SQL: Part I

CS348

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SQL

- SQL: Structured Query Language
  - Pronounced “S-Q-L” or “sequel”
  - The standard query language supported by most DBMS
  - Introduced in 1970s and standardized by ANSI since 1986

SQL

- Data-definition language (DDL): define/modify schemas, delete relations

- Data-manipulation language (DML): query information, and insert/delete/modify tuples

- Integrity constraints: specify constraints that the data stored in the database must satisfy

- Intermediate/Advanced topics: (next week)
    - E.g., triggers, views, indexes, programming, recursive queries

User (uid int, *name* string, *age* int, *pop* float)
Group (gid string, *name* string)
Member (uid int, gid string)

DDL

- CREATE TABLE *table_name* (…, *column_name column_type*, …);

```
CREATE TABLE User(uid INT, name VARCHAR(30), age INT, pop DECIMAL(3,2));
CREATE TABLE Group (gid CHAR(10), name VARCHAR(100));
CREATE TABLE Member (uid INT, gid CHAR(10));
```

- DROP TABLE *table_name*;

```
DROP TABLE User;
DROP TABLE Group;
DROP TABLE Member;
```

Drastic action: deletes ALL info about the table, not just the contents

-- everything from -- to the end of line is ignored.
-- SQL is insensitive to white space.
-- SQL is insensitive to case (e.g., ...CREATE... is equivalent to ...create...).

Basic queries for DML: SFW statement

- SELECT $A_1, A_2, \ldots, A_n$
  FROM $R_1, R_2, \ldots, R_m$
  WHERE $condition$;

- Also called an SPJ (select-project-join) query

- Corresponds to (but not really equivalent to) relational algebra query:

$$\pi_{A_1, A_2, \ldots, A_n}\left(\sigma_{condition}(R_1 \times R_2 \times \cdots \times R_m)\right)$$

Why SFW statements?

- Many queries can be written using only selection, projection, and cross product (or join)

- These queries can be written in a canonical form which is captured by SFW:

$$\pi_L\left(\sigma_p(R_1 \times \cdots \times R_m)\right)$$

  - E.g.: $\pi_{R.A,S.B}\left(R \bowtie_{p_1} S\right) \bowtie_{p_2} \left(\pi_{T.C}\sigma_{p_3}T\right)$ can be written as

$$= \pi_{R.A,S.B,T.C}\sigma_{p_1 \wedge p_2 \wedge p_3}(R \times S \times T)$$

Examples

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

- List all rows in the User table

```
SELECT * FROM User;
```

  - * is a short hand for "all columns"

- List name of users under 18 (selection, projection)

```
SELECT name FROM User where age <18;
```

- When was Lisa born?

```
SELECT 2025-age FROM User where name = 'Lisa';
```

  - SELECT list can contain expressions
  - String literals (case sensitive) are enclosed in quotes

Example: join

User (uid int, *name* string, *age* int, *pop* float)
Group (gid string, *name* string)
Member (uid int, gid string)

- List IDs and names of groups with a user whose name contains "Simpson"

```
SELECT Group.gid, Group.name
        FROM User, Member, Group
        WHERE User.uid = Member.uid
                AND Member.gid = Group.gid
                AND ….;
```

Example: join

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

- List ID’s and names of groups with a user whose name contains “Simpson”

```
SELECT Group.gid, Group.name
    FROM User, Member, Group
    WHERE User.uid = Member.uid
        AND Member.gid = Group.gid
        AND User.name LIKE ‘%Simpson%’;
```

- LIKE matches a string against a pattern
    - % matches any sequence characters
- Okay to omit *table_name* in *table_name.column_name* if *column_name* is unique

Example: rename

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

- IDs of all pairs of users that belong to one group
  - Relational algebra query:

$$\pi_{m_1.uid, m_2.uid} \left(\rho_{m_1} Member \bowtie_{m_1.gid = m_2.gid \wedge m_1.uid \neq m_2.uid} \rho_{m_2} Member \right)$$

