More on Normalization Theory & Database Programming

Module 11

Prof. Alex Brodsky

Database Systems

Example

A	B	C
1	1	2
1	1	3
2	2	3
2	2	2

FDs with A as the left side:	**Satisfied by the relation?**
$A \rightarrow A$	Yes (trivial FD)
$A \rightarrow B$	Yes
$A \rightarrow C$	No: tuples 1&2
$AB \rightarrow A$	Yes (trivial FD)
$AC \rightarrow B$	Yes

Example

Let $F=\{ A \to BC, B \to C \}$. Does $C \to AB$ in F^+?

Answer: No. Either of the following 2 reasons is ok:

Reason 1) $C^+=C$, and does not include AB.

Reason 2) We can find a relation instance such that it satisfies F but does not satisfy $C \to AB$.

A	B	C
1	1	2
2	1	2

List all the non-trivial FDs in F^+

- Given $F=\{ A \rightarrow B, B \rightarrow C\}$. Compute F^+ (with attributes A, B, C).

	A	B	C	AB	AC	BC	ABC
A		√	√	√	√	√	√
B			√			√	
C							
AB			√		√	√	√
AC		√		√		√	√
BC							
ABC							

Attribute closure
$A^+=ABC$
$B^+=BC$
$C^+=C$
$AB^+=ABC$
$AC^+=ABC$
$BC^+=BC$
$ABC^+=ABC$

Example

- Given F={ A $\rightarrow$ B, B $\rightarrow$ C}. Find a relation that satisfies F:

A	B	C
1	1	2
2	1	2

- Given F={ A $\rightarrow$ B, B $\rightarrow$ C}. Find a relation that satisfies F but does not satisfy B $\rightarrow$ A. Well, the above example suffices.
- Can you find an instance that satisfies F but not A $\rightarrow$ C? No. Because A $\rightarrow$ C is in F^+

Examples

$R_1(A, B, C, D, E)$, $A \rightarrow B$, $C \rightarrow D$

Candidate key: ACE.

Intuitively, B cannot be in a candidate key. Reason is that A is not determined by any other attributes (like E), and A has to be in a candidate key (because the a candidate key has to determine all the attributes). Now if A is in a candidate key, B cannot be in the same candidate key, since we can drop B from the candidate without losing the property of being a "key".

Same reasoning apply to others attributes.

Example

$R_1(A, B, C, D, E)$, $A \rightarrow B$, $C \rightarrow D$ [Same as previous]

Which normal form?

Not in BCNF. This is the case where all attributes in the FDs appear in R_1. We consider A, and C to see if either is a superkey or not. Obviously, neither A nor C is a superkey, and hence R_1 is not in BCNF. More precisely, we have $A \rightarrow B$ is in F^+ and non-trivial, but A is not a superkey of R_1.

Example

$R_1(A, B, C, D, E)$, $A \rightarrow B$, $C \rightarrow D$ [Same as previous]

Which normal form?

Not in 3NF. We have $A \rightarrow B$ is in F^+ and non-trivial, but A is not a superkey of R_1. Furthermore, B is not in any candidate key (since the only candidate key is ACE).

Example

- R2(A,B,F), AC $\rightarrow$ E, B $\rightarrow$ F.
- Candidate key: AB.
- BCNF? No, because B $\rightarrow$ F.
- 3NF? No, because B $\rightarrow$ F.

