ECE30030/ITP30010 Database Systems

# Transactions

*Reading: Chapter 27*

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# Agenda

- Transactions
  - Concept and examples
  - Levels of transactions

# Transactions

- A transaction
  - An indivisible “unit” of program execution that accesses and updates data items
    - Indivisible: Either execute entirely or not at all
  - A collection of operations that form a single logical unit of work
  - Consists of a sequence of query and/or update statements

# Transactions

- Why transactions?
  - Database systems are normally being accessed by many users or processes at the same time
    - Both queries and modifications
  - Unlike operating systems, which *support* interaction of processes, a DMBS needs to keep processes from troublesome interactions

# Transactions

- *E.g.*, Bank

# Transactions

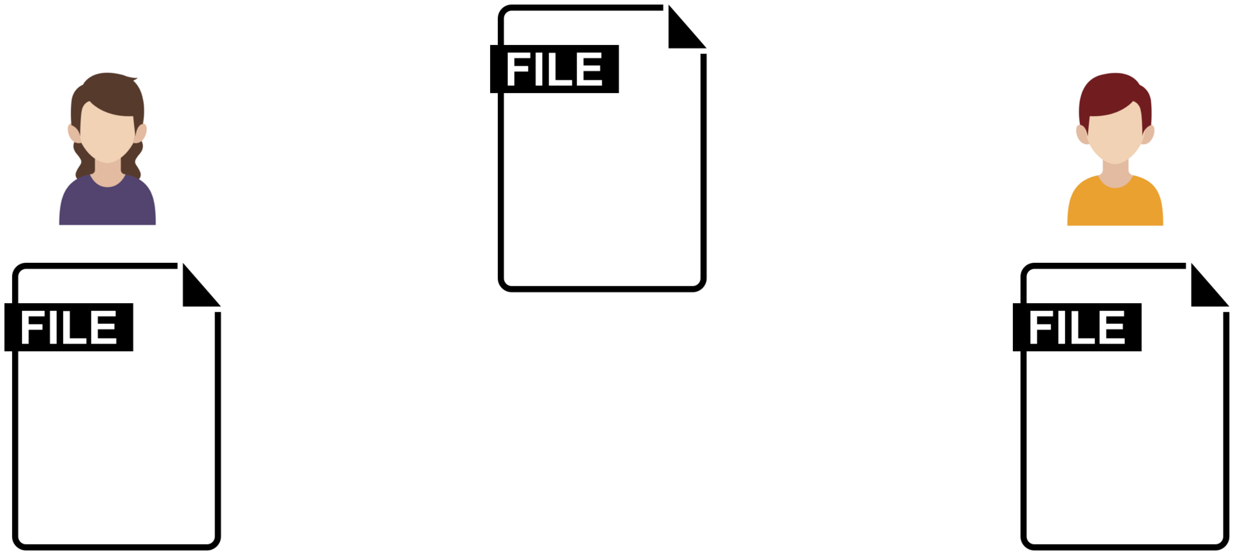
- *E.g.*, Bank


```
UPDATE accounts
SET balance = balance + 100
WHERE accNo = 456;
```

```
UPDATE accounts
SET balance = balance - 100
WHERE accNo = 123;
```

# Transactions

- *C.f.*, File management in an OS
    - An OS allows two people to edit a document at the same time. If both write, one's changes get lost



# Transactions

- A transaction consists of *a sequence of query and/or update statements* and is a "unit" of work
  - To address both atomicity and serialization, group database operations into transactions
  - A transaction is a collection of one or more operations on DB that must be executed atomically
  - Transactions are executed in a serializable manner

# Transactions

- *Transaction* = process involving database queries and/or modification
  - A transaction begins implicitly when an SQL statement is executed (the SQL standard)
  - The transaction must end with one of the following statements:
    - Commit work: The updates performed by the transaction become permanent in the database
    - Rollback work: All the updates performed by the SQL statements in the transaction are undone

# Transactions

- Transactions could be formed by explicit programmer controls

  **START TRANSACTION**;

  …

  **COMMIT**; or **ROLLBACK**;

- **START TRANSACTION** statement is to declare that the guarded queries are of a group of operations that must be executed atomically
  - Each SQL statement that does not belong to any transaction explicitly is *a transaction with the single statement*