  - SQL (not exactly due to duplicates):

```
SELECT m1.uid AS uid1, m2.uid AS uid2
        FROM Member AS m1, Member AS m2
        WHERE m1.gid = m2.gid
              AND m1.uid ≠ m2.uid;
```

  - AS keyword is completely optional

A more complicated example

- Names of all groups that Lisa and Ralph are both in

Tip: Write the FROM clause first, then WHERE, and then SELECT

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

A more complicated example

- Names of all groups that Lisa and Ralph are both in

```
SELECT g.name
    FROM User u1, …, Member m1, …
    WHERE u1.name = 'Lisa' AND …
            AND u1.uid = m1.uid AND …
            AND …;
```

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

A more complicated example

- Names of all groups that Lisa and Ralph are both in

```
SELECT g.name
        FROM User u1, User u2, Member m1, Member m2, …
        WHERE u1.name = 'Lisa' AND u2.name = ‘Ralph’
                AND u1.uid = m1.uid AND u2.uid=m2.uid
                AND …;
```

User (uid int, *name* string, *age* int, *pop* float)
Group (gid string, *name* string)
Member (uid int, gid string)

A more complicated example

- Names of all groups that Lisa and Ralph are both in

```
SELECT g.name
    FROM User u1, User u2, Member m1, Member m2, Group g
    WHERE u1.name = 'Lisa' AND u2.name = ‘Ralph’
            AND u1.uid = m1.uid AND u2.uid=m2.uid
            AND m1.gid = g.gid AND m2.gid = g.gid;
```

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

Set versus bag

User

uid	name	age	pop
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3
…	…	…	…

$\pi_{age} User$

age
10
8
…

Set

- No duplicates
- Relational model and algebra use set semantics

```
SELECT age
FROM User;
```

age
10
10
8
8
…

Bag

- Duplicates allowed
- Rows in output = rows in input (w/o where clause)
- SQL uses bag semantics by default

A case for bag semantics

- Efficiency
  - Saves time of eliminating duplicates

- Which one is more useful?

$\pi_{age} User$

```
SELECT age
FROM User;
```

  - The first query just returns all possible user ages in the table
  - The second query returns the user age distribution

- Besides, SQL provides the option of set semantics with DISTINCT keyword

Forcing set semantics

- IDs of all pairs of users that belong to one group

```
SELECT m1.uid AS uid1, m2.uid AS uid2
        FROM Member AS m1, Member AS m2
        WHERE m1.gid = m2.gid
                AND m1.uid ≠ m2.uid;
```

→Say Lisa and Ralph are in both the book club and the student government, their id pairs will appear twice

- Remove duplicate (uid1, uid2) pairs from the output

```
SELECT DISTINCT m1.uid AS uid1, m2.uid AS uid2
        FROM Member AS m1, Member AS m2
        WHERE m1.gid = m2.gid;
                AND m1.uid ≠ m2.uid;
```

SQL set and bag operations

- Set: UNION, EXCEPT, INTERSECT
  - Exactly like set ∪, −, and ∩ in relational algebra
  - Duplicates in input tables, if any, are first eliminated
  - Duplicates in result are also eliminated (for UNION)

Bag1

fruit
apple
apple
orange

Bag2

fruit
orange
orange
orange

```
(SELECT * FROM Bag1)
UNION
(SELECT * FROM Bag2);
```

fruit
apple
orange

```
(SELECT * FROM Bag1)
EXCEPT
(SELECT * FROM Bag2);
```

fruit
apple

```
(SELECT * FROM Bag1)
INTERSECT
(SELECT * FROM Bag2);
```

fruit
orange

SQL set and bag operations

- Set: UNION, EXCEPT, INTERSECT
  - Exactly like set ∪, −, and ∩ in relational algebra
- Bag: UNION ALL, EXCEPT ALL, INTERSECT ALL
  - Think of each row as having an implicit count (the number of times it appears in the table)

```
(SELECT * FROM Bag1)
UNION ALL
(SELECT * FROM Bag2);
```