Example

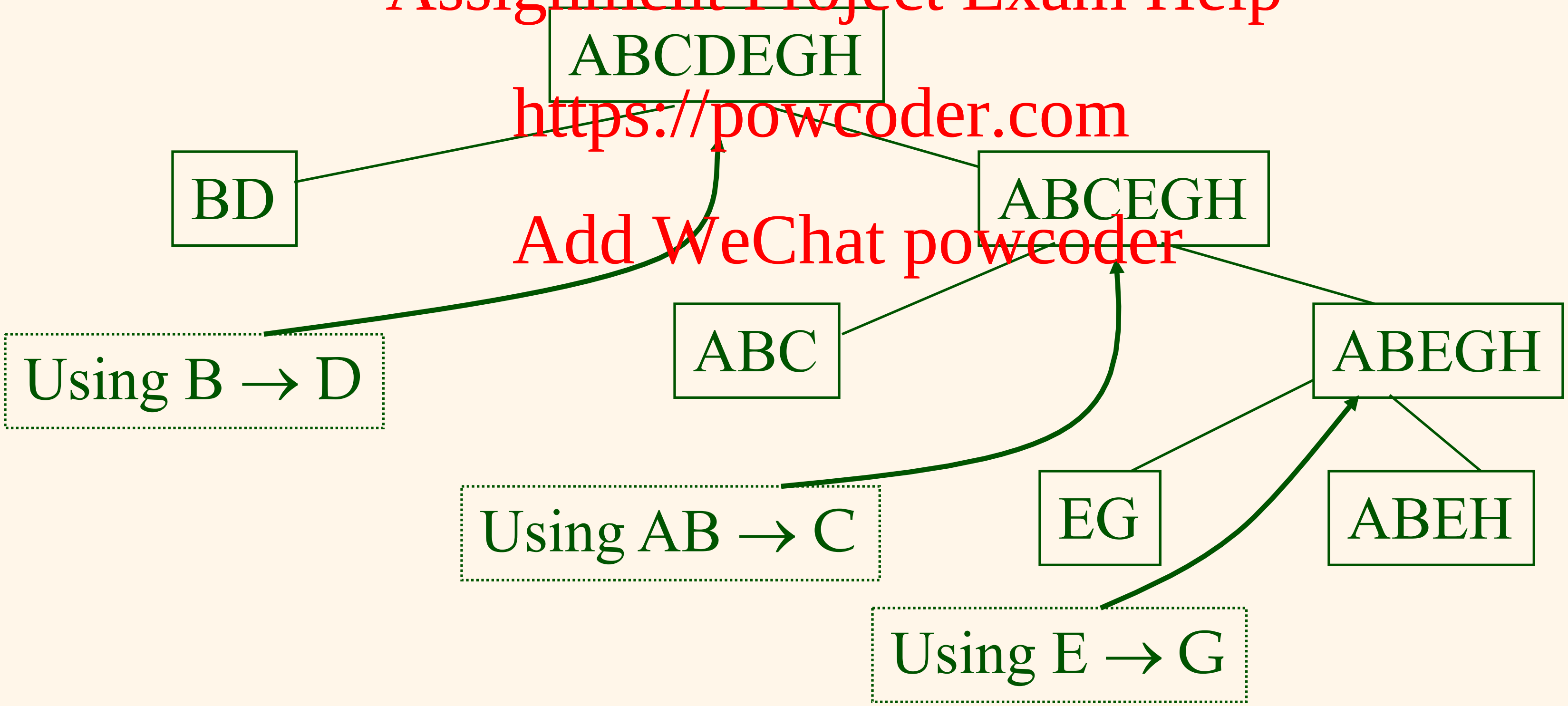
- R_4(D, C, H, G), A $\rightarrow$ I, I $\rightarrow$ A
- Candidate key: DCHG
- BCNF? Yes
- 3NF? Yes

Example

- R(A,B,C,D,E,G,H), F={AB → C, AC → B, B → D, BC → A, E → G}
- Candidate keys?
  - H has to be in all candidate keys
  - E has to be in all candidate keys
  - G cannot be in any candidate key (since E is in all candidate keys already).
  - Since AB → C, AC → B and BC → A, we know no candidate key can have ABC together.
  - AEH, BEH, CEH are not superkeys.
  - Try ABEH, ACEH, BCEH. They are all superkeys. And we know they are all candidate keys (since above properties)
  - These are the only candidate keys: (1) each candidate key either contains A, or B, or C since no attributes other than A,B,C determine A, B, C, and (2) if a candidate key contains A, then it must contain either B, or C, and so on.

