MSiA-413 Introduction to Databases and Information Retrieval

Lecture 15
Recursive queries on networks
Views, existential operators, set comparison

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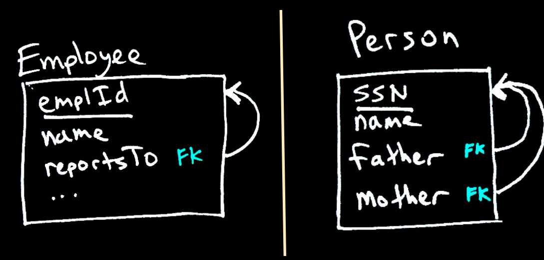
Slides adapted from Steve Tarzia

Last Lecture

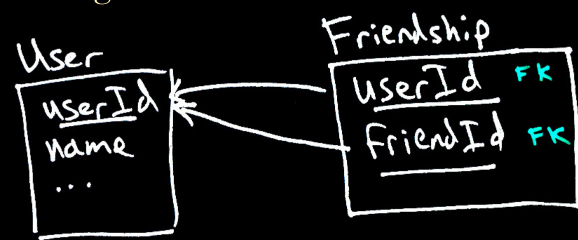
- `UNION`, `INTERSECT` clauses
  - Similar to set operations
- `CASE` statements
  - Similar to *if* … *then* … *else* programming language constructs
- Introduced Regular Expressions
  - Used to *search for text* matching a complex *pattern*
  - It is often a trial-and-error process to find the right regular expression

Hierarchies and Networks

- Occur when:
  - A table has a foreign key referring to the same table (many-to-one):



  - A linking table has foreign keys referring to the same table (many-to-many):



- *Recursion* allows complex structures to be represented with a set of simple relationships

SQL difficulties with networks

- SQL relational databases can model networks, but it's difficult to write queries that traverse the network
- For example, "find all of the classes that must be taken before ACC 257"
  - Prerequisite of ACC 257 is ACC 220
  - Prerequisite of ACC 220 is ACC 210
  - ACC 210 has no prerequisites
- Must do a JOIN or subquery every time you take a step in the network
  - May need to do this many, many times!

“Find all classes that must be taken before ACC 257”

SchoolScheduling.sqlite

Output of each step is listed as a new column

```
SELECT s2.SubjectCode, s3.SubjectCode
 FROM Subjects AS s1
      JOIN Subjects AS s2 ON s2.SubjectCode=s1.SubjectPrereq
      JOIN Subjects AS s3 ON s3.SubjectCode=s2.SubjectPrereq
 WHERE s1.SubjectCode="ACC 257"
```

Two steps in the network

Output is one wide row:

	SubjectCode	SubjectCode
1	ACC 220	ACC 210

This “plain SQL” approach is not scalable

- Query must grow to accommodate additional steps in the transitive relationship
- If we had 5 subjects as prereqs, then we would need 5 joins and 5 output columns
- How many joins to write? (we may not know beforehand how many prereqs there are)

Traversing networks with multiple queries

Use a general-purpose programming language (like Python or R)

- Generate a sequence of SQL commands to traverse the network
- This can be inefficient if the SQL server is remote

Pseudo-python:

```
prereqs = []
subjCode = "ACC 257"
while subjCode:
    queryResult = db.query(
         "SELECT SubjectPrereq FROM Subjects WHERE SubjectCode = " + subjCode)
    subjCode = queryResult.getRow(0).getColumn(0)
    if subjCode != None:
        prereqs.append(subjCode)
return prereqs
```

We want to execute SQL iterations like this:

- Create a temporary table

```
create table prereq(subjCode);
```

- Iteration 1: find prereq of 257

```
insert into prereq
values('ACC 257');
SELECT SubjectPrereq
FROM Subjects
JOIN prereq ON
Subjects.SubjectCode='ACC 257';
```

Output: ACC 220

- Iteration 2: find prereq of 220

```
insert into prereq
values('ACC 220');
SELECT SubjectPrereq
FROM Subjects
JOIN prereq ON
Subjects.SubjectCode='ACC 220';
```

Output: ACC 210

- Iteration 3: find prereq of 210

```
insert into prereq
values('ACC 210');
SELECT SubjectPrereq
FROM Subjects
JOIN prereq ON
Subjects.SubjectCode='ACC 210';
```

Output: NULL

- Iteration 4: find prereq of NULL

```
insert into prereq
values(NULL);
SELECT SubjectPrereq
FROM Subjects
JOIN prereq ON
Subjects.SubjectCode=NULL;
```

- Terminate. Get output

```
SELECT * FROM prereq;
```

	subjCode
1	ACC 257
2	ACC 220
3	ACC 210
4	NULL

Recursive Common Table Expressions example

1. select 257

2. then the statement is called so joins with subset code

- A way to express a chain of dependent queries

before UNION is executed once

Create a temporary table "prereq" with one column named "subjCode"

