Transactions

- We use database transactions everyday
  - Bank $$ transfers
  - Online shopping
  - Signing up for classes

- For this class, a transaction is a series of DB queries
  - Read / Write / Update / Delete / Insert
  - Unit of work issued by a user that is independent from others

Challenges

- Want to execute many apps concurrently
  - All these apps read and write data to the same DB

- Simple solution: only serve one app at a time
  - What's the problem?

- Want: multiple operations to be executed atomically over the same DBMS
What can go wrong?

- Manager: balance budgets among projects
  - Remove $10k from project A
  - Add $7k to project B
  - Add $3k to project C

- CEO: check company’s total balance
  - SELECT SUM(money) FROM budget;

This is called a dirty / inconsistent read aka a WRITE-READ conflict

What can go wrong?

- App 1:
  - SELECT inventory FROM products WHERE pid = 1
- App 2:
  - UPDATE products SET inventory = 0 WHERE pid = 1

- App 1:
  - SELECT inventory * price FROM products WHERE pid = 1

This is known as an unrepeatable read aka READ-WRITE conflict

What can go wrong?

Account 1 = $100
Account 2 = $100
Total = $200

- App 1:
  - Set Account 1 = $200
  - Set Account 2 = $0

- App 2:
  - Set Account 2 = $200
  - Set Account 1 = $0

At the end:
- Total = $200

This is called the lost update aka WRITE-WRITE conflict

What can go wrong?

- Buying tickets to the next Bieber concert:
  - Fill up form with your mailing address
  - Put in debit card number
  - Click submit
  - Screen shows money deducted from your account
  - [Your browser crashes]

Lesson:
Changes to the database should be ALL or NOTHING

Transactions

- Collection of statements that are executed atomically (logically speaking)

  BEGIN TRANSACTION
  [SQL statements]
  COMMIT  or  ROLLBACK (=ABORT)
  [single SQL statement]

  IF BEGIN... missing, then TXN consists of a single instruction

Transactions Demo
Turing Awards in Data Management

Charles Bachman, 1973
IDS and CODASYL

Ted Codd, 1981
Relational model

Jim Gray, 1998
Transaction processing

Michael Stonebraker, 2014
INGRES and Postgres

Know your chemistry transactions: ACID

• **Atomic**
  - State shows either all the effects of txn, or none of them

• **Consistent**
  - Txn moves from a DBMS state where integrity holds, to another where integrity holds
  - remember integrity constraints?

• **Isolated**
  - Effect of txns is the same as txns running one after another (i.e., looks like batch mode)

• **Durable**
  - Once a txn has committed, its effects remain in the database

**Atomic**

• **Definition**: A transaction is ATOMIC if all its updates must happen or not at all.

• **Example**: move $100 from A to B
  - UPDATE accounts SET bal = bal - 100 WHERE acct = A;
  - UPDATE accounts SET bal = bal + 100 WHERE acct = B;
  - BEGIN TRANSACTION;
  - UPDATE accounts SET bal = bal - 100 WHERE acct = A;
  - UPDATE accounts SET bal = bal + 100 WHERE acct = B;
  - COMMIT;

**Consistent**

• Recall: integrity constraints govern how values in tables are related to each other
  - Can be enforced by the DBMS, or ensured by the app

  - How consistency is achieved by the app:
    - App programmer ensures that txns only takes a consistent DB state to another consistent state
    - DB makes sure that txns are executed atomically

  - Can defer checking the validity of constraints until the end of a transaction

**Durable**

• A transaction is durable if its effects continue to exist after the transaction and even after the program has terminated

  - How?
    - By writing to disk!
    - More in CSE 444

**Isolated**

• **Definition** An execution ensures that txns are isolated, if the effect of each txn is as if it were the only txn running on the system.
**Rollback transactions**

- If the app gets to a state where it cannot complete the transaction successfully, execute ROLLBACK
- The DB returns to the state prior to the transaction
- What are examples of such program states?

