CS 133: Databases

Fall 2019
Lec 8 – 10/01
SQL

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Plan for Today

- Enhance understanding of semantics of conceptual query evaluation
- Build on understanding of the role of primary keys and NULL values in queries
- Practice reading and writing more complex SQL queries

SQL: Structured Query Language

- Relational algebra and calculus form the basis for SQL
- SQL is the standard query language supported by most commercial DBMS
  - The standard revised over time, e.g., "SQL 92" or "SQL 99"
- Recall basic query syntax

```
SELECT      [DISTINCT] target-list
FROM        relation-list
[WHERE      qualification]
[ORDER BY field(s) [ASC|DESC]]
[LIMIT num_rows]
```

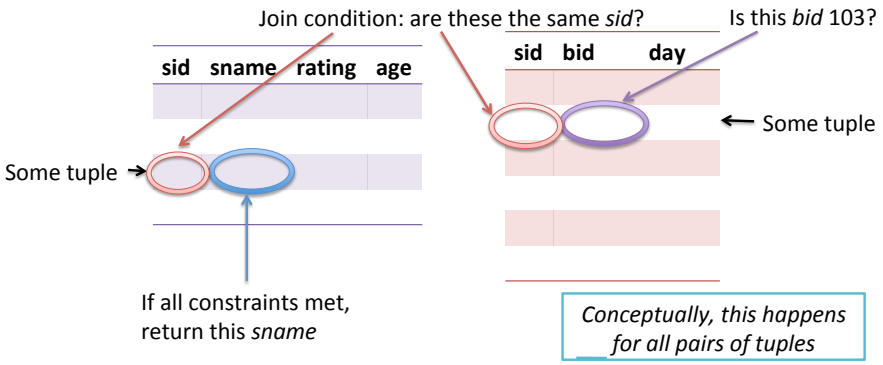
Query Semantics

- Semantics of an SQL query are defined in terms of the following **conceptual evaluation strategy**:
  1. do **FROM** clause: compute *cross-product* of tables (e.g., Students and Enrolled).
  2. do **WHERE** clause: Check conditions, discard tuples that fail. (i.e., "selection").
  3. do **SELECT** clause: Delete unwanted fields. (i.e., "projection").
  4. If **DISTINCT** specified, eliminate duplicate rows.

Not necessarily an *efficient* way to compute a query!
  - An optimizer will find more efficient strategies to get the *same answer*.

Visualizing Query Evaluation

```
SELECT  sname
FROM    Sailors, Reserves
WHERE  Sailors.sid=Reserves.sid AND bid=103
```



Example Relation Instances

We will use these instances of relations in our examples.

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
95	Bob	3	63.5

Sailors

sid	bid	day
22	101	10/10/96
95	103	11/12/96

Reserves

bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

Boats

(Assume appropriate foreign key constraints are used)

Range Variables

- Can associate "**range variables**" with the relations in the FROM clause
  - saves writing, makes queries easier to understand
  - like an alias

```
SELECT S.sname
FROM Sailors S, Reserves R
WHERE S.sid=R.sid AND bid=103;
```

- Needed when ambiguity could arise
  - for example, if same relation used multiple times in same FROM clause (called a "**self-join**")

Range Variables (cntd)

- Example where range variables are required (**self-join** example):

```
SELECT  S1.sname, S1.age, S2.sname, S2.age
FROM Sailors S1, Sailors S2
WHERE  S1.age = S2.age
   AND S1.rating > S2.rating;
```

- Is it possible for the result to contain a pair of Sailors that are *actually the same **person***?

Expressions

- Can use arithmetic expressions in SELECT clause
- Use AS to provide column names

```
SELECT S.sname, S.rating % 2 AS evenOrOddRating
FROM  Sailors S
WHERE  S.age >= 18;
```

- Can also have expressions in WHERE clause:

```
SELECT  S1.sname AS name1, S2.sname AS name2
FROM  Sailors S1, Sailors S2
WHERE  S1.rating > 2*S2.rating;
```

Exercise 2-3: Practice query interpretation

2. Sid, name, and rating for sailors who have reserved multiple different boats on the same day.

3. (a) Yes. Without DISTINCT, the cardinality of the result is the same as the cardinality of Reserves; there could be duplicates if sailors have reserved more than once

   (b) Could have duplicate names, which may or may not be the same sailor

   (c) No results

Null Values

- Field values in a tuple are sometimes missing
  - *unknown* (e.g., a rating or grade has not been assigned)
  - *inapplicable* (e.g., no spouse's name).
  - SQL provides a special value ***null*** for such situations.

- The presence of ***null*** complicates query evaluation. E.g.:
  - Is "*rating > 8*" true or false when *rating* is *null*? What about AND, OR and NOT?
  - You can check if a value is/is not *null* using IS NULL

Null Values – 3 Valued Logic

We need a 3-valued logic.

- Values: True, False and *Unknown*
- Meaning of clauses must be defined carefully
  (e.g., WHERE clause eliminates rows that do not evaluate to true.)

