Data Management Systems
CS 457

Lecture 5: Nested Queries in SQL
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
Subqueries…

- Can return a single constant and this constant can be compared with another value in a WHERE clause
- Can return relations that can be used in various ways in WHERE clauses
- Can appear in FROM clauses, followed by a tuple variable that represents the tuples in the result of the subquery
- Can appear as computed values in a SELECT clause
1. Subqueries in SELECT

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

For each product return the city where it is manufactured
1. Subqueries in SELECT

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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
```
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What happens if the subquery returns more than one city?
We get a runtime error
(SQLite simply ignores the extra values)
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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

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
```
1. Subqueries in SELECT

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
```

We have “unnested” the query
1. Subqueries in SELECT

Compute the number of products made by each company

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

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

But 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
```
1. Subqueries in SELECT

But are these really equivalent?

```sql
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
```

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

No! Different results if a company has no products.
2. Subqueries in FROM

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 !
```
SELECT pname FROM Product
WHERE price > 20 and price < 500
```
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.
3. Subqueries in WHERE

Find all companies that make some products with price < 200
3. Subqueries in WHERE

Find all companies that make some products with price < 200
3. Subqueries in WHERE

Find all companies that make some products with price < 200

Using EXISTS:

```sql
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

Find all companies that make some 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

Find all companies that make some products with price < 200

Using ANY:

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

Find all companies that make some products with price < 200

Using ANY:

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

Existential quantifiers

Not supported in sqlite
3. Subqueries in WHERE

Find all companies that make **some** products with price < 200

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

Find all companies that make some products with price < 200

Existential quantifiers are easy! 😊

Now let's unnest it:

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

Find all companies s.t. all their products have price < 200

same as:

Find all companies that make only products with price < 200
3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

same as:
Find all companies that make only products with price < 200

Universal quantifiers
3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

same as:

Find all companies that make only products with price < 200

Universal quantifiers are hard! 😞
3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

1. Find the other companies: i.e. s.t. some product $\geq 200$

```
SELECT DISTINCT C.cname
FROM Company C
WHERE C.cid IN (SELECT P.cid
                 FROM Product P
                 WHERE P.price >= 200)
```
Find all companies s.t. all their products have price < 200

1. Find the other companies: i.e. s.t. some 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. all 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

Find all companies s.t. all their products have 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)
```
Product (pname, price, cid)
Company(cid, cname, city)

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

Using **ALL**: 

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

Find all companies s.t. all their products have price < 200

Using **ALL**:

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

*Not supported in sqlite*
Question for Database Fans and their Friends

• Can we unnest the *universal quantifier* query?
Monotone Queries

• Definition: A query $Q$ is **monotone** if:
  
  – Whenever we add tuples to one or more input tables, the answer to the query will not lose any of the tuples

<table>
<thead>
<tr>
<th>Product</th>
<th>Company</th>
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</thead>
<tbody>
<tr>
<td><strong>pname</strong></td>
<td><strong>cid</strong></td>
</tr>
<tr>
<td>Gizmo</td>
<td>19.99</td>
</tr>
<tr>
<td>Gadget</td>
<td>999.99</td>
</tr>
<tr>
<td>Camera</td>
<td>149.99</td>
</tr>
<tr>
<td>c002</td>
<td>Sunworks</td>
</tr>
<tr>
<td>c001</td>
<td>DB Inc.</td>
</tr>
<tr>
<td>c003</td>
<td>Builder</td>
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Monotone Queries

• **Theorem:** If Q is a SELECT-FROM-WHERE query that does not have subqueries, and no aggregates, then it is monotone.
Monotone Queries

• **Theorem**: If Q is a SELECT-FROM-WHERE query that does not have subqueries, and no aggregates, then it is monotone.

• **Proof.** We use the nested loop semantics: if we insert a tuple in a relation \( R_i \), this will not remove any tuples from the answer.
Monotone Queries

• The query:

Find all companies s.t. all their products have price < 200

is not monotone

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<table>
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<th>city</th>
</tr>
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Product (pname, price, cid)
Company(cid, cname, city)
Monotone Queries

- The query:

Find all companies s.t. all their products have price < 200

is not monotone

- Consequence: we cannot write it as a SELECT-FROM-WHERE query without nested subqueries
Queries that must be nested

- Queries with universal quantifiers
Where We Are

• Motivation for using a DBMS for managing data
• SQL, SQL, SQL
  – Declaring the schema for our data (CREATE TABLE)
  – Inserting data one row at a time or in bulk (INSERT/.import)
  – Modifying the schema and updating the data (ALTER/UPDATE)
  – Querying the data (SELECT)
  – Practice on SQLite

• Next step: More knowledge of how DBMSs work
  – Relational algebra, query execution, and physical tuning