

CS460: Intro to Database Systems

Class 9: SQL, The Query Language – Part II

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<https://bu-disc.github.io/CS460/>

Recap: Basic SQL Query

```
SELECT    [DISTINCT] target-list
FROM      relation-list
WHERE     qualification
```

relation-list : a list of relations

target-list : a list of attributes of tables in *relation-list*

qualification : comparisons using AND, OR and NOT

comparisons are: $\langle \text{attr} \rangle \langle \text{op} \rangle \langle \text{const} \rangle$ or $\langle \text{attr1} \rangle \langle \text{op} \rangle \langle \text{attr2} \rangle$, where *op* is:

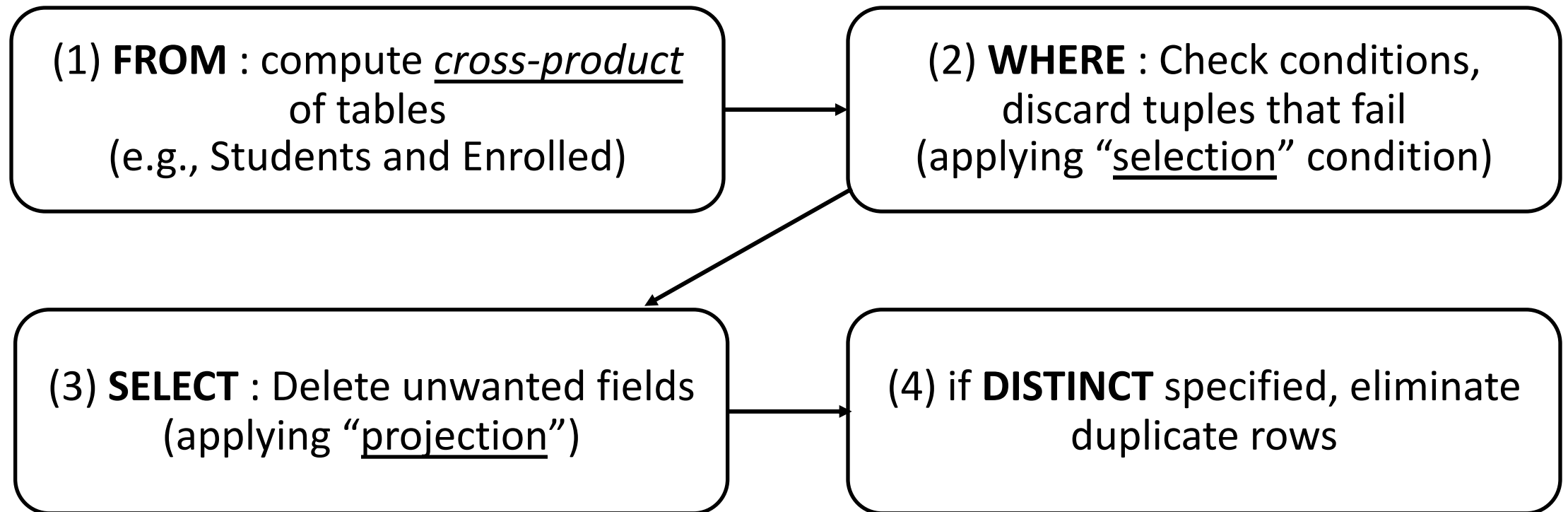
$\langle, \rangle, =, \leq, \geq, \neq$

DISTINCT: *optional*, removes duplicates

By default SQL SELECT does *not* eliminate duplicates! (“multiset”)

Recap: Query Semantics

Conceptually, a SQL query can be computed:



probably the least efficient way to compute a query!

Query Optimization finds the *same answer* more efficiently

Recap: Range Variables

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

can be
rewritten using
range variables as:

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

Can use Range Variables – do not need though. Why?

Recap: Expressions

Use **AS** to provide column names

```
SELECT S.age, S.age-5 AS age1, 2*S.age AS age2
FROM Sailors S
WHERE S.sname = 'dustin'
```

Can also have **expressions** in WHERE clause:

```
SELECT S1.sname AS name1, S2.sname AS name2
FROM Sailors S1, Sailors S2
WHERE 2*S1.rating = S2.rating - 1
```

Recap: String operations

SQL also supports some string operations

“LIKE” is used for string matching.

```
SELECT  S.age, age1=S.age-5, 2*S.age AS age2
FROM    Sailors S
WHERE   S.sname LIKE 'B_%B'
```

'_' stands for any one character

'%' stands for 0 or more arbitrary characters

>, < string comparison is supported by most systems

Recap: Nested Queries

WHERE clause can itself contain an SQL query!