Values of first row

Contents of "prereq" table

```
WITH RECURSIVE
  prereq(subjCode)
  AS (
    VALUES('ACC 257')
    UNION
    SELECT SubjectPrereq
      FROM Subjects
         JOIN prereq
         ON Subjects.SubjectCode=prereq.subjCode
  )
SELECT * FROM prereq;
```

recursion iterates for every row in cube

Whatever is in cube gets selected

*Recursive query to get more rows from each **new** prereq row*

Each new row goes into cube

temp table destroyed

When you finish the recursion, here is the output I want

Output:

	subjCode
1	ACC 257
2	ACC 220
3	ACC 210
4	NULL

Recursive Common Table Expressions

```
WITH RECURSIVE
  tmp_table(column_name1, column_name2, …)
  AS (
    non_recursive_initial_SELECT
    UNION [ALL]
    recursive_SELECT
) final_SELECT
```

either a constant or SQL statement

whatever this statement evaluates to will be the first set of rows for the algorithm

temporary table to store results

SELECT query or constant for the initial rows of the results

ALL optionally includes duplicate rows

SELECT query that refers to table tmp_table and generates new rows

final SELECT query that retrieves data from table tmp_table

Mechanics (see `https://sqlite.org/lang_with.html`):

1. Create an empty temporary table matching the defined schema
2. Run the first query to generate initial rows and add these to a queue
3. Remove a row from the queue
   a) Add the row to the temporary table
   b) Run the recursive `SELECT` using just this one row to represent the temporary table
   c) Add results to the queue and repeat step 3 until the queue is empty
4. Run the final `SELECT` query, using the temporary table generated above

subcode = 257	252	

WITH SQL Clause

```
CREATE TABLE mytable(StaffID, SubjectCode, SubjectPreReq);
INSERT INTO mytable
       SELECT F.StaffID, S.SubjectCode, S.SubjectPreReq
       FROM Subjects AS S NATURAL JOIN Faculty_Subjects AS F;
SELECT StaffID AS Faculty,
       SubjectCode || ",  " || SubjectPreReq AS SubjChain
FROM mytable;
DROP TABLE mytable;
```

… is equivalent to … without recursion

```
WITH mytable AS
       (SELECT F.StaffID, S.SubjectCode, S.SubjectPreReq
       FROM Subjects AS S NATURAL JOIN Faculty_Subjects AS F)
SELECT StaffID AS Faculty,
       SubjectCode || ",  " || SubjectPreReq AS SubjChain
FROM mytable;
```

Create a temporary table "mytable"

creating temp table populated with return of join

Populate "mytable"

Query "mytable"

Drop "mytable" when done

Set Comparison: SOME and ANY

join - cartesian product
don't have on so everything joins to everything

Find the instructors with salary greater than that of some (at least one) instructor in the Biology department

```
SELECT T.name
FROM instructor AS T, instructor AS S
WHERE T.salary > S.salary AND S.dept_name = 'Biology';
```

results in 100s of rows

- Same query using **SOME** clause

```
SELECT name
FROM instructor
WHERE salary > SOME (SELECT salary
                     FROM instructor
                     WHERE dept_name = 'Biology');
```

- **SOME** and **ANY** are equivalent. Neither is supported by SQLite.

Set Comparison: ALL

Find the instructors with salary greater than that of all instructors in the Biology department

```
SELECT name
FROM instructor
WHERE salary > ALL (SELECT salary
                    FROM instructor
                    WHERE dept_name = 'Biology');
```

- ALL is not supported by SQLite

Test for empty relations: `EXISTS`

Find the employees with salary greater than that of a manager's

```
SELECT name
FROM employee
WHERE salary > SOME (SELECT salary
                     FROM manager);
```

- Same query using **EXISTS** clause

```
SELECT name
FROM employee AS E
WHERE EXISTS (SELECT salary
              FROM manager AS M
              WHERE E.salary > M.salary);
```

- The query becomes mathematical: $\{e.name \mid e \in E \ \land \ \exists m \in M: e.salary > m.salary\}$
- The **NOT EXISTS** clause does the opposite

Views

- Sometimes, it is not desirable for all users to see the entire logical model
- Say, we want to allow users to know who the rich agents are, but we do not want to reveal their actual salary

```
SELECT Agentid, AgtFirstName, AgtLastName
FROM Agents WHERE Salary > 30000;
```

AgentID	AgtFirstName	AgtLastName
1	William	Thompson
6	John	Kennedy

- A **view** provides a mechanism to achieve this
- Any relation that is not of the conceptual model, but it is made visible to a user as a "virtual relation" is called a **view**

View definition and use

- A view definition causes the saving of an expression

```
CREATE VIEW rich_agents AS
  SELECT Agentid, AgtFirstName, AgtLastName
  FROM Agents
  WHERE Salary > 30000;
```

- The expression is substituted into queries that use the view

```
SELECT * FROM rich_agents;
```

AgentID	AgtFirstName	AgtLastName
1	William	Thompson
6	John	Kennedy

- Is equivalent to

```
SELECT * FROM (SELECT Agentid, AgtFirstName, AgtLastName
               FROM Agents
               WHERE Salary > 30000);
```

- ...but without revealing the salary value used in the conditional
- The `WITH` clause defines a temporary view with scope limited to the query