Example

- Same as previous
- Not in BCNF, not in 3NF
- Decomposition:



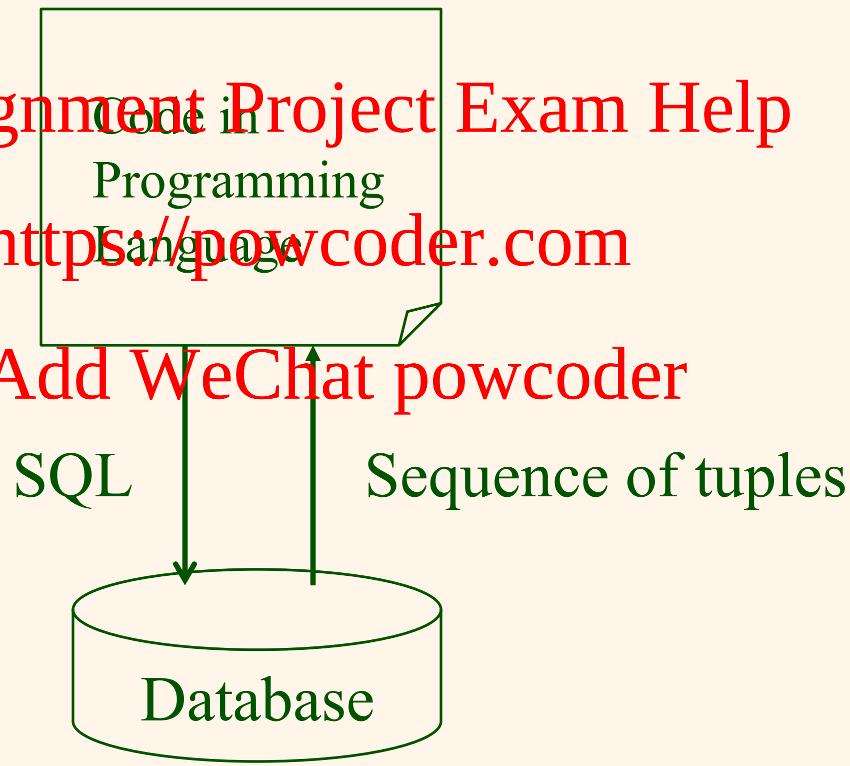
Example

- R(A,B,C,D,E,G,H), F={AB $\rightarrow$ C, AC $\rightarrow$ B, B $\rightarrow$ D, BC $\rightarrow$ A, E $\rightarrow$ G}
- Decomposition: BD, ABC, EG, ABEH
- Why good decomposition?
  - They are all in BCNF
  - Lossless-join decomposition
  - All dependencies are preserved.

Example

- R=(ABDE) decomposed into R1(ABD), R2(ABE),
- F={AB $\rightarrow$ DE}
- It is a dependency preserving decomposition!
  - AB $\rightarrow$ D can be checked in R1
  - AB $\rightarrow$ E can be checked in R2
  - {AB $\rightarrow$ DE} is equivalent to {AB $\rightarrow$ D, AB $\rightarrow$ E}

Database Programming



Embedded SQL

- SQL commands can be called from within a host language (e.g., C or COBOL) program.
  - SQL statements can refer to host variables (including special variables used to return status).
  - Must include a statement to *connect* to the right database.

- SQL relations are (multi-) sets of records, with no *a priori* bound on the number of records. No such data structure in C.
  - SQL supports a mechanism called a *cursor* to handle this.

Cursors

- Can declare a cursor on a relation or query statement (which generates a relation).
- Can *open* a cursor, and repeatedly *fetch* a tuple then *move* the cursor, until all tuples have been retrieved.
  - Can use a special clause, called ORDER BY, in queries that are accessed through a cursor, to control the order in which tuples are returned.
    - Fields in ORDER BY clause must also appear in SELECT clause.
  - The ORDER BY clause, which orders answer tuples, is *only* allowed in the context of a cursor.
- Can also modify/delete tuple pointed to by a cursor.

