SQL

April 25th, 2002

Agenda

- Grouping and aggregation
- Sub-queries
- Updating the database
- Views
- More on views

Union, Intersection, Difference

```
(SELECT  name
 FROM    Person
 WHERE   City="Seattle")

    UNION

(SELECT  name
 FROM    Person, Purchase
 WHERE   buyer=name AND store="The Bon")
```

Similarly, you can use INTERSECT and EXCEPT.
You must have the same attribute names (otherwise: rename).

Aggregation

```
SELECT  Sum(price)
FROM    Product
WHERE   maker="Toyota"
```

SQL supports several aggregation operations:

SUM, MIN, MAX, AVG, COUNT

Aggregation: Count

```
SELECT  Count(*)
FROM    Product
WHERE   year > 1995
```

Except COUNT, all aggregations apply to a single attribute

Aggregation: Count

COUNT applies to duplicates, unless otherwise stated:

```
SELECT  Count(name, category)        same as Count(*)
FROM    Product
WHERE   year > 1995
```

Better:

```
SELECT  Count(DISTINCT name, category)
FROM    Product
WHERE   year > 1995
```

Simple Aggregation

Purchase(product, date, price, quantity)

Example 1: **find total sales for the entire database**

```
SELECT  Sum(price * quantity)
FROM    Purchase
```

Example 1': **find total sales of bagels**

```
SELECT  Sum(price * quantity)
FROM    Purchase
WHERE   product = 'bagel'
```

Simple Aggregations

Product	Date	Price	Quantity
Bagel	10/21	0.85	15
Banana	10/22	0.52	7
Banana	10/19	0.52	17
Bagel	10/20	0.85	20

Grouping and Aggregation

Usually, we want aggregations on certain parts of the relation.

Purchase(product, date, price, quantity)

Example 2: **find total sales after 9/1 per product.**

```
SELECT    product, Sum(price*quantity) AS TotalSales
FROM      Purchase
WHERE     date > "9/1"
GROUPBY   product
```

Grouping and Aggregation

1. Compute the relation (I.e., the FROM and WHERE).
2. Group by the attributes in the GROUPBY
3. Select one tuple for every group (and apply aggregation)

SELECT can have (1) grouped attributes or (2) aggregates.

First compute the relation (date > "9/1") then group by product:

Product	Date	Price	Quantity
Banana	10/19	0.52	17
Banana	10/22	0.52	7
Bagel	10/20	0.85	20
Bagel	10/21	0.85	15

Then, aggregate

Product	TotalSales
Bagel	$29.75
Banana	$12.48

```
SELECT    product, Sum(price*quantity) AS TotalSales
FROM      Purchase
WHERE     date > "9/1"
GROUPBY   product
```

Another Example

Product	SumSales	MaxQuantity
Banana	$12.48	17
Bagel	$29.75	20

For every product, what is the total sales and max quantity sold?

```
SELECT     product, Sum(price * quantity) AS SumSales
                    Max(quantity) AS MaxQuantity
FROM       Purchase
GROUP BY   product
```

HAVING Clause

Same query, except that we consider only products that had at least 100 buyers.

```
SELECT     product, Sum(price * quantity)
FROM       Purchase
WHERE      date > "9/1"
GROUP BY   product
HAVING     Sum(quantity) > 30
```

HAVING clause contains conditions on aggregates.

General form of Grouping and Aggregation

SELECT S
FROM $R_1,\ldots,R_n$
WHERE C1
GROUP BY $a_1,\ldots,a_k$
HAVING C2

S = may contain attributes $a_1,\ldots,a_k$ and/or any aggregates but NO OTHER ATTRIBUTES
C1 = is any condition on the attributes in $R_1,\ldots,R_n$
C2 = is any condition on aggregate expressions

General form of Grouping and Aggregation

SELECT S
FROM $R_1,\ldots,R_n$
WHERE C1
GROUP BY $a_1,\ldots,a_k$
HAVING C2

Evaluation steps:

1. Compute the FROM-WHERE part, obtain a table with all attributes in $R_1,\ldots,R_n$
2. Group by the attributes $a_1,\ldots,a_k$
3. Compute the aggregates in C2 and keep only groups satisfying C2
4. Compute aggregates in S and return the result

Aggregation

Author(<u>login</u>,name)
Document(<u>url</u>, title)
Wrote(login,url)
Mentions(url,word)

- Find all authors who wrote at least 10 documents:

```
Select author.name
From author, wrote
Where author.login=wrote.login
Groupby author.name
Having count(wrote.url) > 10
```

- Find all authors who have a vocabulary over 10000:

```
Select author.name
From author, wrote, mentions
Where author.login=wrote.login and wrote.url=mentions.url
Groupby author.name
Having count(distinct mentions.word) > 10000
```

Exercises

Product (pname, price, category, maker)
Purchase (buyer, seller, store, product)
Company (cname, stock price, country)
Person(per-name, phone number, city)

Ex #1: Find people who bought telephony products.
Ex #2: Find names of people who bought American products
Ex #3: Find names of people who bought American products and did not buy French products
Ex #4: How much money did Fred spend on purchases?
Ex #5: What is the number and sum of the product sales by country of origin?