**ACID**

- Atomic
- Consistent
- Isolated
- Durable

- Enjoy this in HW8!
- Again: by default each statement is its own txn
  - Unless auto-commit is off then each statement starts a new txn

**Transaction Schedules**

An **schedule** is a sequence of interleaved actions from all transactions

**Serial Schedule**

- A **serial schedule** is one in which transactions are executed one after the other, in some sequential order
- **Fact**: nothing can go wrong if the system executes transactions serially
  - (up to what we have learned so far)
  - But DBMS don’t do that because we want better overall system performance

**Example**

<table>
<thead>
<tr>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>READ(A, t)</td>
<td>READ(A, s)</td>
</tr>
<tr>
<td>t := t+100</td>
<td>s := s*2</td>
</tr>
<tr>
<td>WRITE(A, t)</td>
<td>WRITE(A, s)</td>
</tr>
<tr>
<td>READ(B, t)</td>
<td>READ(B, s)</td>
</tr>
<tr>
<td>t := t+100</td>
<td>s := s*2</td>
</tr>
<tr>
<td>WRITE(B, t)</td>
<td>WRITE(B, s)</td>
</tr>
</tbody>
</table>

A and B are elements in the database
A and B are variables in txn source code
Example of a (Serial) Schedule

T1  T2
READ(A, t)
t := t+100
WRITE(A, t)
t := t+100
WRITE(B, t)
READ(A, s)
s := s*2
WRITE(A, s)
READ(B, s)
s := s*2
WRITE(B, s)

Another Serial Schedule

T1  T2
READ(A, s)
s := s*2
WRITE(A, s)
READ(B, s)
s := s*2
WRITE(B, s)
READ(A, t)
t := t+100
WRITE(A, t)
READ(B, t)
t := t+100
WRITE(B, t)

Review: Serializable Schedule

A schedule is **serializable** if it is equivalent to a serial schedule.

A Non-Serializable Schedule

T1  T2
READ(A, t)
t := t+100
WRITE(A, t)
READ(A, s)
s := s*2
WRITE(A, s)
READ(B, s)
s := s*2
WRITE(B, s)
READ(B, t)
t := t+100
WRITE(B, t)

How do We Know if a Schedule is Serializable?

Notation:

T1: r1(A); w1(A); r1(B); w1(B)
T2: r2(A); w2(A); r2(B); w2(B)

Key Idea: Focus on conflicting operations.
Conflicts

- Write-Read – WR
- Read-Write – RW
- Write-Write – WW
- Read-Read?

Conflict Serializability

Conflicts: (i.e., swapping will change program behavior)
- Two actions by same transaction $T_i$: $r_i(X); w_j(Y)$
- Two writes by $T_i, T_j$ to same element: $w_i(X); w_j(X)$
- Read/write by $T_i, T_j$ to same element: $w_i(X); r_j(X)$

Conflict Serializability

- A schedule is conflict serializable if it can be transformed into a serial schedule by a series of swappings of adjacent non-conflicting actions
- Every conflict-serializable schedule is serializable
- The converse is not true (why?)

Example:

$[r_1(A); w_1(A); r_2(A); w_2(A); r_1(B); w_1(B); r_2(B); w_2(B)]$
Testing for Conflict-Serializability

Precedence graph:
- A node for each transaction \( T_i \)
- An edge from \( T_i \) to \( T_j \) whenever an action in \( T_i \) conflicts with, and comes before an action in \( T_j \)
- The schedule is conflict-serializable iff the precedence graph is acyclic

Example 1

\[ r_2(A); r_1(B); w_2(A); r_3(A); w_1(B); r_2(B); w_2(B) \]

This schedule is conflict-serializable

Example 2

\[ r_2(A); r_1(B); w_2(A); r_3(A); w_1(B); w_3(A); r_2(B); w_2(B) \]
Example 2

This schedule is NOT conflict-serializable.