Cursor that gets names of sailors who've reserved a red boat, in alphabetical order

```
EXEC SQL DECLARE sinfo CURSOR FOR
        SELECT  S.sname
        FROM  Sailors S, Boats B, Reserves R
        WHERE  S.sid=R.sid AND R.bid=B.bid AND
                B.color='red'
        ORDER BY  S.sname
```

Embedding SQL in C: An Example

```
char SQLSTATE[6];
EXEC SQL BEGIN DECLARE SECTION
char c_sname[20]; short c_minrating; float c_age;
EXEC SQL END DECLARE SECTION
c_minrating = random();
EXEC SQL DECLARE sinfo CURSOR FOR
   SELECT S.sname, S.age FROM Sailors S
   WHERE S.rating > :c_minrating
   ORDER BY S.sname;
do {
   EXEC SQL FETCH sinfo INTO :c_sname, :c_age;
   printf("%s is %d years old\n", c_sname, c_age);
} while (SQLSTATE != '02000');
EXEC SQL CLOSE sinfo;
```

Database APIs: Alternative to embedding

Rather than modify compiler, add library with database calls (API)

- special standardized interface: procedures/objects

- passes SQL strings from language, presents result sets in a language-friendly way

- Microsoft's *ODBC* becoming C/C++ standard on Windows

- Sun's *JDBC* a Java equivalent
- Supposedly DBMS-neutral
  - a "driver" traps the calls and translates them into DBMS-specific code
  - database can be across a network

SQL API in Java (JDBC)

```
Connection con = // connect
   DriverManager.getConnection(url, ”login", ”pass");
Statement stmt = con.createStatement(); // set up stmt
String query = "SELECT name, rating FROM Sailors";
ResultSet rs = stmt.executeQuery(query);
try { // handle exceptions
    // loop through result tuples
    while (rs.next()) {
        String s = rs.getString(“name");
        Int n = rs.getFloat(“rating");
        System.out.println(s + "   " + n);
    }
} catch(SQLException ex) {
    System.out.println(ex.getMessage ()
        + ex.getSQLState () + ex.getErrorCode ());
}
```

TRANSACTION MANAGEMENT

Airline Reservations — many updates

Statistical Abstract of the US — many queries

Atomicity – all or nothing principle

Serializability – the effect of transactions as if they occurred one at a time

Items – units of data to be controlled

- fine-grained – small items
- course-grained – large items
- (granularity)

Controlling access by locks

- Read – sharable with other readers — shared
- Write – not sharable with anyone else — exclusive

Model – (item, locktype, transaction ID)

Transactions

Transaction = a unit of work that must be:

1. *Atomic* = either all work is done, or none of it.
2. *Consistent* = relationships among values maintained.
3. *Isolated* = appear to have been executed when no other DB operations were being performed.
   – Often called *serializable* behavior.
4. *Durable* = effects are permanent even if system crashes.

Commit/Abort Decision

Each transaction ends with either:

1. *Commit* = the work of the transaction is installed in the database; previously its changes may be invisible to other transactions.
2. *Abort* = no changes by the transaction appear in the database; it is as if the transaction never occurred.
   – `ROLLBACK` is the term used in SQL and the Oracle system.

- In the ad-hoc query interface (*e.g.*, PostgreSQL psql interface), transactions are single queries or modification statements.
  – Oracle allows `SET TRANSACTION READ ONLY` to begin a multistatement transaction that doesn't change any data, but needs to see a consistent "snapshot" of the data.

- In program interfaces, transactions begin whenever the database is accessed, and end when either a `COMMIT` or `ROLLBACK` statement is executed.

Example

`Sells(bar, beer, price)`

- Joe's Bar sells Bud for $2.50 and Miller for $3.00.
- Sally is querying the database for the highest and lowest price Joe charges:

(1)
```
SELECT MAX(price) FROM Sells
WHERE bar = 'Joe''s Bar';
```

(2)
```
SELECT MIN(price) FROM Sells
WHERE bar = 'Joe''s Bar';
```


- At the same time, Joe has decided to replace Miller and Bud by Heineken at $3.50:

(3)
```
DELETE FROM Sells
WHERE bar = 'Joe''s Bar' AND
         (beer = 'Miller' OR beer = 'Bud');
```


(4)
```
INSERT INTO Sells
VALUES('Joe''s bar', 'Heineken', 3.50);
```

- If the order of statements is 1, 3, 4, 2, then it appears to Sally that Joe’s minimum price is greater than his maximum price.
- Fix the problem by grouping Sally’s two statements into one transaction, *e.g.*, with one SQL statement.

