

# *SQL: Queries, Constraints, Triggers*

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# *Slides are based on*

- *Raghu Ramakrishnan, Johannes Gehrke, Database Management Systems, McGraw-Hill, 3<sup>rd</sup> ed., 2007.*
- *Slides from „Cow Book“: R.Ramakrishnan, <http://pages.cs.wisc.edu/~dbbbook/>*

# Example Instances

*R1*

<u>sid</u>	<u>bid</u>	<u>day</u>
22	101	10/10/96
58	103	11/12/96

- We will use these instances of the Sailors and Reserves relations in our examples.
- If the key for the Reserves relation contained only the attributes *sid* and *bid*, how would the semantics differ?

*s1*

<u>sid</u>	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

*s2*

<u>sid</u>	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

# Basic SQL Query

SELECT	[DISTINCT] <i>target-list</i>
FROM	<i>relation-list</i>
WHERE	<i>qualification</i>

- *relation-list* A list of relation names (possibly with a *range-variable* after each name).
- *target-list* A list of attributes of relations in *relation-list*
- *qualification* Comparisons (Attr *op* const or Attr1 *op* Attr2, where *op* is one of  $<$ ,  $>$ ,  $=$ ,  $\leq$ ,  $\geq$ ,  $\neq$  ) combined using AND, OR and NOT.
- **DISTINCT** is an optional keyword indicating that the answer should not contain duplicates. Default is that duplicates are not eliminated!

# Conceptual Evaluation Strategy

- Semantics of an SQL query defined in terms of the following conceptual evaluation strategy:
  - Compute the cross-product of *relation-list*.
  - Discard resulting tuples if they fail *qualifications*.
  - Delete attributes that are not in *target-list*.
  - If **DISTINCT** is specified, eliminate duplicate rows.
- This strategy is probably the least efficient way to compute a query! An optimizer will find more efficient strategies to compute *the same answers*.

# Example of Conceptual Evaluation

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

(sid)	sname	rating	age	(sid)	bid	day
22	dustin	7	45.0	22	101	10/ 10/ 96
22	dustin	7	45.0	58	103	11/ 12/ 96
31	lubber	8	55.5	22	101	10/ 10/ 96
31	lubber	8	55.5	58	103	11/ 12/ 96
58	rusty	10	35.0	22	101	10/ 10/ 96
58	rusty	10	35.0	58	103	11/ 12/ 96

# A Note on Range Variables

- Really needed only if the same relation appears twice in the FROM clause. The previous query can also be written as:

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

OR

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

*It is good style,  
however, to use  
range variables  
always!*

# Find sailors who've reserved at least one boat

```
SELECT S.sid  
FROM Sailors S, Reserves R  
WHERE S.sid=R.sid
```

- Would adding DISTINCT to this query make a difference?
- What is the effect of replacing *S.sid* by *S.sname* in the SELECT clause? Would adding DISTINCT to this variant of the query make a difference?



# Expressions and Strings

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

- Illustrates use of arithmetic expressions and string pattern matching: *Find triples (of ages of sailors and two fields defined by expressions) for sailors whose names begin and end with B and contain at least three characters.*
- **AS** and **=** are two ways to name fields in result.
- **LIKE** is used for string matching. **`\_`** stands for any one character and **`%`** stands for 0 or more arbitrary characters.

# Find sid's of sailors who've reserved a red or a green boat

- **UNION**: Can be used to compute the union of any two *union-compatible* sets of tuples (which are themselves the result of SQL queries).
- If we replace **OR** by **AND** in the first version, what do we get?
- Also available: **EXCEPT** (What do we get if we replace **UNION** by **EXCEPT**?)

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

**UNION**

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

# Find sid's of sailors who've reserved a red and a green boat

- **INTERSECT:** Can be used to compute the intersection of any two *union-compatible* sets of tuples.
- Included in the SQL/92 standard, but some systems don't support it.
- Contrast symmetry of the UNION and INTERSECT queries with how much the other versions differ.

```
SELECT S.sid
FROM Sailors S, Boats B1, Reserves R1,
      Boats B2, Reserves R2
WHERE S.sid=R1.sid AND R1.bid=B1.bid
      AND S.sid=R2.sid AND R2.bid=B2.bid
      AND (B1.color='red' AND B2.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'
```

 Key field!

# Nested Queries

*Find 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)
```

- A very powerful feature of SQL: a WHERE clause can itself contain an SQL query! (Actually, so can FROM and HAVING clauses.)
- To find sailors who've *not* reserved #103, use NOT IN.
- To understand semantics of nested queries, think of a nested loops evaluation: *For each Sailors tuple, check the qualification by computing the subquery.*

# 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)
```



- **EXISTS** is another set comparison operator, like **IN**.
- If **UNIQUE** is used, and \* is replaced by *R.bid*, finds sailors with at most one reservation for boat #103. (UNIQUE checks for duplicate tuples; \* denotes all attributes. Why do we have to replace \* by *R.bid*?)
- Illustrates why, in general, subquery must be re-computed for each Sailors tuple.

