SQL, Part 2

Relations as Bags

Grouping and Aggregation

Database Modification

Defining Schemas and Views

Union, Intersection, and Difference

- Union, intersection, and difference of relations are expressed by the following forms, each involving subqueries:
  - (subquery) UNION (subquery)
  - (subquery) INTERSECT (subquery)
  - (subquery) EXCEPT (subquery)

Example

- From relations
  Likes(drinker, beer),
  Sells(bar, beer, price) and
  Frequents(drinker, bar),

  find the drinkers and beers such that:
  1. The drinker likes the beer, and
  2. The drinker frequents at least one bar that sells the beer.

Solution

(SELECT * FROM Likes)

INTERSECT

```
(SELECT drinker, beer
 FROM Sells, Frequents
 WHERE Frequents.bar = Sells.bar
);
```

The drinker frequents a bar that sells the beer.

Bag Semantics

- Although the SELECT-FROM-WHERE statement uses bag semantics, the **default** for union, intersection, and difference is **set** semantics.
  - That is, **duplicates are eliminated** as the operation is applied.

Motivation: Efficiency

- When doing projection in relational algebra, it is easier to avoid eliminating duplicates.
  - Just work tuple-at-a-time.
- When doing intersection or difference, it is most efficient to **sort** the relations first.
  - At that point you may as well eliminate the duplicates anyway.

Controlling Duplicate Elimination

- Force the result to be a set by SELECT DISTINCT . . .
- Force the result to be a bag (i.e., don't eliminate duplicates) by ALL, as in . . . UNION ALL . . .

Example: DISTINCT

- From Sells(bar, beer, price), find all the different prices charged for beers:

```
SELECT DISTINCT price
FROM Sells;
```

- Notice that without DISTINCT, each price would be listed as many times as there were bar/beer pairs at that price.

Example: ALL

- Using relations Frequents(drinker, bar) and Likes(drinker, beer):

```
(SELECT drinker FROM Frequents)
    EXCEPT ALL
(SELECT drinker FROM Likes);
```

- Lists drinkers who frequent more bars than they like beers, and does so as many times as the difference of those counts.

Join Expressions

- SQL provides a number of expression forms that act like varieties of join in relational algebra.
  - But using bag semantics, not set semantics.
- These expressions can be stand-alone queries or used in place of relations in a FROM clause.

Products and Natural Joins

- Natural join is obtained by:

  R NATURAL JOIN S;

- Product is obtained by:

  R CROSS JOIN S;

- Example:

  ```
  Likes NATURAL JOIN Serves;
  ```

- Relations can be parenthesized subexpressions, as well.

Theta Join

- R JOIN S ON <condition> is a theta-join, using <condition> for selection.
- Example: using Drinkers(name, addr) and Frequents(drinker, bar):

```
Drinkers JOIN Frequents ON
    name = drinker;
```

gives us all (*d, a, d, b*) quadruples such that drinker *d* lives at address *a* and frequents bar *b*.

Outerjoins

- R OUTER JOIN S is the core of an outerjoin expression. It is modified by:
  1. Optional NATURAL in front of OUTER.
  2. Optional ON <condition> after JOIN.
  3. Optional LEFT, RIGHT, or FULL before OUTER.
     - LEFT = pad dangling tuples of R only.
     - RIGHT = pad dangling tuples of S only.
     - FULL = pad both; this choice is the default.

Aggregations

- SUM, AVG, COUNT, MIN, and MAX can be applied to a column in a SELECT clause to produce that aggregation on the column.
- Also, COUNT(*) counts the number of tuples.

Example: Aggregation

- From Sells(bar, beer, price), find the average price of Bud:

```
SELECT AVG(price)
FROM Sells
WHERE beer = 'Bud';
```

Eliminating Duplicates in an Aggregation

- DISTINCT inside an aggregation causes duplicates to be eliminated before the aggregation.

- Example: find the number of different prices charged for Bud:

```
SELECT COUNT(DISTINCT price)
FROM Sells
WHERE beer = 'Bud';
```

NULL's Ignored in Aggregation

- NULL never contributes to a sum, average, or count, and can never be the minimum or maximum of a column.

- But if there are **no** non-NULL values in a column, then the result of the aggregation is NULL.

Example: Effect of NULL's

```
SELECT count(*)
FROM Sells
WHERE beer = 'Bud';
```

The number of bars that sell Bud.

```
SELECT count(price)
FROM Sells
WHERE beer = 'Bud';
```

The number of bars that sell Bud at a **non-NULL** price.