sum up the counts from two tables

Bag1

fruit
apple
apple
orange

apple: 2
orange:1

Bag2

fruit
apple
orange
orange

apple: 1
orange:2

fruit
apple
apple
orange
apple
orange
orange

apple: 3
orange:3

SQL set and bag operations

- Set: UNION, EXCEPT, INTERSECT
  - Exactly like set ∪, −, and ∩ in relational algebra
- Bag: UNION ALL, EXCEPT ALL, INTERSECT ALL
  - Think of each row as having an implicit count (the number of times it appears in the table)

Bag1

fruit
apple
apple
orange

apple: 2
orange:1

Bag2

fruit
apple
orange
orange

apple: 1
orange:2

```
(SELECT * FROM Bag1)
EXCEPT ALL
(SELECT * FROM Bag2);
```

proper-subtract the two counts

fruit
apple

apple: 1
orange:0

SQL set and bag operations

- Set: UNION, EXCEPT, INTERSECT
  - Exactly like set ∪, −, and ∩ in relational algebra
- Bag: UNION ALL, EXCEPT ALL, INTERSECT ALL
  - Think of each row as having an implicit count (the number of times it appears in the table)

Bag1

fruit
apple
apple
orange

apple: 2
orange:1

Bag2

fruit
apple
orange
orange

apple: 1
orange:2

```
(SELECT * FROM Bag1)
INTERSECT ALL
(SELECT * FROM Bag2);
```

take the minimum of the two counts

fruit
apple
orange

apple: 1
orange:1

Set versus bag operations

Poke (*uid1*, *uid2*, *timestamp*)

- uid1 poked uid2 at timestamp

Question: How do these two queries differ?

```
Q1:
(SELECT uid1 FROM Poke)
EXCEPT
(SELECT uid2 FROM Poke);
```

```
Q2:
(SELECT uid1 FROM Poke)
EXCEPT ALL
(SELECT uid2 FROM Poke);
```

Set versus bag operations

Poke (*uid1*, *uid2*, *timestamp*)

- uid1 poked uid2 at timestamp

Question: How do these two queries differ?

```
Q1:
(SELECT uid1 FROM Poke)
EXCEPT
(SELECT uid2 FROM Poke);
```

```
Q2:
(SELECT uid1 FROM Poke)
EXCEPT ALL
(SELECT uid2 FROM Poke);
```

Users who poked others but never got poked by others

Users who poked others more than others poked them

In class exercises

Consider this db instance:

User

uid	*name*	*age*	*pop*
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3

Member

uid	*gid*
857	dps
123	gov
857	abc
857	gov
456	abc
456	gov

- What is the output of these queries?

```
SELECT gid FROM Member m, User u where u.name=‘Lisa’ and u.uid=m.uid
```

```
SELECT gid FROM Member m, User u where u.name=‘Lisa’ and u.uid=m.uid
UNION
SELECT gid FROM Member m, User u where u.name=‘Ralph’ and u.uid=m.uid
```

```
SELECT gid FROM Member m, User u where u.name=‘Lisa’ and u.uid=m.uid
UNION ALL
SELECT gid FROM Member m, User u where u.name=‘Ralph’ and u.uid=m.uid
```

Semantics of SFW

- SELECT [DISTINCT] $E_1, E_2, \ldots, E_n$
  FROM $R_1, R_2, \ldots, R_m$
  WHERE $condition$;
-

```
For each $t_1$ in $R_1$:
    For each $t_2$ in $R_2$: … …
        For each $t_m$ in $R_m$:
            If $condition$ is true over $t_1, t_2, \ldots, t_m$:
                Compute and output $E_1, E_2, \ldots, E_n$ as a row
 If DISTINCT is present
     Eliminate duplicate rows in output
```

- $t_1, t_2, \ldots, t_m$ are often called tuple variables

SQL features covered so far

- Query
  - SELECT-FROM-WHERE statements
  - Set/bag (DISTINCT, UNION/EXCEPT/INTERSECT (ALL))

☞ Next: how to nest SQL queries
  - Subqueries (table, scalar, IN, EXISTS, ALL, ANY)
  - Aggregation and grouping (GROUP BY, HAVING)
  - Ordering (ORDER)
  - Joins

Table subqueries

- Use query result as a table
    - In set and bag operations, FROM clauses, etc.

