Introduction to Data Management CSE 344

Lecture 7: Nested Queries in SQL

Lecture Goals

- Today we will learn how to write more powerful SQL queries
- They are needed in Homework 3
- Reminder: Book chapters associated with lectures are listed on the calendar page of the course website

Subqueries

- A subquery is a SQL query nested inside a larger query
- Such inner-outer queries are called nested queries
- A subquery may occur in:
  - A SELECT clause
  - A FROM clause
  - A WHERE clause
- Rule of thumb: avoid writing nested queries when possible; keep in mind that sometimes it's impossible

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

For each product return the city where it is manufactured

```
SELECT X.pname, (SELECT Y.city
                 FROM Company Y
                 WHERE Y.cid=X.cid) as City
FROM  Product X
```

"correlated subquery"

What happens if the subquery returns more than one city ?

We get a runtime error
(SQLite simply ignores the extra values)

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

Whenever possible, don't use a nested queries:

```
SELECT X.pname, (SELECT Y.city
                 FROM Company Y
                 WHERE Y.cid=X.cid) as City
FROM  Product X
```

=

```
SELECT X.pname, Y.city
FROM   Product X, Company Y
WHERE X.cid=Y.cid
```

We have "unnested" the query

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

Compute the number of products made by each company

```
SELECT DISTINCT C.cname, (SELECT count(*)
                          FROM Product P
                          WHERE P.cid=C.cid)
FROM  Company C
```

Better: we can unnest by using a GROUP BY

```
SELECT C.cname, count(*)
FROM Company C, Product P
WHERE C.cid=P.cid
GROUP BY C.cname
```

1. Subqueries in SELECT

Are these really equivalent?

```
SELECT DISTINCT C.cname, (SELECT count(*)
                           FROM Product P
                           WHERE P.cid=C.cid)
FROM  Company C
```

```
SELECT C.cname, count(*)
FROM Company C, Product P
WHERE C.cid=P.cid
GROUP BY C.cname
```

No! Different results if a company has no products

```
SELECT C.cname, count(pname)
FROM Company C LEFT OUTER JOIN Product P
ON C.cid=P.cid
GROUP BY C.cname
```

2. Subqueries in FROM

Product (pname, price, cid)
Company(cid, cname, city)

Find all products whose prices is > 20 and < 500

```
SELECT X.pname
FROM (SELECT * FROM Product AS Y WHERE price > 20) as X
WHERE X.price < 500
```

Unnest this query !

2. Subqueries in FROM

- At the end of the lecture we will see that sometimes we really need a subquery and one option will be to put it in the FROM clause (see “finding witnesses”).

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Existential quantifiers

Find all companies that make <u>some</u> products with price < 200

Using EXISTS:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE  EXISTS (SELECT *
                FROM Product P
                WHERE C.cid = P.cid and P.price < 200)
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Existential quantifiers

Find all companies that make <u>some</u> products with price < 200

Using IN

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE C.cid IN (SELECT P.cid
                FROM Product P
                WHERE P.price < 200)
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Existential quantifiers

Find all companies that make <u>some</u> products with price < 200

Using ANY:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE 200 > ANY (SELECT price
                  FROM Product P
                  WHERE P.cid = C.cid)
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Existential quantifiers

Find all companies that make <u>some</u> products with price < 200

Now let's unnest it:

```
SELECT DISTINCT  C.cname
FROM     Company C, Product P
WHERE  C.cid= P.cid and P.price < 200
```

Existential quantifiers are easy ! ☺

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Find all companies that make <u>only</u> products with price < 200

same as:

Find all companies whose products <u>all</u> have price < 200

Universal quantifiers are hard ! ☹

3. Subqueries in WHERE

1. Find *the other* companies: i.e. s.t. <u>some</u> product ≥ 200

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE  C.cid IN (SELECT P.cid
                  FROM Product P
                  WHERE P.price >= 200)
```

2. Find all companies s.t. <u>all</u> their products have price < 200

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE  C.cid NOT IN (SELECT P.cid
                      FROM Product P
                      WHERE P.price >= 200)
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Find all companies that make <u>only</u> products with price < 200

Using EXISTS:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE NOT EXISTS (SELECT *
                   FROM Product P
                   WHERE P.cid = C.cid and P.price >= 200)
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Find all companies that make <u>only</u> products with price < 200

Using ALL:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE 200 > ALL  (SELECT price
                   FROM Product P
                   WHERE P.cid = C.cid)
```

Question for Database Fans and their Friends

- Can we unnest the *universal quantifier* query ?