Example: Problem With Rollback

- Suppose Joe executes statement 4 (insert Heineken), but then, during the transaction thinks better of it and issues a `ROLLBACK` statement.
- If Sally is allowed to execute her statement 1 (find max) just before the rollback, she gets the answer \$3.50, even though Joe doesn't sell any beer for \$3.50.
- Fix by making statement 4 a transaction, or part of a transaction, so its effects cannot be seen by Sally unless there is a `COMMIT` action.

SQL Isolation Levels

Isolation levels determine what a transaction is allowed to see. The declaration, valid for one transaction, is:

`SET TRANSACTION ISOLATION LEVEL` *X*`;`

where:

- *X* = `SERIALIZABLE`: this transaction must execute as if at a point in time, where all other transactions occurred either completely before or completely after.
  - Example: Suppose Sally's statements 1 and 2 are one transaction and Joe's statements 3 and 4 are another transaction. If Sally's transaction runs at isolation level SERIALIZABLE, she would see the `Sells` relation either before or after statements 3 and 4 ran, but not in the middle.

- X = `READ COMMITTED`: this transaction can read only committed data.
  - Example: if transactions are as above, Sally could see the original `Sells` for statement 1 and the completely changed `Sells` for statement 2.
- X = `REPEATABLE READ`: if a transaction reads data twice, then what it saw the first time, it will see the second time (it may see more the second time).

  - Moreover, all data read at any time must be committed; *i.e.*, `REPEATABLE READ` is a strictly stronger condition than `READ COMMITTED`.
  - Example: If 1 is executed before 3, then 2 must see the Bud and Miller tuples when it computes the min, even if it executes after 3. But if 1 executes between 3 and 4, then 2 may see the Heineken tuple.

- X = `READ UNCOMMITTED`: essentially no constraint, even on reading data written and then removed by a rollback.
  - Example: 1 and 2 could see Heineken, even if Joe rolled back his transaction.

Independence of Isolation Levels

Isolation levels describe what a transaction *T* with that isolation level sees.

- They *do not* constrain what other transactions, perhaps at different isolation levels, can see of the work done by *T*.

Example

If transaction 3-4 (Joe) runs serializable, but transaction 1-2 (Sally) does not, then Sally might see `NULL` as the value for both min and max, since it could appear to Sally that her transaction ran between steps 3 and 4.

Authorization in SQL

- File systems identify certain access privileges on files, *e.g.*, read, write, execute.
- In partial analogy, SQL identifies six access privileges on relations, of which the most important are:

1. `SELECT` = the right to query the relation.
2. `INSERT` = the right to insert tuples into the relation – may refer to one attribute, in which case the privilege is to specify only one column of the inserted tuple.
3. `DELETE` = the right to delete tuples from the relation.
4. `UPDATE` = the right to update tuples of the relation – may refer to one attribute.

Granting Privileges

- You have all possible privileges to the relations you create.
- You may grant privileges to any user if you have those privileges "with grant option."
  - You have this option to your own relations.

Example

1. Here, Sally can query `Sells` and can change prices, but cannot pass on this power:


```
GRANT SELECT ON Sells,
      UPDATE(price) ON Sells
TO sally;
```


2. Here, Sally can also pass these privileges to whom she chooses:

```
GRANT SELECT ON Sells,
      UPDATE(price) ON Sells
TO sally
WITH GRANT OPTION;
```

Revoking Privileges

- Your privileges can be revoked.
- Syntax is like granting, but `REVOKE ... FROM` instead of `GRANT ... TO`.
- Determining whether or not you have a privilege is tricky, involving "grant diagrams" as in text. However, the basic principles are:

a) If you have been given a privilege by several different people, then all of them have to revoke in order for you to lose the privilege.

b) Revocation is transitive. if *A* granted *P* to *B*, who then granted *P* to *C*, and then *A* revokes *P* from *B*, it is as if *B* also revoked *P* from *C*.