- Example: names of users belonging to at least two groups

```
SELECT DISTINCT name
FROM User,
     (SELECT m1.uid
     FROM Member m1, Member m2
     WHERE m1.uid=m2.uid and m1.gid != m2.gid)
     AS T
WHERE User.uid = T.uid;
```

Scalar subqueries

- A query that returns a single row can be used as a value in WHERE, SELECT, etc.
- Example: users at the same age as Bart (uid=142)

```
SELECT *
FROM User,
WHERE age = (SELECT age
            FROM User
            WHERE uid = 142);
```

- When can this query go wrong?
  - Return more than 1 row (WHERE name = ‘Bart’)
  - Return no rows

WITH clause

- WITH clause provides a way of defining a temporary relation whose definition is available only to the query in which the with clause occurs

- Ex: List group ids of users with age > 10 and pop < 0.5

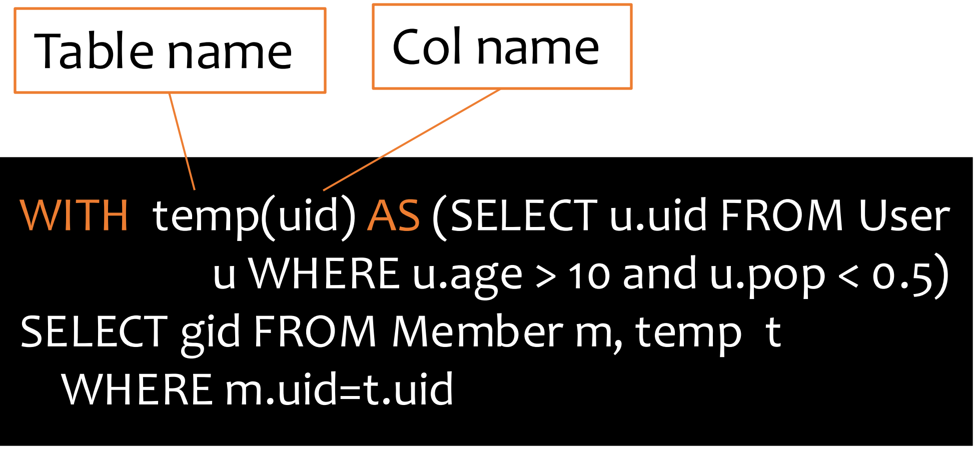


Table name

Col name

```
WITH  temp(uid) AS (SELECT u.uid FROM User
          u WHERE u.age > 10 and u.pop < 0.5)
SELECT gid FROM Member m, temp  t
   WHERE m.uid=t.uid
```