Subqueries

A subquery producing a single tuple:

```
SELECT Purchase.product
FROM     Purchase
WHERE  buyer =
           (SELECT  name
             FROM     Person
             WHERE   ssn = “123456789”);
```

In this case, the subquery returns one value.

If it returns more, it’s a run-time error.

Can we express this query without a subquery?

Subqueries Returning Relations

Find companies who manufacture products bought by Joe Blow.

```
SELECT  Company.name
FROM     Company, Product
WHERE  Company.name=maker
       AND  Product.name  IN
              (SELECT product
               FROM   Purchase
               WHERE  buyer = “Joe Blow”);
```

Here the subquery returns a set of values

Subqueries Returning Relations

Equivalent to:

```
SELECT  Company.name
FROM     Company, Product, Purchase
WHERE  Company.name=maker
       AND  Product.name  = product
       AND  buyer = “Joe Blow”
```

Is this query equivalent to the previous one ?

Subqueries Returning Relations

You can also use: s > ALL R
s > ANY R
EXISTS R

Product (pname, price, category, maker)
Find products that are more expensive than all those produced By “Gizmo-Works”

```
SELECT  name
FROM     Product
WHERE  price >  ALL (SELECT price
                     FROM    Purchase
                     WHERE  maker=“Gizmo-Works”)
```

Question for Database Fans and their Friends

- Can we express this query as a single SELECT-FROM-WHERE query, without subqueries ?
- Hint: show that all SFW queries are monotone (figure out what this means). A query with **ALL** is not monotone

Conditions on Tuples

```
SELECT  Company.name
FROM    Company, Product
WHERE   Company.name=maker
        AND (Product.name,price) IN
              (SELECT product, price)
               FROM   Purchase
               WHERE  buyer = "Joe Smith");
```

Correlated Queries

Movie (title, year, director, length)

Find movies whose title appears more than once.

```
SELECT  title
FROM    Movie AS x
WHERE   year < ANY
             (SELECT  year
              FROM    Movie
              WHERE   title = x.title);
```

correlation

Note (1) scope of variables (2) this can still be expressed as single SFW

Complex Correlated Query

Product (pname, price, category, maker, year)

- Find products (and their manufacturers) that are more expensive than all products made by the same manufacturer before 1972

```
SELECT  pname, maker
FROM    Product AS x
WHERE   price > ALL  (SELECT  price
                      FROM    Product AS y
                      WHERE   x.maker = y.maker AND y.year < 1972);
```

Powerful, but much harder to optimize !

Removing Duplicates

```
SELECT  DISTINCT Company.name
FROM    Company, Product
WHERE   Company.name=maker
        AND (Product.name,price) IN
              (SELECT product, price)
               FROM   Purchase
               WHERE  buyer = "Joe Blow");
```

Conserving Duplicates

The UNION, INTERSECTION and EXCEPT operators operate as sets, not bags.

```
(SELECT  name
 FROM    Person
 WHERE   City="Seattle")

   UNION  ALL

(SELECT  name
 FROM    Person, Purchase
 WHERE   buyer=name AND store="The Bon")
```

Modifying the Database

Three kinds of modifications

- Insertions
- Deletions
- Updates

Sometimes they are all called "updates"

Insertions

General form:

```
INSERT INTO R(A1,…., An) VALUES (v1,…., vn)
```

Example: Insert a new purchase to the database:

```
INSERT INTO Purchase(buyer, seller, product, store)
        VALUES ('Joe', 'Fred', 'wakeup-clock-espresso-machine',
                'The Sharper Image')
```

Missing attribute → NULL.
May drop attribute names if give them in order.