# Transactions

- Transactions could be formed by explicit programmer controls

  **START TRANSACTION**;

  …

  **COMMIT**; or **ROLLBACK**;

- **COMMIT** or **ROLLBACK** declares the end of a transaction
  - **COMMIT** causes a transaction to complete
    - The database modifications are now permanent in the database
  - **ROLLBACK** ends the transaction by aborting
    - No effects on the database
    - Failures like division by 0 or a constraint violation can also cause rollback, even if the programmer does not request it

# Transactions

- *E.g.*, Bank


- **START TRANSACTION**;
  **UPDATE** accounts **SET** balance = balance + 100 **WHERE** accNo = 456;
  **UPDATE** accounts **SET** balance = balance - 100 **WHERE** accNo = 123;
  **COMMIT**;

# A Transaction Example

- **START TRANSACTION**;
  **SELECT** @A:=SUM(salary) **FROM** *instructor* **WHERE** dept_name='Comp. Sci.';
  **UPDATE** budget_summary **SET** summary=@A **WHERE** dept_name='Comp. Sci.';
  **COMMIT**;

  - *C.f.*, Session variable - *@var_name*
    - Usages
      - **SET** *@var_name* = value or **SET** *@var_name* := value
      - *@var_name* := value in a **SELECT** clause
    - Declaration is not required
    - Data type: Defined at the assignment
    - Scope: Until the end of the current session

**Examples**

```
-- Initialize to string
SET @id = 'A';

SELECT CONCAT(@id, 'B');
-- Result: AB

-- Assign a number to the
-- same session variable
SET @id = 13;

SELECT @id * 3;
-- Result: 39

SELECT CONCAT(@id, 'B');
-- Result: 13B
```

* Source: http://www.sqlines.com/mysql/session_variables

# Another Transaction Example

- **SELECT** * **FROM** sales_history;

| code | sales | month |
|---|---|---|
| A103 | 101 | 4 |
| A102 | 54 | 5 |
| A104 | 181 | 4 |
| A101 | 184 | 4 |
| A101 | 300 | 5 |
| A103 | 17 | 5 |
| A102 | 200 | 6 |
| A104 | 87 | 6 |

# Another Transaction Example

- **SELECT** * **FROM** sales_history;
- **START TRANSACTION**;

| code | sales | month |
| --- | --- | --- |
| A103 | 101 | 4 |
| A102 | 54 | 5 |
| A104 | 181 | 4 |
| A101 | 184 | 4 |
| A101 | 300 | 5 |
| A103 | 17 | 5 |
| A102 | 200 | 6 |
| A104 | 87 | 6 |

# Another Transaction Example

- **SELECT * FROM** sales_history;
- **START TRANSACTION**;
- **DELETE FROM** sales_history;
- **SELECT * FROM** sales_history;

| code | sales | month |
|---|---|---|

# Another Transaction Example

- **SELECT * FROM** sales_history;
- **START TRANSACTION**;
- **DELETE FROM** sales_history;
- **SELECT * FROM** sales_history;
- **ROLLBACK**;
- **SELECT * FROM** sales_history;

| code | sales | month |
|---|---|---|
| A103 | 101 | 4 |
| A102 | 54 | 5 |
| A104 | 181 | 4 |
| A101 | 184 | 4 |
| A101 | 300 | 5 |
| A103 | 17 | 5 |
| A102 | 200 | 6 |
| A104 | 87 | 6 |

# A Competing Scenario

- Example: Interacting process
  - Assume a usual Sells(store, chocobar, price) relation, and suppose that Joe's Store sells only Snickers for $1.00 and Twix for $1.50
  - Sally is querying Sells for the highest and lowest price Joe charges
  - Joe decides to stop selling Snickers and Twix, but to sell only M&M's at $2.00