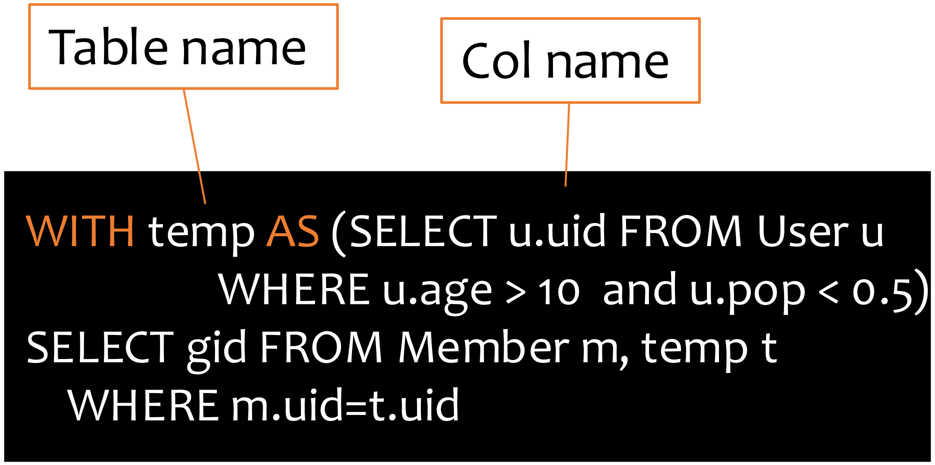


Table name

Col name

```
WITH temp AS (SELECT u.uid FROM User u
          WHERE u.age > 10  and u.pop < 0.5)
SELECT gid FROM Member m, temp t
   WHERE m.uid=t.uid
```

- Supported by many but not all DBMSs
- Can be written using subqueries

IN subqueries

- x IN ($\mathit{subquery}$) checks if x is in the result of $\mathit{subquery}$

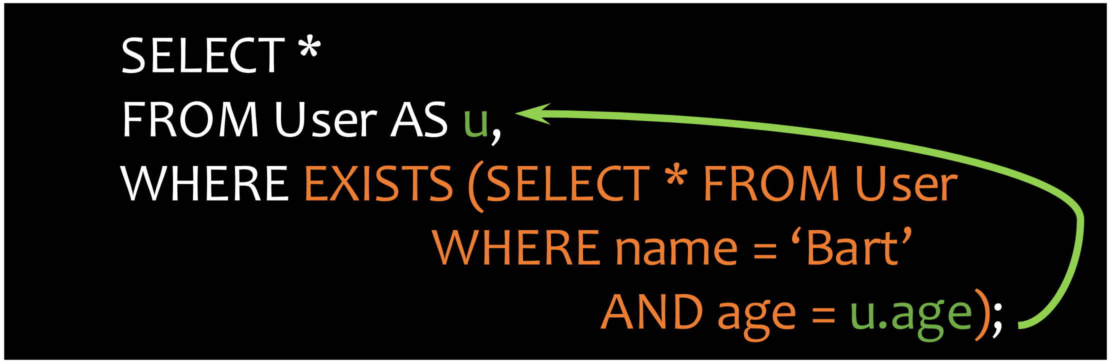
- Example: users that have the same age as (some) Bart

```
SELECT *
FROM User,
WHERE age IN (SELECT age
              FROM User
              WHERE name = ‘Bart’);
```

EXISTS subqueries

- EXISTS (*subquery*) checks if the result of *subquery* is non-empty

- Example: users that have the same age as (some) Bart



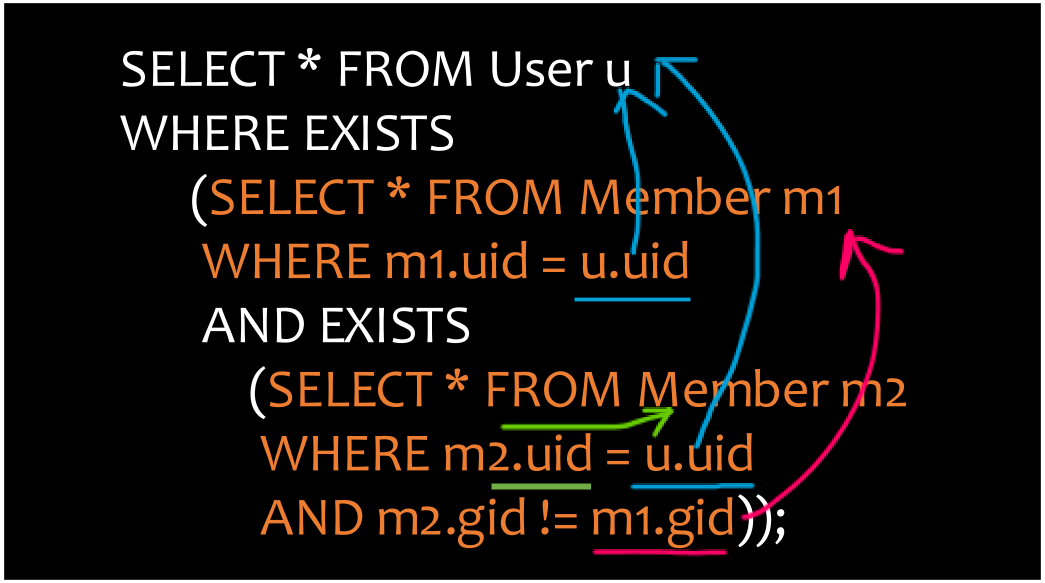
```
SELECT *
FROM User AS u,
WHERE EXISTS (SELECT * FROM User
                   WHERE name = ‘Bart’
                         AND age = u.age);
```