Insertions

```
INSERT INTO PRODUCT(name)

   SELECT DISTINCT Purchase.product
   FROM     Purchase
   WHERE  Purchase.date > "10/26/01"
```

The query replaces the VALUES keyword.
Here we insert *many* tuples into PRODUCT

Insertion: an Example

Product(name, listPrice, category)
Purchase(prodName, buyerName, price)

prodName is foreign key in Product.name

Suppose database got corrupted and we need to fix it:

Product

name	listPrice	category
gizmo	100	gadgets

Purchase

prodName	buyerName	price
camera	John	200
gizmo	Smith	80
camera	Smith	225

Task: insert in Product all prodNames from Purchase

Insertion: an Example

```
INSERT INTO Product(name)

SELECT DISTINCT prodName
FROM Purchase
WHERE  prodName NOT IN (SELECT name FROM Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	-	-

Insertion: an Example

```
INSERT INTO Product(name, listPrice)

SELECT DISTINCT prodName, price
FROM Purchase
WHERE  prodName NOT IN (SELECT name FROM Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	200	-
camera ??	225 ??	-

← Depends on the implementation

Deletions

Example:

```
DELETE   FROM   PURCHASE

WHERE   seller = 'Joe'   AND
        product = 'Brooklyn Bridge'
```

Factoid about SQL: there is no way to delete only a single occurrence of a tuple that appears twice in a relation.

Updates

Example:

```
UPDATE  PRODUCT
SET   price = price/2
WHERE  Product.name  IN
          (SELECT product
           FROM   Purchase
           WHERE  Date ='Oct, 25, 1999');
```

Data Definition in SQL

So far we have see the ***Data Manipulation Language***, DML
Next: ***Data Definition Language*** (DDL)

Data types:
Defines the types.

Data definition: defining the schema.

- Create tables
- Delete tables
- Modify table schema

Indexes: to improve performance

Data Types in SQL

- Character strings (fixed of varying length)
- Bit strings (fixed or varying length)
- Integer (SHORTINT)
- Floating point
- Dates and times

Domains (=types) will be used in table declarations.

To reuse domains:
CREATE DOMAIN address AS VARCHAR(55)

Creating Tables

Example:

```
CREATE   TABLE Person(

      name                    VARCHAR(30),
      social-security-number  INTEGER,
      age                     SHORTINT,
      city                    VARCHAR(30),
      gender                  BIT(1),
      Birthdate               DATE

 );
```

Deleting or Modifying a Table

Deleting:

Example: `DROP Person;`

Altering: (adding or removing an attribute).

Example:

```
ALTER TABLE   Person
      ADD   phone  CHAR(16);

ALTER  TABLE   Person
      DROP  age;
```

What happens when you make changes to the schema?

Default Values

Specifying default values:

```
CREATE  TABLE Person(
        name                  VARCHAR(30),
        social-security-number INTEGER,
        age       SHORTINT  DEFAULT 100,
        city    VARCHAR(30) DEFAULT  'Seattle',
        gender       CHAR(1)  DEFAULT  '?',
        Birthdate             DATE
```

The default of defaults: NULL

Indexes

REALLY important to speed up query processing time.

Suppose we have a relation

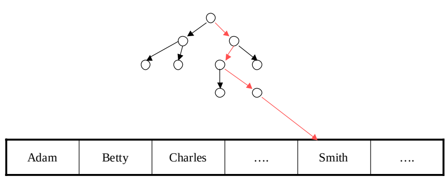
Person (name, age, city)

```
SELECT *
FROM    Person
WHERE   name = "Smith"
```

Sequential scan of the file Person may take long

Indexes

- Create an index on name:



- B+ trees have fan-out of 100s: max 4 levels !

Creating Indexes

Syntax:

```
CREATE INDEX  nameIndex ON Person(name)
```

Creating Indexes

Indexes can be created on more than one attribute:

Example:

```
CREATE INDEX doubleindex ON
                 Person (age, city)
```

Helps in:

```
SELECT *
FROM    Person
WHERE age = 55 AND city = "Seattle"
```

But not in:

```
SELECT *
FROM    Person
WHERE city = "Seattle"
```

Creating Indexes

Indexes can be useful in range queries too:

```
CREATE INDEX ageIndex ON  Person (age)
```

B+ trees help in:

```
SELECT *
FROM Person
WHERE age > 25 AND age < 28
```

Why not create indexes on everything?

Defining Views

Views are relations, except that they are not physically stored.