# A Competing Scenario

- Example: Interacting process
  - Sally's Program
    - Sally executes the following two SQL statements called (min) and (max) to help us remember what they do
      - (max) SELECT MAX(price) FROM Sells
        WHERE store = 'Joe''s Store';
      - (min) SELECT MIN(price) FROM Sells
        WHERE store = 'Joe''s Store';
  - Joe's Program
    - At about the same time, Joe executes the following steps: (del) and (ins)
      - (del) DELETE FROM Sells
        WHERE store = 'Joe''s Store';
      - (ins) INSERT INTO Sells
        VALUES('Joe''s Store', 'M&M's', 2.00);

# A Competing Scenario

- Example: Interacting process
  - Interleaving of Statements
    - Although (max) must come before (min), and (del) must come before (ins), there are no other constraints on the order of these statements
      - Unless we group Sally's and/or Joe's statements into transactions
  - Strange interleaving
    - Suppose the steps execute in the order (max)(del)(ins)(min)
      - Joe's Prices: {1.00, 1.50} {1.00, 1.50} {2.00}
      - Statement: (max) (del) (ins) (min)
      - Result: 1.50 2.00
    - Sally sees MAX < MIN

# A Competing Scenario

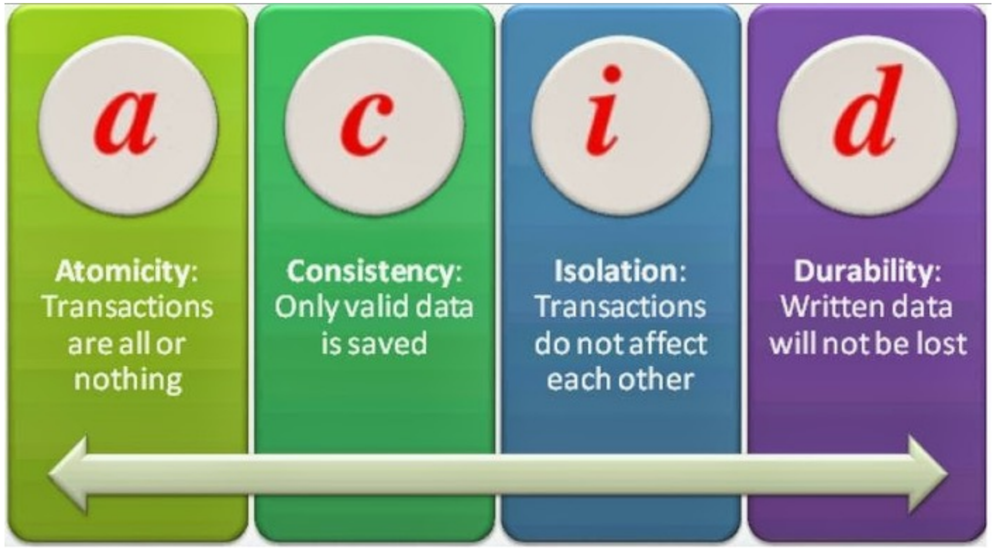
- Example: Interacting process
  - Fixing the Problem by Using Transactions
    - If we group Sally's statements (max)(min) into one transaction, then she cannot see the previous inconsistency
    - She sees Joe's prices at some fixed time
      - Either before or after he changes prices, or in the middle, but the MAX and MIN are computed from the same prices

# A Competing Scenario

- Example: Interacting process
  - Another Problem: Rollback
    - Suppose Joe executes (del)(ins), not as a transaction, but after executing these statements, thinks better of it and issues a ROLLBACK statement
    - If Sally executes her statements after Joe's (ins) but before the rollback, she sees a value, 2.00, that never existed in the database
  - Solution
    - If Joe executes (del)(ins) as a transaction, its effect cannot be seen by others until the transaction executes COMMIT
    - If the transaction executes ROLLBACK instead, then its effects can *never* be seen

# ACID Properties

- ACID properties
  - Atomic: Either fully executed or rolled back as if it never occurred
  - Consistent: Database constraints preserved
  - Isolated: Isolation from concurrent transactions – It appears to the user as if only one process executes at a time
  - Durable: Effects of a process survive a crash