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

Recap: Nested Queries **with Correlation**

Subquery must be recomputed for each Sailors tuple.

Think of subquery as a function call that runs a query!

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



Recap: Set Operations

```
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'
```

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

INTERSECT

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

Recap: ANY and ALL Set-Comparison Operators

Find sailors with rating greater than the rating of at least one sailor called 'Horatio':

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

Find sailors with rating greater than the rating of all 20-year old sailors:

```
SELECT *
FROM sailors S
WHERE S.rating > ALL (SELECT S2.rating
                     FROM sailors S2
                     WHERE S2.age = 20)
```

Recap: Set-Difference using NOT IN

Find all sailors who have not reserved a red boat

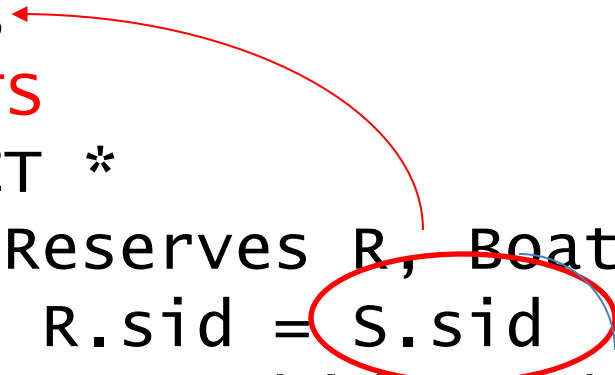
```
SELECT S.sid
FROM   Sailors S
WHERE  S.sid NOT IN
      (SELECT R.sid
       FROM Reserves R, Boats B
       WHERE R.bid = B.bid
            AND B.color = 'red')
```

Nested – NO correlation!

Recap: Set-Difference using NOT EXISTS

Find all sailors who have not reserved a red boat

```
SELECT S.sid
FROM Sailors S
WHERE NOT EXISTS
      (SELECT *
       FROM Reserves R, Boats B
       WHERE R.sid = S.sid
            AND R.bid = B.bid
            AND B.color = 'red')
```



Nested – correlation!

Aggregate Operators

Significant extension of relational algebra.

```
SELECT COUNT (*)  
FROM Sailors S
```

```
SELECT AVG (S.age)  
FROM Sailors S  
WHERE S.rating=10
```

```
SELECT COUNT (DISTINCT S.rating)  
FROM Sailors S  
WHERE S.sname='Bob'
```

```
COUNT (*)  
COUNT ( [DISTINCT] A)  
SUM ( [DISTINCT] A)  
AVG ( [DISTINCT] A)  
MAX (A)  
MIN (A)
```

single column

Find name and age of the oldest sailor(s)

The first query is incorrect!

```
SELECT S.sname, MAX (S.age)
FROM Sailors S
```

Third query equivalent to second query

allowed in SQL/92 standard, but not supported in some systems.

```
SELECT S.sname, S.age
FROM Sailors S
WHERE S.age =
      (SELECT MAX (S2.age)
       FROM   Sailors S2)
```

```
SELECT S.sname, S.age
FROM   Sailors S
WHERE  (SELECT MAX (S2.age)
        FROM   Sailors S2)
        = S.age
```

ARGMAX?

The Sailor with the highest rating

What about ties for highest?

```
SELECT *  
FROM   sailors s  
WHERE  s.rating >= ALL  
       (SELECT s2.rating  
        FROM   sailors s2)
```

```
SELECT *  
FROM   sailors s  
WHERE  s.rating =  
       (SELECT MAX(s2.rating)  
        FROM   sailors s2)
```

```
SELECT *  
FROM   sailors s  
ORDER BY rating DESC  
LIMIT 1;
```

Division in SQL

Find sailors who have reserved all boats.