Grouping

- We may follow a SELECT-FROM-WHERE expression by **GROUP BY** and a list of attributes.
- The relation that results from the SELECT-FROM-WHERE is grouped according to the values of all those attributes, and any **aggregation is applied only within each group.**

Example: Grouping

- From Sells(bar, beer, price), find the average price for each beer:

```
SELECT beer, AVG(price)
FROM Sells
GROUP BY beer;
```

Example: Grouping

- From Sells(bar, beer, price) and Frequents(drinker, bar), find for each drinker the average price of Bud at the bars they frequent:

```
SELECT drinker, AVG(price)
FROM Frequents, Sells
WHERE beer = 'Bud' AND
      Frequents.bar = Sells.bar
GROUP BY drinker;
```

Compute drinker-bar-price of Bud tuples first, then group by drinker.

Restriction on SELECT Lists With Aggregation

- If **any** aggregation is used, then each element of the SELECT list must be either:
  1. Aggregated, or
  2. An attribute on the GROUP BY list.

Illegal Query Example

- You might think you could find the bar that sells Bud the cheapest by:

  SELECT bar, MIN(price)

  FROM Sells

  WHERE beer = 'Bud';

- But this query is illegal in SQL.
  - Why? Note **bar** is neither aggregated nor on the GROUP BY list.

HAVING Clauses

- HAVING <condition> may follow a GROUP BY clause.
- If so, the condition applies **to each group**, and groups **not** satisfying the condition are eliminated.

Requirements on HAVING Conditions

- These conditions may refer to any relation or tuple-variable in the FROM clause.
- They may refer to attributes of those relations, as long as the attribute makes sense within a group; i.e., it is either:
  1. A grouping attribute, or
  2. Aggregated.

Example: HAVING

- From Sells(bar, beer, price) and Beers(name, manf), find the average price of those beers that are either:
  - served in at least three bars, or
  - are manufactured by Pete's.

Solution

```
SELECT beer, AVG(price)
FROM Sells
GROUP BY beer
HAVING COUNT(bar) >= 3 OR
    beer IN (SELECT name
             FROM Beers
             WHERE manf = 'Pete''s');
```

Beer groups with at least 3 non-NULL bars and also beer groups where the manufacturer is Pete's.

Beers manufactured by Pete's.

Database Modifications

- A modification command does not return a result as a query does, but it changes the database in some way.
- There are three kinds of modifications:
  1. *Insert* a tuple or tuples.
  2. *Delete* a tuple or tuples.
  3. *Update* the value(s) of an existing tuple or tuples.

Insertion

- To insert a single tuple:

  INSERT INTO <relation>

  VALUES (<list of values>);

- Example: add to Likes(drinker, beer) the fact that Sally likes Bud.

```
INSERT INTO Likes
VALUES('Sally', 'Bud');
```

Specifying Attributes in INSERT

- We may add to the relation name a list of attributes.
- There are two reasons to do so:
  1. We **forget, or don't wish to use,** the standard order of attributes for the relation.
  2. We **don't have values** for all attributes, and we want the system to fill in missing components with **NULL** or a **default** value.

Example: Specifying Attributes

- Another way to add the fact that Sally likes Bud to Likes(drinker, beer):

```
INSERT INTO Likes(beer, drinker)
VALUES('Bud', 'Sally');
```

Inserting Many Tuples

- We may insert the **entire result** of a query into a relation, using the form:

  INSERT INTO <relation>

  (<subquery>);

Example: Insert a Subquery

- Using Frequents(drinker, bar), enter into the new relation

  PotentialBuddies(name)

  all of Sally's "potential buddies," i.e., those drinkers who frequent at least one bar that Sally also frequents.

Solution

The other drinker

Pairs of Drinker tuples where the first is for Sally, the second is for someone else, and the bars are the same.

```
INSERT INTO PotentialBuddies
(SELECT d2.drinker
 FROM Frequents d1, Frequents d2
 WHERE d1.drinker = 'Sally' AND
   d2.drinker <> 'Sally' AND
   d1.bar = d2.bar
);
```

Deletion

- To delete tuples satisfying a condition from some relation:

  DELETE FROM <relation>

  WHERE <condition>;

  We don't specify any attributes of relation, since the entire tuple is deleted.