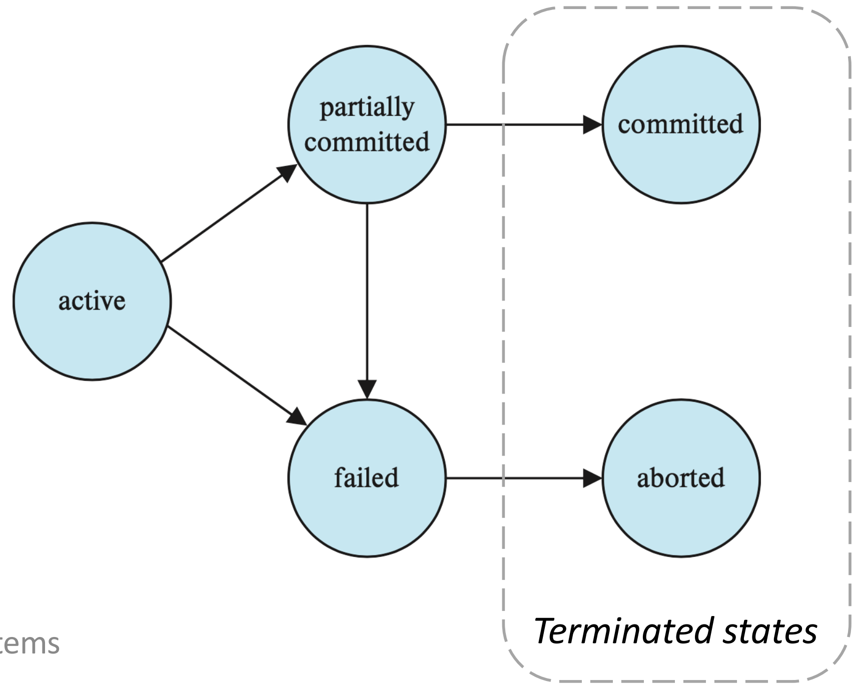

* Image src: https://morpheusdata.com/blog/2015-01-29-when-do-you-need-acid-compliance

# ACID Properties

- ACID properties
  - Atomic: Either fully executed or rolled back as if it never occurred
    - The *all-or-none* property
  - Consistent: All database constraints should be preserved
  - Isolated: Isolation from concurrent transactions – It appears to the user as if only one process executes at a time
    - DBMS must ensure that transactions operate properly without interference from other concurrently executing statements
  - Durable: Effects of a process survive a crash
    - The results of transactions must persist in the system

# States of a Transaction

- A transaction must be in one of the following states:
  - Active: Initial state; transactions stay in this state while executing
  - Partially committed: After the final statement has been executed
  - Failed: After the discovery that normal execution can no longer proceed
  - Aborted: After the transaction has been rolled back and the database has been restored
  - Committed: After successful completion



# A Toy Example

- $T_1$: read($A$);
  $A$ := $A$ - 50;
  write($A$);
  read($B$);
  $B$ := $B$ + 50;
  write($B$)

- $T_2$: read($A$);
  *temp* := $A$ * 0.1;
  $A$ := $A$ - *temp*;
  write(A)
  read($B$);
  $B$ := $B$ + *temp*;
  write($B$)

# A Toy Example

| $T_1$ | $T_2$ |
|---|---|
| read($A$) | |
| $A := A - 50$ | |
| write($A$) | |
| read($B$) | |
| $B := B + 50$ | |
| write($B$) | |
| commit | |
| | read($A$) |
| | $temp := A * 0.1$ |
| | $A := A - temp$ |
| | write($A$) |
| | read($B$) |
| | $B := B + temp$ |
| | write($B$) |
| | commit |

| $T_1$ | $T_2$ |
|---|---|
| | read($A$) |
| | $temp := A * 0.1$ |
| | $A := A - temp$ |
| | write($A$) |
| | read($B$) |
| | $B := B + temp$ |
| | write($B$) |
| | commit |
| read($A$) | |
| $A := A - 50$ | |
| write($A$) | |
| read($B$) | |
| $B := B + 50$ | |
| write($B$) | |
| commit | |

| $T_1$ | $T_2$ |
|---|---|
| read($A$) | |
| $A := A - 50$ | |
| | read($A$) |
| | $temp := A * 0.1$ |
| | $A := A - temp$ |
| | write($A$) |
| | read($B$) |
| write($A$) | |
| read($B$) | |
| $B := B + 50$ | |
| write($B$) | |
| commit | |
| | $B := B + temp$ |
| | write($B$) |
| | commit |