Sailors S for which ...

```

SELECT S.sname
FROM Sailors S there is no boat B without ...
WHERE NOT EXISTS (SELECT B.bid
                  FROM Boats B
                  WHERE NOT EXISTS (SELECT R.bid
                                   FROM Reserves R
                                   WHERE R.bid=B.bid
                                   a Reserves tuple AND R.sid=S.sid))
showing S reserved B

```


SQL DDL

Recap: SQL DDL

```
CREATE TABLE Enrolled
(sid CHAR(20),
 cid CHAR(20),
 grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students )
```

SQL DDL – General Constraints

```
CREATE TABLE Enrolled
(sid CHAR(20),
 cid CHAR(20),
 grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students,
 CHECK grade LIKE 'A' OR grade LIKE 'B'
       OR grade LIKE 'C' OR grade LIKE 'D')
```

SQL DDL – General Constraints

```
CREATE TABLE Enrolled
(sid CHAR(20),
 cid CHAR(20),
 grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students,
 CONSTRAINT checkGrade
 CHECK (grade LIKE 'A' OR grade LIKE 'B'
       OR grade LIKE 'C' OR grade LIKE 'D')) )
```

SQL DDL – General Constraints

```
CREATE TABLE Enrolled
(sid CHAR(20),
 cid CHAR(20),
 grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students,
 CONSTRAINT checkNumber
 CHECK ( (SELECT COUNT (sid) FROM Students)
        +
        (SELECT COUNT DISTINCT (cid) FROM Enrolled)
        < 1000 ) )
```

JOINS

Joins

```
SELECT (column_list)
FROM table_name
  [INNER | NATURAL | {LEFT | RIGHT | FULL} | {OUTER}]
JOIN table_name
  ON qualification_list
WHERE ...
```

INNER is default

```
SELECT sname FROM sailors S JOIN reserves R ON S.sid=R.sid;
```

```
SELECT sname FROM sailors S NATURAL JOIN reserves R
WHERE R.bid = 102;
```

Inner Joins

```
SELECT s.sid, s.sname, r.bid  
FROM Sailors s, Reserves r  
WHERE s.sid = r.sid
```

```
SELECT s.sid, s.sname, r.bid  
FROM Sailors s INNER JOIN Reserves r  
ON s.sid = r.sid
```

They are
equivalent!

Left Outer Join

Returns all matched rows, plus all unmatched rows from the table on the **left** of the join clause

(use nulls in fields of non-matching tuples)

```
SELECT s.sid, s.sname, r.bid
FROM sailors s LEFT OUTER JOIN
Reserves r
ON s.sid = r.sid;
```

Returns all sailors & bid for boat in any of their reservations

Note: no match for s.sid? r.sid IS NULL!

```

SELECT s.sid, s.sname, r.bid
FROM Sailors s LEFT OUTER JOIN Reserves r
ON s.sid = r.sid;

```

| <u>sid</u> | sname | rating | age |
|------------|--------|--------|------|
| 22 | Dustin | 7 | 45.0 |
| 31 | Lubber | 8 | 55.5 |
| 95 | Bob | 3 | 63.5 |

| <u>sid</u> | <u>bid</u> | <u>day</u> |
|------------|------------|------------|
| 22 | 101 | 10/10/96 |
| 95 | 103 | 11/12/96 |

| s.sid | s.name | r.bid |
|-------|--------|-------|
| 22 | Dustin | 101 |
| 95 | Bob | 103 |
| 31 | Lubber | |

← NULL

Right Outer Join

Returns all matched rows, plus all unmatched rows from the table on the **right** of the join clause

(use nulls in fields of non-matching tuples)

```
SELECT r.sid, b.bid, b.bname
FROM Reserves r RIGHT OUTER JOIN
Boats b
ON r.bid = b.bid;
```

Returns all boats & information on which ones are reserved

Note: no match for b.bid? r.bid IS NULL!

Full Outer Join

Full Outer Join returns all (matched or unmatched) rows from the tables on both sides of the join clause

```
SELECT r.sid, b.bid, b.bname
FROM Reserves2 r FULL OUTER JOIN
Boats2 b
ON r.bid = b.bid;
```

Returns all boats & all information on reservations

No match for r.bid?

- b.bid IS NULL AND b.bname is NULL

No match for b.bid?

- r.sid is NULL

GROUP BY AND HAVING

GROUP BY and HAVING

So far, we've applied aggregate operators to all (qualifying) tuples.

Sometimes, we want to apply them to each of several *groups* of tuples.

Consider: *Find the age of the youngest sailor for each rating level.*

In general, we don't know how many rating levels exist, and what the rating values for these levels are!