  - This happens to be a correlated subquery—a subquery that references tuple variables in surrounding queries

Another example

User (uid int, *name* string, *age* int, *pop* float)
Group (gid string, *name* string)
Member (uid int, gid string)

- Users who join at least two groups



```
SELECT * FROM User u
WHERE EXISTS
    (SELECT * FROM Member m1
     WHERE m1.uid = u.uid
     AND EXISTS
        (SELECT * FROM Member m2
         WHERE m2.uid = u.uid
         AND m2.gid != m1.gid));
```

Use *table_name.column_name* notation when appropriate to avoid confusion

- How to find which table a column belongs to?
  - Start with the immediately surrounding query
  - If not found, look in the one surrounding that; repeat if necessary

Quantified subqueries

- Universal quantification (for all):
  - ... WHERE x op ALL($subquery$) ...
  - True iff for all t in the result of $subquery$, x op t

```
SELECT *
FROM User
WHERE pop >= ALL(SELECT pop FROM User);
```

- Existential quantification (exists):
  - ... WHERE x op ANY($subquery$) ...
  - True iff there exists some t in $subquery$ result s.t. x op t

```
SELECT *
FROM User
WHERE NOT
   (pop < ANY(SELECT pop FROM User));
```

More ways to get the most popular

- Which users are the most popular?

```
Q1. SELECT *
FROM User
WHERE pop >= ALL(SELECT pop FROM User);
```

```
Q2. SELECT *
FROM User
WHERE NOT
   (pop < ANY(SELECT pop FROM User);
```

EXISTS or IN?

```
Q3. SELECT *
FROM User AS u
WHERE NOT [EXISTS or IN?]
   (SELECT * FROM User
    WHERE pop > u.pop);
```

```
Q4. SELECT * FROM User
WHERE uid NOT [EXISTS or IN?]
   (SELECT u1.uid
    FROM User AS u1, User AS u2
    WHERE u1.pop < u2.pop);
```

In class exercises

Consider this db instance:

User

uid	*name*	*age*	*pop*
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3

Member

uid	*gid*
857	dps
123	gov
857	abc
857	gov
456	abc
456	gov

- What is the output of these queries?

```
SELECT name FROM User WHERE age <=ALL(SELECT age FROM User)
```

```
SELECT name FROM User WHERE pop < ANY (SELECT pop FROM User)
```

```
WITH temp AS (SELECT uid FROM User WHERE pop < ANY (
                                        SELECT pop FROM User))
SELECT name FROM User WHERE uid NOT IN (SELECT uid FROM temp)
```

```
SELECT uid FROM User u WHERE EXISTS (SELECT gid FROM Member m
                                 WHERE m.uid = u.uid)
```

Take home exercises

- Using EXISTS, write a query to list user ids belonging to at least 2 groups

- Using WITH-AS and (NOT) IN, write a query to list group ids that Lisa belongs to but Ralph does not

- Write the same query but using EXCEPT (you may or may not use any other keywords)

SQL features covered so far

- SELECT-FROM-WHERE statements
- Set and bag operations
- Subqueries
  - Subqueries allow queries to be written in more declarative ways (recall the “most popular” query)
  - But in many cases, they don’t add expressive power

☞Next: aggregation and grouping