# A Toy Example

| $T_1$ | $T_2$ |
|---|---|
| read($A$) | |
| $A := A - 50$ | |
| write($A$) | |
| read($B$) | |
| $B := B + 50$ | |
| write($B$) | |
| commit | |
| | read($A$) |
| | $temp := A * 0.1$ |
| | $A := A - temp$ |
| | write($A$) |
| | read($B$) |
| | $B := B + temp$ |
| | write($B$) |
| | commit |

| $T_1$ | $T_2$ |
|---|---|
| | read($A$) |
| | $temp := A * 0.1$ |
| | $A := A - temp$ |
| | write($A$) |
| | read($B$) |
| | $B := B + temp$ |
| | write($B$) |
| | commit |
| read($A$) | |
| $A := A - 50$ | |
| write($A$) | |
| read($B$) | |
| $B := B + 50$ | |
| write($B$) | |
| commit | |

| $T_1$ | $T_2$ |
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| read($A$) | |
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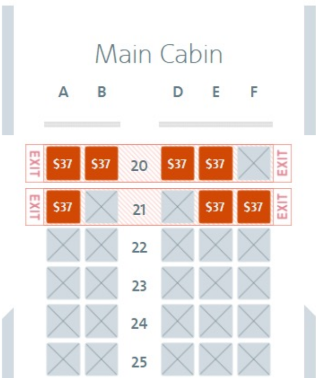
| | write($A$) |
| read($B$) | |
| $B := B + 50$ | |
| write($B$) | |
| commit | |
| | read($B$) |
| | $B := B + temp$ |
| | write($B$) |
| | commit |

# Serializable Behaviors

- When there are more than one operations overlap in time, affecting the same data source
  - Each operation could perform correctly
  - While the global result might not be correct
  - *E.g.*, Flight reservation





time

User 1 finds seat empty

User 2 finds seat empty

User 1 sets seat 22A occupied

User 2 sets seat 22A occupied

# Serializable Behaviors

- When there are more than one operations overlap in time, affecting the same data source
  - Each operation could perform correctly
  - While the global result might not be correct

- SQL allows the programmer to state that certain operations must be serializable with respect to other operations
  - Operations must behave "as if" they were run *serially* – one at a time, with no overlap

# Agenda

- Transactions
  - Concept and examples
  - **Levels of transactions**

# Read-Only Transactions

- **SET TRANSACTION READ ONLY**;
  **START TRANSACTION**;
  …
  **COMMIT**;    or    **ROLLBACK**;

- Declare that the coming transaction reads data from the database, but never writes
  - By default, a transaction is set as READ WRITE
- READ ONLY is useful to increase the parallelism of read-only transactions, compared to the regular (read & write) transactions

# Isolation Levels of Transactions

- **SET TRANSACTION ISOLATION LEVEL** <level>;
  **START TRANSACTION**;
  …
  **COMMIT**; or **ROLLBACK**;

- Declare kinds of interferences (by other transactions) allowed for a transaction
  - Declare the level of "locking" (enforcing limits on access to) data
  - Tradeoffs: Concurrency ⇌ Data integrity

# Isolation Levels of Transactions

- SQL supports four isolation levels (*i.e.*, <level>)
  - **SERIALIZABLE (level 3)**
  - **REPEATABLE READ (level 2)** – *the default isolation level in MySQL*
  - **READ COMMITTED (level 1)**
  - **READ UNCOMMITTED (level 0)**

  - Higher isolation level ⇒ more data integrity
  - Lower isolation level ⇒ more concurrency; higher throughput

# Possible Issues

- Phantom read
  - Same SELECT queries in the same transaction can have different results by 'INSERT' in another committed transaction
- Nonrepeatable read
  - Same SELECT queries in the same transaction can have different results by 'UPDATE' or 'DELETE' in another committed transaction
- Dirty read
  - Read dirty data that is written by an ongoing transaction (not committed yet)