Example: Deletion

- Delete from Likes(drinker, beer) the fact that Sally likes Bud:

```
DELETE FROM Likes
WHERE drinker = 'Sally' AND
    beer = 'Bud';
```

Example: Delete all Tuples

- Make the relation Likes empty:

```
DELETE FROM Likes;
```

- Note no WHERE clause needed.

Example: Delete Many Tuples

- Delete from Beers(name, manf) all beers for which there is another beer by the same manufacturer.

```
DELETE FROM Beers b
WHERE EXISTS (
    SELECT name FROM Beers
    WHERE manf = b.manf AND
        name <> b.name);
```

Beers with the same manufacturer and a different name from the name of the beer represented by tuple b.

Semantics of Deletion -- 1

- Suppose Anheuser-Busch makes only Bud and Bud Lite.
- Suppose we come to the tuple *b* for Bud first.
- The subquery is nonempty, because of the Bud Lite tuple, so we delete Bud.
- Now, When *b* is the tuple for Bud Lite, do we delete that tuple too?

Semantics of Deletion -- 2

- The answer is that we *do* delete Bud Lite as well.
- The reason is that deletion proceeds in two stages:
  1. Mark all tuples for which the WHERE condition is satisfied in the original relation.
  2. Delete the marked tuples.

Updates

- To change certain attributes in certain tuples of a relation:

  UPDATE <relation>

  SET <list of attribute assignments>

  WHERE <condition on tuples>;

Example: Update

- Change drinker Fred's phone number to 555-1212:

```
UPDATE Drinkers
SET phone = '555-1212'
WHERE name = 'Fred';
```

Example: Update Several Tuples

- Make $4 the maximum price for beer:

```
UPDATE Sells
SET price = 4.00
WHERE price > 4.00;
```

Defining a Database Schema

Defining a Database Schema

- A database schema comprises declarations for the relations ("tables") of the database.
- Many other kinds of elements may also appear in the database schema, including views, indexes, and triggers, which we'll introduce later.

Declaring a Relation

- Simplest form is:

```
CREATE TABLE <name> (
        <list of elements>
);
```

- And you may remove a relation from the database schema by:

```
DROP TABLE <name>;
```

Elements of Table Declarations

- The principal element is a pair consisting of an attribute and a type.
- The most common types are:
  - INT or INTEGER (synonyms).
  - REAL or FLOAT (synonyms).
  - CHAR(*n*) = fixed-length string of *n* characters.
  - VARCHAR(*n*) = variable-length string of up to *n* characters.

Example: Create Table

```
CREATE TABLE Sells (
    bar     CHAR(20),
    beer    VARCHAR(20),
    price   REAL
);
```

Dates and Times

- DATE and TIME are types in SQL.
- The form of a date value is:

  DATE 'yyyy-mm-dd'

  - Example: DATE '2002-09-30' for Sept. 30, 2002.

Times as Values

- The form of a time value is:

  TIME ‘hh:mm:ss’

with an optional decimal point and fractions of a second following.

  - Example: TIME ’15:30:02.5’ = two and a half seconds after 3:30PM.

Declaring Keys

- An attribute or list of attributes may be declared PRIMARY KEY or UNIQUE.
- These each say the attribute(s) so declared functionally determine all the attributes of the relation schema.
- There are a few distinctions to be mentioned later.

Declaring Single-Attribute Keys

- Place PRIMARY KEY or UNIQUE after the type in the declaration of the attribute.
- Example:

```
CREATE TABLE Beers (
    name    CHAR(20) UNIQUE,
    manf    CHAR(20)
);
```

Declaring Multiattribute Keys

- A key declaration can also be another element in the list of elements of a CREATE TABLE statement.
- This form is **essential** if the key consists of more than one attribute.
  - May be used even for one-attribute keys.

Example: Multiattribute Key

- The bar and beer together are the key for Sells:

```
CREATE TABLE Sells (
        bar         CHAR(20),
        beer        VARCHAR(20),
        priceREAL,
        PRIMARY KEY (bar, beer)
);
```

PRIMARY KEY Versus UNIQUE

- The SQL standard allows DBMS implementers to make their own distinctions between PRIMARY KEY and UNIQUE.
  - Example: some DBMS might automatically create an ***index*** (data structure to speed search) in response to PRIMARY KEY, but not UNIQUE.

Required Distinctions

- However, standard SQL requires these distinctions:
  1. There can be only **one** PRIMARY KEY for a relation, but several UNIQUE attributes.
  2. No attribute of a PRIMARY KEY can ever be NULL in any tuple. But attributes declared UNIQUE may have NULL's, and there may be several tuples with NULL.