Monotone Queries

- A query Q is monotone if:
  - Whenever we add tuples to one or more of the tables…
  - … the answer to the query cannot contain fewer tuples
- Fact: all unnested queries are monotone
  - Proof: using the "nested for loops" semantics
- Fact: Query with universal quantifier is not monotone
- Consequence: we cannot unnest a query with a universal quantifier

Queries that must be nested

- Queries with universal quantifiers or with negation
- The drinkers-bars-beers example next
- This is a famous example from textbook on databases by Ullman

The drinkers-bars-beers example

Likes(drinker, beer)
Frequents(drinker, bar)
Serves(bar, beer)

Challenge: write these in SQL

Find drinkers that frequent some bar that serves some beer they like.

x: $\exists y. \exists z.$ Frequents(x, y)$\wedge$Serves(y,z)$\wedge$Likes(x,z)

Find drinkers that frequent only bars that serves some beer they like.

x: $\forall y.$ Frequents(x, y)$\Rightarrow$ ($\exists z.$ Serves(y,z)$\wedge$Likes(x,z))

Find drinkers that frequent some bar that serves only beers they like.

x: $\exists y.$ Frequents(x, y)$\wedge\forall z.$(Serves(y,z) $\Rightarrow$ Likes(x,z))

Find drinkers that frequent only bars that serves only beer they like.

x: $\forall y.$ Frequents(x, y)$\Rightarrow$ $\forall z.$(Serves(y,z) $\Rightarrow$ Likes(x,z))

GROUP BY v.s. Nested Queries

```
SELECT     product, Sum(quantity) AS TotalSales
FROM       Purchase
WHERE      price > 1
GROUP BY   product
```

```
SELECT DISTINCT  x.product, (SELECT Sum(y.quantity)
                             FROM    Purchase y
                             WHERE x.product = y.product
                                     AND price > 1)
                            AS TotalSales
FROM        Purchase x
WHERE       price > 1
```

Why twice ?

Unnesting Aggregates

Product (pname, price, cid)
Company(cid, cname, city)

Find the number of companies in each city

```
SELECT DISTINCT city, (SELECT count(*)
                       FROM Company Y
                       WHERE X.city = Y.city)
FROM  Company X
```

Equivalent queries

```
SELECT city, count(*)
FROM   Company
GROUP BY city
```

Note: no need for DISTINCT (DISTINCT *is the same* as GROUP BY)

Unnesting Aggregates

Product (pname, price, cid)
Company(cid, cname, city)

What if there are no products for a city?

Find the number of products made in each city

```
SELECT DISTINCT X.city, (SELECT count(*)
                         FROM Product Y, Company Z
                         WHERE Z.cid=Y.cid
                       AND Z.city = X.city)
FROM  Company X
```

```
SELECT X.city, count(*)
FROM Company X, Product Y
WHERE X.cid=Y.cid
GROUP BY X.city
```

They are NOT equivalent ! (WHY?)

More Unnesting

Author(<u>login</u>,name)
Wrote(login,url)

- Find authors who wrote ≥ 10 documents:
- Attempt 1: with nested queries

This is SQL by a novice

```
SELECT DISTINCT Author.name
FROM        Author
WHERE        (SELECT count(Wrote.url)
              FROM Wrote
              WHERE Author.login=Wrote.login)
                 > 10
```

More Unnesting

- Find all authors who wrote at least 10 documents:
- Attempt 2: SQL style (with GROUP BY)

```
SELECT      Author.name
FROM        Author, Wrote
WHERE       Author.login=Wrote.login
GROUP BY Author.name
HAVING      count(wrote.url) > 10
```

This is SQL by an expert

Finding Witnesses

Product (pname, price, cid)
Company(cid, cname, city)

For each city, find the most expensive product made in that city

Finding Witnesses

Product (pname, price, cid)
Company(cid, cname, city)

For each city, find the most expensive product made in that city
Finding the maximum price is easy…

```
SELECT x.city, max(y.price)
FROM Company x, Product y
WHERE x.cid = y.cid
GROUP BY x.city;
```

But we need the *witnesses*, i.e. the products with max price

Finding Witnesses

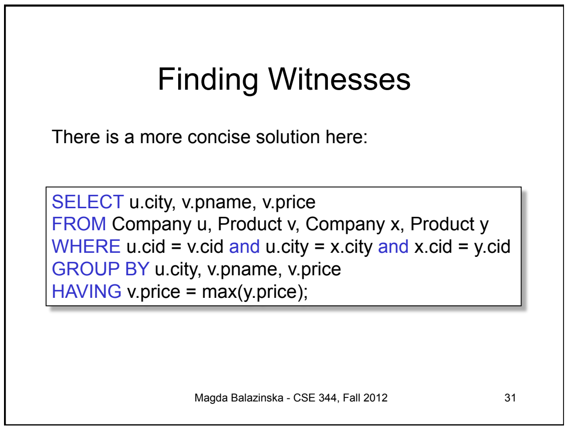
And another one:

```
SELECT u.city, v.pname, v.price
FROM Company u, Product v
WHERE u.cid = v.cid
  and v.price >= ALL (SELECT y.price
                      FROM Company x, Product y
                      WHERE u.city=x.city
                         and x.cid=y.cid);
```

Finding Witnesses

To find the witnesses, compute the maximum price in a subquery

```
SELECT DISTINCT u.city, v.pname, v.price
FROM Company u, Product v,
     (SELECT x.city, max(y.price) as maxprice
      FROM Company x, Product y
      WHERE x.cid = y.cid
      GROUP BY x.city) w
WHERE u.cid = v.cid
      and u.city = w.city
      and v.price=w.maxprice;
```



Finding Witnesses

There is a more concise solution here:

```
SELECT u.city, v.pname, v.price
FROM Company u, Product v, Company x, Product y
WHERE u.cid = v.cid and u.city = x.city and x.cid = y.cid
GROUP BY u.city, v.pname, v.price
HAVING v.price = max(y.price);
```