# Isolation Levels of Transactions

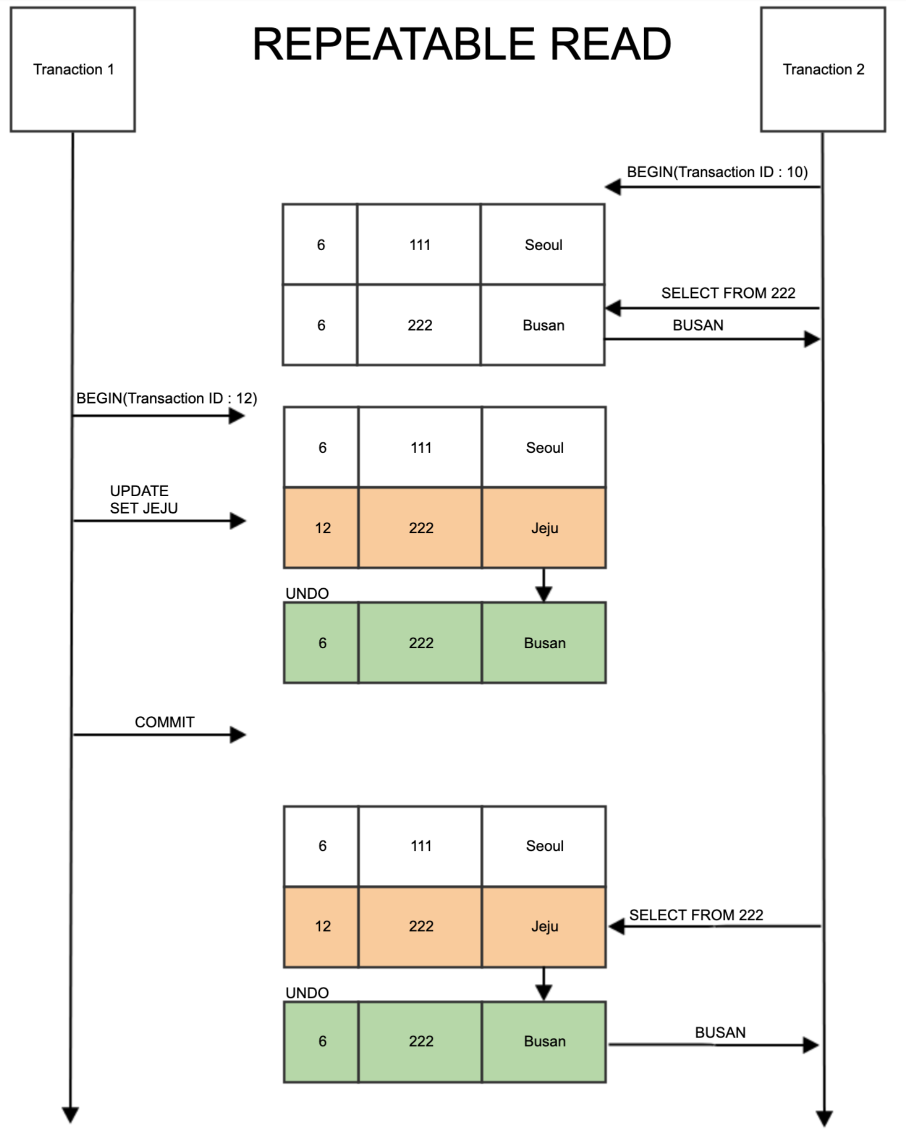
- **SERIALIZABLE** transactions
  - A serializable transaction must behave with respect to other transactions as if they were executed one by one without any parallel execution (*i.e.*, serially)
    - While a serializable transaction runs, all data it accesses are locked (other parallel transactions cannot modify nor insert)
  - Serializable is the most strict transaction isolation level – guarantees the highest level of data integrity
  - May slow down the transaction handling performance

# Isolation Levels of Transactions

- **REPEATABLE READ** transactions
  - A repeatable read transaction must see for multiple executions of the same query that a tuple in the first result also appears at the later results
  - A repeatable read transaction must be isolated from the other transaction committed concurrently
    - A repeatable read transaction only accesses data that has been committed before it starts
  - The second and the subsequence results of the same query may have phantom reads
    - Other parallel transactions may insert new tuples in a middle of a transaction, while not changing the existing tuples

