CSE 344

JANUARY 19TH – SUBQUERIES 2 AND RELATIONAL ALGEBRA

ASSORTED MINUTIAE

- **Winter storm Inga**
- **Online quiz out after class**
  - Still due Wednesday, will be shorter but through today's lecture
- **For SQLite submissions, please use AS when aliasing**

TODAY'S LECTURE

- Review of ordering
- Subqueries in FROM and WHERE
- Intro to relational algebra (maybe)

SEMANTICS OF SQL WITH GROUP-BY

```
SELECT    S
FROM      R1,…,Rn
WHERE     C1
GROUP BY  a1,…,ak
HAVING    C2
```

FWGHOS

Evaluation steps:

1. **Evaluate FROM-WHERE using Nested Loop Semantic**
2. **Group by the attributes $a_1,\ldots,a_k$**
3. **Apply condition C2 to each group (may have aggrega**
4. **Compute aggregates in S and return the result**

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 nested queries when possible

- But sometimes it's impossible, as we will see

SUBQUERIES…

Can return a single value to be included in a `SELECT` clause

Can return a relation to be included in the `FROM` clause, aliased using a tuple variable

Can return a single value to be compared with another value in a `WHERE` clause

Can return a relation to be used in the `WHERE` or `HAVING` clause under an existential quantifier

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

(and 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
```

We have "unnested" the query

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
```

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 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?

```
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

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
```

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
```

Try unnest this query !

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
```

Side note: This is not a correlated subquery. (why?)

Try unnest this query !

2. SUBQUERIES IN FROM

Sometimes we need to compute an intermediate table only to use it later in a SELECT-FROM-WHERE

Option 1: use a subquery in the FROM clause

Option 2: use the WITH clause

2. SUBQUERIES IN FROM

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

=

A subquery whose result we called myTable

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

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

Existential quantifiers

3. SUBQUERIES IN WHERE

Find all companies that make some products with price < 200

Existential quantifiers

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

Find all companies that make some products with price < 200

Existential quantifiers

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

Existential quantifiers

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

Find all companies that make some products with price < 200

Existential quantifiers

Using ANY:

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

Not supported in sqlite

3. SUBQUERIES IN WHERE

Find all companies that make some products with price < 200

Existential quantifiers

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 that make some products with price < 200

Existential quantifiers

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

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

Universal quantifiers are hard!

3. SUBQUERIES IN WHERE

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

1. Find *the other* companies that make some product ≥ 200

```
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 s.t. all their products have price < 200

1. Find *the other* companies that make 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

Universal quantifiers

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

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

Universal quantifiers

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

Universal quantifiers

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 THEORY FANS AND THEIR FRIENDS

Can we unnest the *universal quantifier* query?

We need to first discuss the concept of *monotonicity*

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

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

```
SELECT a1, a2, …, ak
FROM   R1 AS x1, R2 AS x2, …, Rn AS xn
WHERE  Conditions
```

```
for x1 in R1 do
  for x2 in R2 do
    …
    for xn in Rn do
      if Conditions
        output (a1,…,ak)
```

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

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

MONOTONE QUERIES

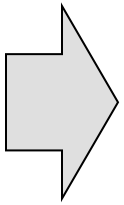
The query:

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

is not monotone

pname	price	cid
Gizmo	19.99	c001

cid	cname	city
c001	Sunworks	Bonn



cname
Sunworks

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

MONOTONE QUERIES

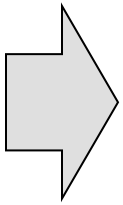
The query:

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

is not monotone

pname	price	cid
Gizmo	19.99	c001

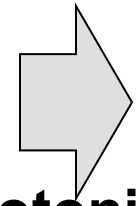
cid	cname	city
c001	Sunworks	Bonn



cname
Sunworks

pname	price	cid
Gizmo	19.99	c001
Gadget	999.99	c001

cid	cname	city
c001	Sunworks	Bonn



cname

Consequence: If a query is not monotonic, then we cannot write it as a SELECT-FROM-WHERE query without nested subqueries

QUERIES THAT MUST BE NESTED

Queries with universal quantifiers or with negation

QUERIES THAT MUST BE NESTED

Queries with universal quantifiers or with negation

Queries that use aggregates in certain ways

- `sum(..)` and `count(*)` are NOT monotone, because they do not satisfy set containment
- `select count(*) from R` is not monotone!