Suppose we know that rating values go from 1 to 10; we can write 10 queries that look like this (!):

```
For  $i = 1, 2, \dots, 10$ :  
SELECT MIN (S.age)  
FROM   Sailors S  
WHERE  S.rating =  $i$ 
```

Queries With GROUP BY and HAVING

```
SELECT      [DISTINCT] target-list
FROM        relation-list
WHERE       qualification
GROUP BY    grouping-list
[HAVING     group-qualification]
```

Group rows by columns in *grouping-list*

Every column from *target-list* must appear in the *grouping-list*

HAVING restricts through an *aggregate* which group-rows are part of the result

Conceptual Evaluation

(1) Cross-product of *relation-list*

(2) Select only tuples that follow the where clause *qualification*)

(3) Partition rows by the value of attributes in *grouping-list*

(4) Select only groups that follow the *group-qualification*

(5) One answer tuple is generated per qualifying group, showing *target-list*

Attributes in *target-list* must also be in *grouping-list*.

Expressions in *group-qualification* must have a single value per group! That is, attributes in *group-qualification* must be part of an aggregate op / must appear in the *grouping-list*.

Find the age of the youngest sailor with age ≥ 18 ,
for each rating with at least 2 such sailors

```
SELECT  S.rating,  MIN (S.age)
FROM    Sailors S
WHERE   S.age >= 18
GROUP BY S.rating
HAVING  COUNT (*) > 1
```

| sid | sname | rating | age |
|-----|---------|--------|------|
| 22 | dustin | 7 | 45.0 |
| 31 | lubber | 8 | 55.5 |
| 71 | zorba | 10 | 16.0 |
| 64 | horatio | 7 | 35.0 |
| 29 | brutus | 1 | 33.0 |
| 58 | rusty | 10 | 35.0 |

2

| rating | age |
|--------|------|
| 1 | 33.0 |
| 7 | 45.0 |
| 7 | 35.0 |
| 8 | 55.5 |
| 10 | 35.0 |

3

| rating | m-age | count |
|--------|-------|-------|
| 1 | 33.0 | 1 |
| 7 | 35.0 | 2 |
| 8 | 55.0 | 1 |
| 10 | 35.0 | 1 |

4

| rating | |
|--------|------|
| 7 | 35.0 |

Find sailors who have reserved all boats.

Can you do this using Group By and Having?

```
SELECT  S.name
FROM    Sailors S, Reserves R
WHERE   S.sid = R.sid
GROUP BY S.name, S.sid
HAVING  COUNT(DISTINCT R.bid) =
        (SELECT COUNT (*) FROM Boats)
```

Note: must have both sid and name in the GROUP BY clause. Why?

- (1) Attributes in *target-list* must also be in *grouping-list*.
- (2) Expressions in *group-qualification* must have a single value per group!

```

SELECT  S.name, S.sid
FROM    sailors S, reserves R
WHERE   S.sid = R.sid
GROUP BY S.name, S.sid
HAVING  COUNT(DISTINCT R.bid) =
        (select COUNT (*) FROM Boats)

```

| s.name | s.sid | r.sid | r.bid |
|--------|-------|-------|-------|
| Dustin | 22 | 22 | 101 |
| Lubber | 31 | 22 | 101 |
| Bob | 95 | 22 | 101 |
| Dustin | 22 | 95 | 102 |
| Lubber | 31 | 95 | 102 |
| Bob | 95 | 95 | 102 |

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

Count (*) from boats = 4

| s.name | s.sid | bcount |
|--------|-------|--------|
| Dustin | 22 | 1 |
| Bob | 95 | 1 |

Apply having clause to groups



| s.name | s.sid |
|--------|-------|
| | |

Sorting the Results of a Query

ORDER BY *column* [ASC | DESC] [, ...]

```
SELECT    S.rating, S.sname, S.age
FROM      Sailors S, Boats B, Reserves R
WHERE     S.sid=R.sid AND R.bid=B.bid
          AND B.color='red'
ORDER BY  S.rating, S.sname;
```

Extra reporting power obtained by combining with aggregation.

```
SELECT    S.sid, COUNT (*) AS redrescnt
FROM      Sailors S, Boats B, Reserves R
WHERE     S.sid=R.sid AND R.bid=B.bid
          AND B.color='red'
GROUP BY  S.sid
ORDER BY  redrescnt DESC;
```

Summary: The SQL Query

| | |
|----------|-------------------------------|
| SELECT | [DISTINCT] <i>target-list</i> |
| FROM | <i>relation-list</i> |
| WHERE | <i>qualification</i> |
| GROUP BY | <i>grouping-list</i> |
| HAVING | <i>group-qualification</i> |
| ORDER BY | <i>attribute-list</i> |