# Isolation Levels of Transactions

- **REPEATABLE READ** transactions

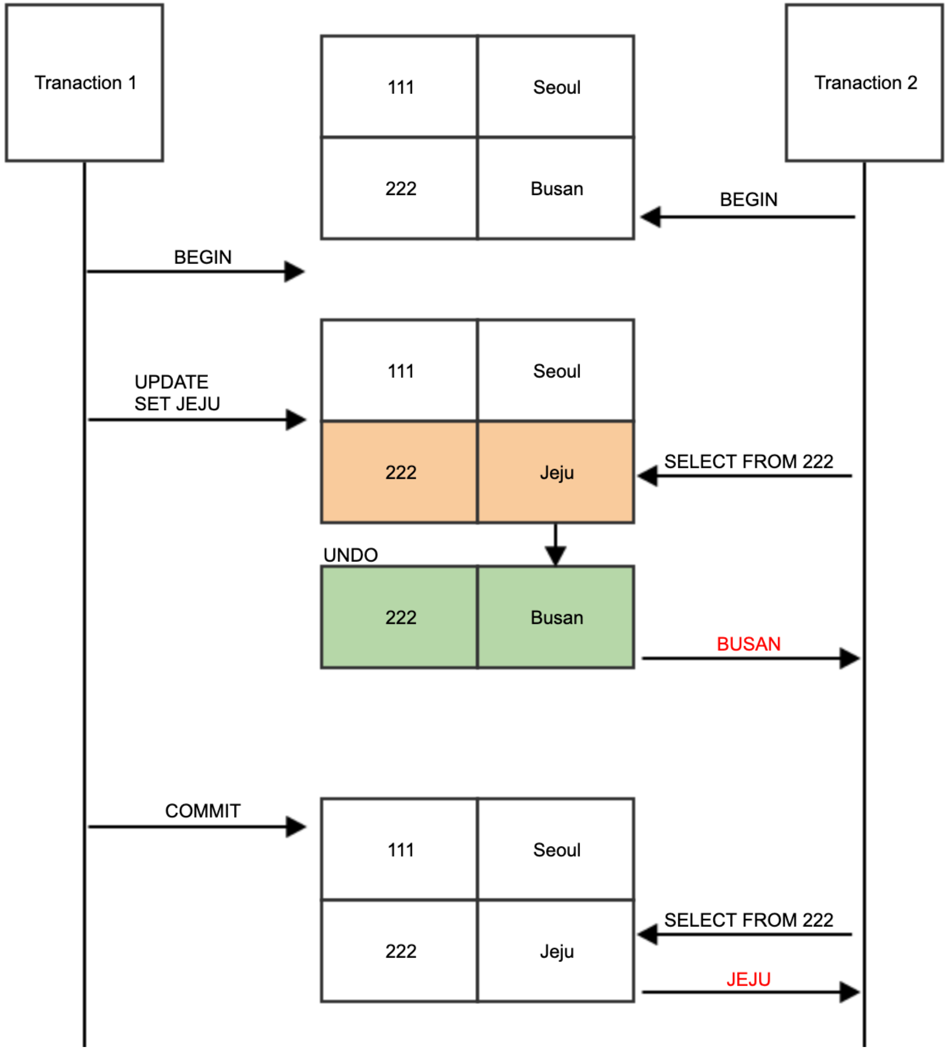


# Isolation Levels of Transactions

- **READ COMMITTED** transactions
  - A read committed transaction must see for multiple executions of the same query that a tuple in the first result also appears at the later results
  - A read-committed transaction must read the databases that are committed
  - The second and the subsequence results of the same query may have nonrepeatable reads
    - Other parallel transactions may commit changes in a middle of a transaction, while not changing the existing tuples