Other Declarations for Attributes

- Two other declarations we can make for an attribute are:
  1. **NOT NULL** means that the value for this attribute may never be NULL.
  2. **DEFAULT** <value> says that if there is no specific value known for this attribute's component in some tuple, use the stated <value>.

Example: Default Values

```
CREATE TABLE Drinkers (
   name CHAR(30) PRIMARY KEY,
   addr CHAR(50)
      DEFAULT '123 Sesame St.',
   phone CHAR(16)
);
```

Effect of Defaults -- 1

- Suppose we insert the fact that Sally is a drinker, but we know neither her address nor her phone.

- An INSERT with a partial list of attributes makes the insertion possible:

```
INSERT INTO Drinkers(name)
VALUES('Sally');
```

Effect of Defaults -- 2

- But what tuple appears in Drinkers?

name	addr	phone
'Sally'	'123 Sesame St'	NULL

- If we had declared phone NOT NULL, this insertion would have been rejected.

Adding Attributes

- We may **change a relation schema** by adding a new attribute ("column") by:

  ALTER TABLE <name> ADD

  <attribute declaration>;

- Example:

```
ALTER TABLE Bars ADD
phone CHAR(16)DEFAULT 'unlisted';
```

Deleting Attributes

- Remove an attribute from a relation schema by:

  ALTER TABLE <name>

  DROP <attribute>;

- Example: we don't really need the license attribute for bars:

```
ALTER TABLE Bars DROP license;
```

Defining Views

Views

- A view is a "virtual table," a relation that is defined in terms of the contents of other tables and views.
- Declare by:

  CREATE VIEW <name> AS <query>;
- In contrast, a relation whose value is really stored in the database is called a *base table*.

Example: View Definition

- CanDrink(drinker, beer) is a view "containing" the drinker-beer pairs such that the drinker frequents at least one bar that serves the beer:

```
CREATE VIEW CanDrink AS
    SELECT drinker, beer
    FROM Frequents, Sells
    WHERE Frequents.bar = Sells.bar;
```

Example: Accessing a View

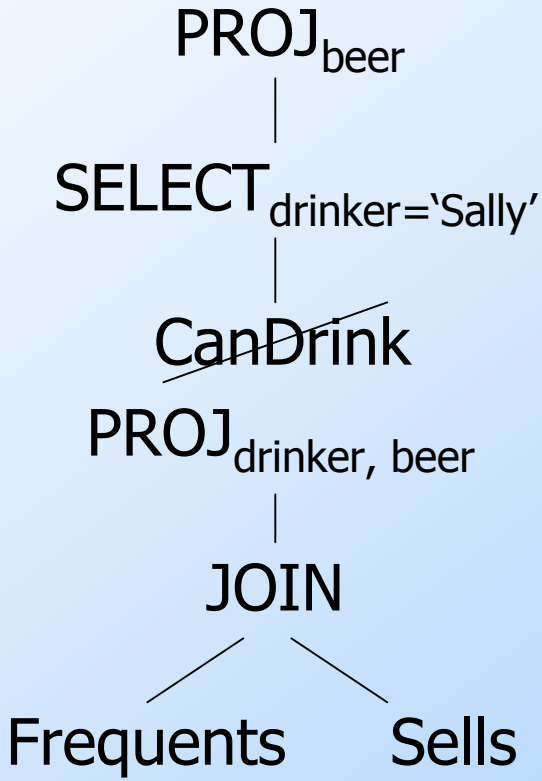
- You may query a view as if it were a base table.
  - There is a limited ability to modify views if the modification makes sense as a modification of the underlying base table.
- Example:

```
SELECT beer FROM CanDrink
WHERE drinker = 'Sally';
```

What Happens When a View Is Used?

- The DBMS starts by interpreting the query as if the view were a base table.
  - Typical DBMS turns the query into something like relational algebra.
- The queries defining any views used by the query are also replaced by their algebraic equivalents, and "spliced into" the expression tree for the query.

Example: View Expansion



DMBS Optimization

- It is interesting to observe that the typical DBMS will then "optimize" the query by transforming the algebraic expression to one that can be executed faster.
- Key optimizations:
  1. Push selections down the tree.
  2. Eliminate unnecessary projections.

Example: Optimization

Notice how most tuples are eliminated from Frequents before the expensive join.