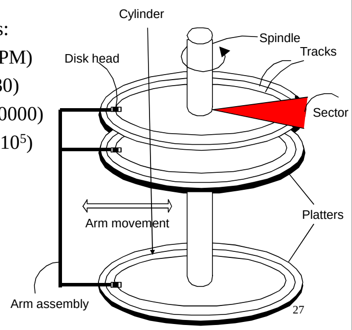
WILL STUDY IN DETAILS IN A WEEK

The Mechanics of Disk

Mechanical characteristics:

- Rotation speed (5400RPM)
- Number of platters (1-30)
- Number of tracks (<=10000)
- Number of bytes/track(10^5)

Unit of read or write:
disk block
Once in memory:
page
Typically: 4k or 8k or 16k



Disk Access Characteristics

- Disk latency = time between when command is issued and when data is in memory
- Disk latency = seek time + rotational latency
  - Seek time = time for the head to reach cylinder
    - 10ms – 40ms
  - Rotational latency = time for the sector to rotate
    - Rotation time = 10ms
    - Average latency = 10ms/2
- Transfer time = typically 40MB/s
- Disks read/write one block at a time

RAID

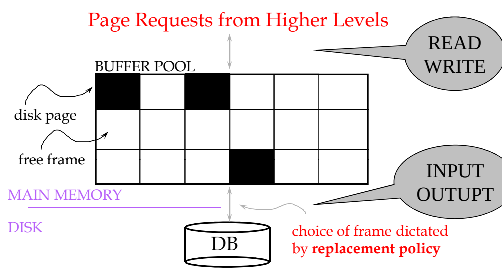
Several disks that work in parallel

- Redundancy: use parity to recover from disk failure
- Speed: read from several disks at once

Various configurations (called *levels*):

- RAID 1 = mirror
- RAID 4 = n disks + 1 parity disk
- RAID 5 = n+1 disks, assign parity blocks round robin
- RAID 6 = "Hamming codes"

Buffer Management in a DBMS



- Data must be in RAM for DBMS to operate on it!
- Table of <frame#, pageid> pairs is maintained

Buffer Manager

Needs to decide on page replacement policy

- LRU
- Clock algorithm

Both work well in OS, but not always in DB

Enables the higher levels of the DBMS to assume that the needed data is in main memory.

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Least Recently Used (LRU)

- Order pages by the time of last accessed
- Always replace the least recently accessed

P5, P2, P8, P4, P1, P9, P6, P3, P7

Access P6

P6, P5, P2, P8, P4, P1, P9, P3, P7

LRU is expensive (why ?); the clock algorithm is good approx

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Buffer Manager

Why not use the Operating System for the task??

Main reason: need fine grained control for transactions

Other reasons:
- DBMS may be able to anticipate access patterns
- Hence, may also be able to perform prefetching
- DBMS needs the ability to force pages to disk, for recovery purposes

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Transaction Management and the Buffer Manager

The transaction manager operates on the buffer pool

- **Recovery**: 'log-file write-ahead', then careful policy about which pages to force to disk
- **Concurrency control**: locks at the page level, multiversion concurrency control

Will discuss details during the next few lectures

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