# Isolation Levels of Transactions

- **READ COMMITTED** transactions



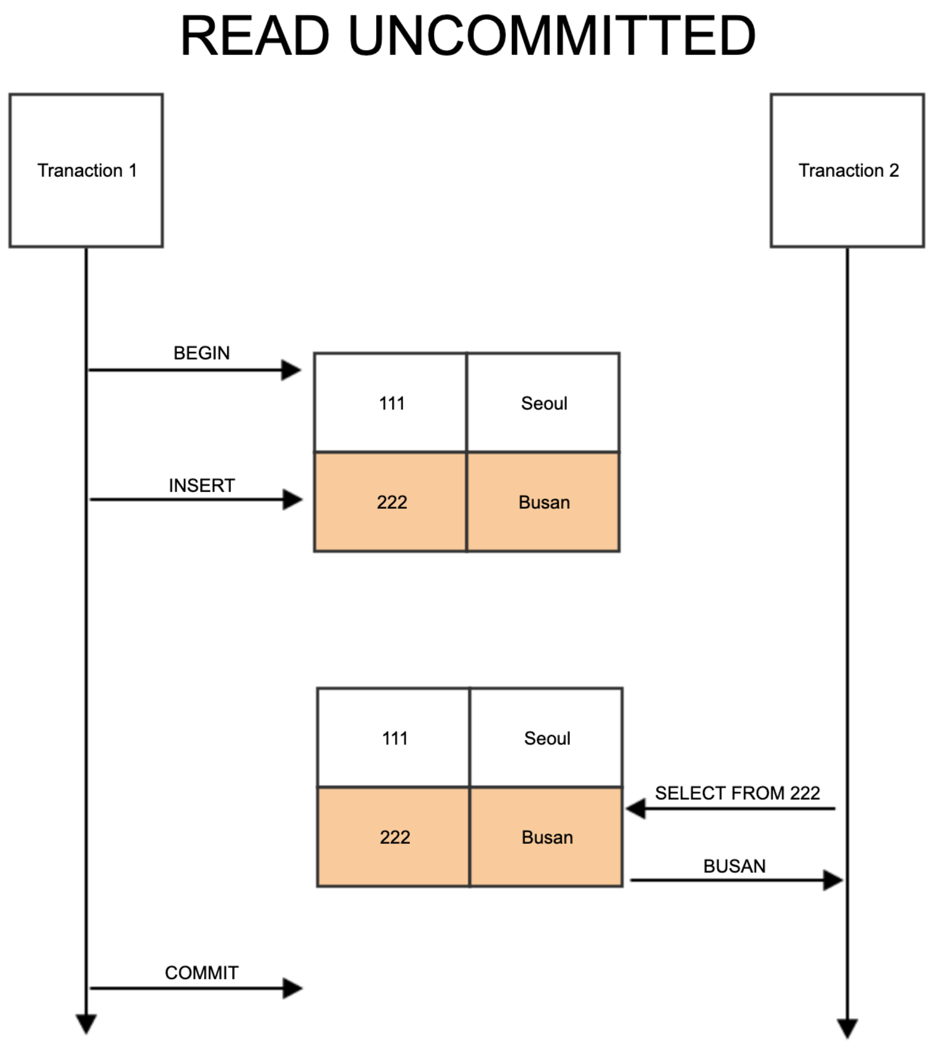

* Image src: https://nesoy.github.io/articles/2019-05/Database-Transaction-isolation

# Isolation Levels of Transactions

- **READ UNCOMMITTED** transactions
  - A read-uncommitted transaction may read dirty data, the *data written by a transaction that has not yet committed*
    - A dirty data may disappear if its writer transaction aborts
  - A careful use of dirty read allows fast processing of transactions
  - Practically there is no isolation; recommended not to use

# Isolation Levels of Transactions

- **READ UNCOMMITTED** transactions

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# Possible Issues in Different Isolation Levels

| Isolation level | Phantom read | Nonrepeatable read | Dirty read |
|---|---|---|---|
| **SERIALIZABLE** | Not allowed | Not allowed | Not allowed |
| **REPEATBLE READ** | Possible | Not allowed | Not allowed |
| **READ COMMITTED** | Possible | Possible | Not allowed |
| **READ UNCOMMITTED** | Possible | Possible | Possible |

# EOF

- Coming next:
  - Storage systems