For presenting different information to different users

Employee(ssn, name, department, project, salary)

```
CREATE VIEW  Developers AS
  SELECT name, project
  FROM  Employee
  WHERE department = "Development"
```

Payroll has access to Employee, others only to Developers

A Different View

Person(name, city)
Purchase(buyer, seller, product, store)
Product(name, maker, category)

```
CREATE VIEW  Seattle-view  AS

      SELECT  buyer, seller, product, store
      FROM    Person, Purchase
      WHERE   Person.city = "Seattle"    AND
              Person.name = Purchase.buyer
```

We have a new virtual table:
Seattle-view(buyer, seller, product, store)

A Different View

We can later use the view:

```
SELECT   name, store
FROM     Seattle-view, Product
WHERE    Seattle-view.product = Product.name  AND
         Product.category = "shoes"
```

What Happens When We Query a View ?

```
SELECT   name, Seattle-view.store
FROM     Seattle-view, Product
WHERE    Seattle-view.product = Product.name  AND
         Product.category = "shoes"
```

↓

```
SELECT  name, Purchase.store
FROM    Person, Purchase, Product
WHERE   Person.city = "Seattle"    AND
        Person.name = Purchase.buyer    AND
        Purchase.product = Product.name  AND
        Product.category = "shoes"
```

Types of Views

- Virtual views:
  - Used in databases
  - Computed only on-demand – slow at runtime
  - Always up to date
- Materialized views
  - Used in data warehouses (but recently also in DBMS)
  - Precomputed offline – fast at runtime
  - May have stale data

Updating Views

How can I insert a tuple into a table that doesn't exist?

Employee(ssn, name, department, project, salary)

```
CREATE VIEW  Developers AS
  SELECT name, project
  FROM  Employee
  WHERE department = "Development"
```

If we make the following insertion:

```
INSERT INTO  Developers
VALUES("Joe", "Optimizer")
```

It becomes:

```
INSERT INTO  Employee
VALUES(NULL, "Joe", NULL, "Optimizer", NULL)
```

Non-Updatable Views

```
CREATE VIEW Seattle-view AS

    SELECT seller, product, store
    FROM   Person, Purchase
    WHERE  Person.city = "Seattle"   AND
           Person.name = Purchase.buyer
```

How can we add the following tuple to the view?

("Joe", "Shoe Model 12345", "Nine West")

What do we put in the Person.name and Purchase.buyer columns?

Answering Queries Using Views

- What if we want to *use* a set of views to answer a query.
- Why?
  - The obvious reason…
  - Answering queries over web data sources.
- *Very* cool stuff! (i.e., I did a lot of research on this).

Reusing a Materialized View

- Suppose I have **only** the result of SeattleView:

```
SELECT buyer, seller, product, store
FROM   Person, Purchase
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer
```

- and I want to answer the query

```
SELECT buyer, seller
FROM   Person, Purchase
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer AND
       Purchase.product='gizmo'.
```

Then, I can rewrite the query using the view.

Query Rewriting Using Views

Rewritten query:

```
SELECT buyer, seller
FROM   SeattleView
WHERE  product= 'gizmo'
```

Original query:

```
SELECT buyer, seller
FROM   Person, Purchase
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer AND
       Purchase.product='gizmo'.
```

Another Example

- I still have **only** the result of SeattleView:

```
SELECT buyer, seller, product, store
FROM   Person, Purchase
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer
```

- but I want to answer the query

```
SELECT buyer, seller
FROM   Person, Purchase
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer AND
       Person.Phone  LIKE '206 543 %'.
```

And Now?

- I still have **only** the result of SeattleView:

```
SELECT buyer, seller, product, store
FROM   Person, Purchase
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer
```

- but I want to answer the query

```
SELECT buyer, seller
FROM   Person, Purchase, Product
WHERE  Person.city = 'Seattle'   AND
       Person.per-name = Purchase.buyer AND
       Person.Phone  LIKE '206 543 %' AND
       Purchase.product = Product.name.
```

And Now?

- I still have **only** the result of:

  SELECT seller, buyer, Sum(Price)
  FROM Purchase
  WHERE Purchase.store = 'The Bon'
  Group By seller, buyer
- but I want to answer the query

  SELECT seller, Sum(Price)
  FROM Purchase
  WHERE Person.store = 'The Bon'
  Group By seller

And what if it's the other way around?

Finally…

- I still have **only** the result of:

  SELECT seller, buyer, Count(*)
  FROM Purchase
  WHERE Purchase.store = 'The Bon'
  Group By seller, buyer
- but I want to answer the query

  SELECT seller, Count(*)
  FROM Purchase
  WHERE Person.store = 'The Bon'
  Group By seller

The General Problem

- Given a set of views V1,…,Vn, and a query Q, can we answer Q using only the answers to V1,…,Vn?
- Why do we care?
  - We can answer queries more efficiently.
  - We can query data sources on the WWW in a principled manner.
- Many, many papers on this problem.
- The best performing algorithm: The MiniCon Algorithm, (Pottinger & (Ha)Levy, 2000).