(null > 0)	unknown
(null + 1)	unknown
(null = 0)	unknown
null AND true	unknown
NOT unknown	unknown

AND	T	F	Null
T	T	F	Unknown
F	F	F	F
NULL	Unknown	F	Unknown

OR	T	F	Null
T	T	T	T
F	T	F	Unknown
NULL	T	Unknown	Unknown

Query: Find sids of sailors who've reserved a red **or** a green boat

```
SELECT DISTINCT R.sid
FROM Boats B,Reserves R
WHERE R.bid=B.bid
   AND (B.color='red' OR B.color='green');
```

What is DISTINCT achieving?

UNION: compute the union of any two *union-compatible* sets of tuples (which are themselves the result of SQL queries)

(**note**: UNION eliminates duplicates by default. Override w/ UNION ALL)

```
SELECT  R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid AND B.color='red'
UNION
SELECT R.sid
FROM Boats B, Reserves R
WHERE  R.bid=B.bid AND
B.color='green';
```

Query: Find sids of sailors who've reserved a red **and** a green boat

- If we simply replace OR by AND in the previous query, we get the wrong answer. (Why?)

```
SELECT DISTINCT R.sid
FROM Boats B,Reserves R
WHERE R.bid=B.bid
   AND (B.color='red' AND B.color='green')
```

red **and** a green boat (cntd)…

- INTERSECT:
  - Discussed in textbook.
  - Can be used to compute the intersection of any two *union-compatible* sets of tuples.
- Also in textbook: EXCEPT (sometimes called MINUS)
  - Included in the SQL 92 standard,
  - but many systems don't support them.

```
SELECT R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid
    AND B.color='red'
INTERSECT
SELECT R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid
     AND B.color='green'
```

Nested Queries

- Can use SQL queries to aid the evaluation of *another SQL query*
- **WHERE** clause can itself contain an SQL query!
  - so can **FROM** and **HAVING** clauses.
- Example:

```
SELECT  S.sid
FROM  Sailors S
WHERE  S.rating > (SELECT AVG(rating) FROM Sailors);
```

How many results does this *subquery* return?

Nested Queries

- Subqueries can also be relations with *many* tuples

Names of sailors who've reserved boat #103:

```
SELECT  S.sname
FROM  Sailors S
WHERE  S.sid IN ( SELECT R.sid
                  FROM  Reserves R
                  WHERE  R.bid=103)
```

For a given tuple in the *outer* query, check if `sid` == **any** result tuple from the *inner* query

- Semantics of nested queries:
  - Think of a *nested loops* evaluation: *For each Sailors tuple, check the qualification by computing the subquery*

- To find sailors who have ***not*** reserved #103, use **NOT IN**

In general, watch out for attributes that could be `NULL`!

More on Set-Comparison Operators

- Operators to filter tuples; applied to a relation *R* to yield a **boolean result**
  - *value* IN *R:* true iff *value* is equal to one of the values in unary *R*
  - EXISTS *R:* true iff R is not empty
  - UNIQUE *R:* true iff *R* has no duplicates (or is empty)
  - *value <op>* ANY *R:* true iff *value* <op> some value in unary *R*
  - *value <op>* ALL *R:* true iff *value* <op> all values in unary *R*

- Another Example:

```
SELECT  *
FROM  Sailors S
WHERE  S.age > ANY (SELECT  S2.age
                    FROM  Sailors S2
                    WHERE S2.sname='Horatio')
```

Exercise 4

```
SELECT S.sid
FROM Sailors S
WHERE S.rating >= ALL ( SELECT S2.rating
                        FROM Sailors S2 )
```

Nested Queries with Correlation

Find names of sailors who've reserved boat #103:

```
SELECT  S.sname
FROM  Sailors S
WHERE EXISTS (SELECT  *
              FROM  Reserves R
              WHERE R.bid=103 AND S.sid=R.sid)
```

- Subquery recomputed for each Sailors tuple.
  - Think of subquery as a function call that runs a query!

Nested Queries with Correlation

- If we change previous query by replacing EXISTS with UNIQUE and inner SELECT * with SELECT R.bid, *what does query result mean now?*

```
SELECT  S.sname
FROM  Sailors S
WHERE UNIQUE (SELECT  R.bid
              FROM  Reserves R
              WHERE R.bid=103 AND S.sid=R.sid)
```

Rewriting INTERSECT Queries Using IN

Find sids of sailors who've reserved both a red and a green boat:

```
SELECT  R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid
      AND B.color='red'
      AND R.sid IN (SELECT R2.sid
                    FROM  Boats B2, Reserves R2
                    WHERE  R2.bid=B2.bid
                    AND  B2.color='green')
```

Similarly, EXCEPT queries can be re-written using NOT IN.

Exercise 5

```
SELECT S.sname
FROM Sailors S
WHERE  1 >= (SELECT COUNT(*)
             FROM Reserves R
             WHERE R.bid=103
                AND S.sid=R.sid);
```