Querying the WWW

- Assume a virtual schema of the WWW, e.g.,
  - Course(number, university, title, prof, quarter)
- Every data source on the web contains the answer to a view over the virtual schema:

UW database: SELECT number, title, prof
FROM Course
WHERE univ='UW' AND quarter='2/02'

Stanford database: SELECT number, title, prof, quarter
FROM Course
WHERE univ='Stanford'

User query: find all professors who teach "database systems"

Null Values and Outerjoins

- If x=Null then 4*(3-x)/7 is still NULL
- If x=Null then x="Joe" is UNKNOWN
- Three boolean values:
  - FALSE = 0
  - UNKNOWN = 0.5
  - TRUE = 1

Null Values and Outerjoins

- C1 AND C2 = min(C1, C2)
- C1 OR C2 = max(C1, C2)
- NOT C1 = 1 – C1

SELECT *
FROM Person
WHERE (age < 25) AND
(height > 6 OR weight > 190)

Rule in SQL: include only tuples that yield TRUE

Null Values and Outerjoins

Unexpected behavior:

SELECT *
FROM Person
WHERE age < 25 OR age >= 25

Some Persons are not included !

Null Values and Outerjoins

Can test for NULL explicitly:
- x IS NULL
- x IS NOT NULL

SELECT *
FROM Person
WHERE age < 25 OR age >= 25 OR age IS NULL

Now it includes all Persons

Null Values and Outerjoins

Explicit joins in SQL:
Product(name, category)
Purchase(prodName, store)

SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName

Same as:
SELECT Product.name, Purchase.store
FROM Product, Purchase
WHERE Product.name = Purchase.prodName

But Products that never sold will be lost !

Null Values and Outerjoins

Left outer joins in SQL:
Product(name, category)
Purchase(prodName, store)

SELECT Product.name, Purchase.store
FROM Product LEFT OUTER JOIN Purchase ON
Product.name = Purchase.prodName

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	-

Outer Joins

- Left outer join:
  - Include the left tuple even if there’s no match
- Right outer join:
  - Include the right tuple even if there’s no match
- Full outer join:
  - Include the both left and right tuples even if there’s no match

SQL: Constraints and Triggers

- Chapter 6 Ullman and Widom
- Certain properties we'd like our database to hold
- Modification of the database may break these properties
- Build handlers into the database definition
- Key constraints
- Referential integrity constraints.

Declaring a Primary Keys in SQL

```
CREATE TABLE MovieStar (
  name CHAR(30) PRIMARY KEY,
  address VARCHAR(255),
  gender CHAR(1));
```

OR:

```
CREATE TABLE MovieStar (
  name CHAR(30),
  address VARCHAR(255),
  gender CHAR(1)
  PRIMARY KEY (name));
```

Primary Keys with Multiple Attributes

```
CREATE TABLE MovieStar (
  name CHAR(30),
  address VARCHAR(255),
  gender CHAR(1),
  PRIMARY KEY (name, address));
```

Other Keys

```
CREATE TABLE MovieStar (
  name CHAR(30),
  address VARCHAR(255),
  phone  CHAR(10)  UNIQUE,
  gender CHAR(1),
  petName  CHAR(50),
  PRIMARY KEY (name),
  UNIQUE (gender, petName));
```

Foreign Key Constraints

```
CREATE TABLE ActedIn (
  Name CHAR(30) PRIMARY KEY,
  MovieName CHAR(30)
     REFERENCES Movies(MovieName),
  Year INT);
```

Foreign Key Constraints

- OR

```
CREATE TABLE ActedIn (
  Name CHAR(30) PRIMARY KEY,
  MovieName CHAR(30),
  Year INT,
  FOREIGN KEY MovieName
     REFERENCES Movies(MovieName)
```

- MovieName must be a PRIMARY KEY

How do we Maintain them?

- Given a change to DB, there are several possible violations:
  - Insert new tuple with bogus foreign key value
  - Update a tuple to a bogus foreign key value
  - Delete a tuple in the referenced table with the referenced foreign key value
  - Update a tuple in the referenced table that changes the referenced foreign key value

How to Maintain?

- Recall, ActedIn has FK MovieName...

Movies(MovieName, year)
(Fatal Attraction, 1987)

ActedIn(ActorName, MovieName)
(Michael Douglas, Fatal Attraction)
insert: (Rick Moranis, Strange Brew)

How to Maintain?

- Policies for handling the change…
  - Reject the update (default)
  - Cascade (example: cascading deletes)
  - Set NULL
- Can set update and delete actions independently in CREATE TABLE

```
MovieName CHAR(30)
    REFERENCES Movies(MovieName))
        ON DELETE SET NULL
        ON UPDATE CASCADE
```