# More on Set-Comparison Operators

- We've already seen IN, EXISTS and UNIQUE. Can also use NOT IN, NOT EXISTS and NOT UNIQUE.
- Also available: *op* ANY, *op* ALL, *op* IN  $>, <, =, \geq, \leq, \neq$
- Find sailors whose rating is greater than that of some sailor called Horatio:

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

# Rewriting INTERSECT Queries Using IN

*Find sid's of sailors who've reserved both a red and a green boat:*

```
SELECT S.sid
FROM Sailors S, Boats B, Reserves R
WHERE S.sid=R.sid AND R.bid=B.bid AND B.color='red'
      AND S.sid IN (SELECT S2.sid
                    FROM Sailors S2, Boats B2, Reserves R2
                    WHERE S2.sid=R2.sid AND R2.bid=B2.bid
                      AND B2.color='green')
```

- Similarly, EXCEPT queries re-written using NOT IN.
- To find *names* (not *sid's*) of Sailors who've reserved both red and green boats, just replace *S.sid* by *S.sname* in SELECT clause. (What about INTERSECT query?)

# Division in SQL

(1)

Find sailors who've reserved  
all boats.

- Let's do it the hard way,  
without EXCEPT:

```
SELECT S.sname
FROM Sailors S
WHERE NOT EXISTS
    ((SELECT B.bid
      FROM Boats B)
  EXCEPT
  (SELECT R.bid
   FROM Reserves R
   WHERE R.sid=S.sid))
```

(2)

```
SELECT S.sname
FROM Sailors S
WHERE NOT EXISTS (SELECT B.bid
                  FROM Boats B
                  WHERE NOT EXISTS (SELECT R.bid
```

```
    FROM Reserves R
    WHERE R.bid=B.bid
    AND R.sid=S.sid))
```

*Sailors S such that ...*

*there is no boat B without ...*

*a Reserves tuple showing S reserved B*



# Aggregate Operators

- Significant extension of relational algebra.

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

*single column*

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

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

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

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

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

# Find name and age of the oldest sailor(s)

- The first query is illegal! (We'll look into the reason a bit later, when we discuss **GROUP BY**.)
- The third query is equivalent to the second query, and is allowed in the SQL/92 standard, but is not supported in some systems.

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

```
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
```

# Motivation for Grouping

- 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] <i>target-list</i>
FROM	<i>relation-list</i>
WHERE	<i>qualification</i>
GROUP BY	<i>grouping-list</i>
HAVING	<i>group-qualification</i>

- The *target-list* contains (i) attribute names (ii) terms with aggregate operations (e.g., MIN (S.age)).
  - The attribute list (i) must be a subset of *grouping-list*. Intuitively, each answer tuple corresponds to a *group*, and these attributes must have a single value per group. (A *group* is a set of tuples that have the same value for all attributes in *grouping-list*.)

# Conceptual Evaluation

- The cross-product of *relation-list* is computed, tuples that fail *qualification* are discarded, 'unnecessary' fields are deleted, and the remaining tuples are partitioned into groups by the value of attributes in *grouping-list*.
- The *group-qualification* is then applied to eliminate some groups. Expressions in *group-qualification* must have a *single value per group!*
  - In effect, an attribute in *group-qualification* that is not an argument of an aggregate op also appears in *grouping-list*. (SQL does not exploit primary key semantics here!)
- One answer tuple is generated per qualifying group.

# Find the number of reservations for each red boat.

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

- Grouping over a join of three relations.
- What do we get if we remove *B.color='red'* from the WHERE clause and add a HAVING clause with this condition?
- What if we drop Sailors and the condition involving S.sid?

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

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

*Sailors instance:*

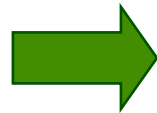
<u>sid</u>	sname	rating	age
22	dustin	7	45.0
29	brutus	1	33.0
31	lubber	8	55.5
32	andy	8	25.5
58	rusty	10	35.0
64	horatio	7	35.0
71	zorba	10	16.0
74	horatio	9	35.0
85	art	3	25.5
95	bob	3	63.5
96	frodo	3	25.5

*Answer relation:*

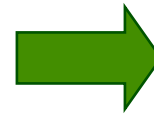
rating	minage
3	25.5
7	35.0
8	25.5

Find age of the youngest sailor with age  $\geq 18$ ,  
for each rating with at least 2 such sailors.

rating	age
7	45.0
1	33.0
8	55.5
8	25.5
10	35.0
7	35.0
10	16.0
9	35.0
3	25.5
3	63.5
3	25.5



rating	age
1	33.0
3	25.5
3	63.5
3	25.5
7	45.0
7	35.0
8	55.5
8	25.5
9	35.0
10	35.0



rating	minage
3	25.5
7	35.0
8	25.5



Find age of the youngest sailor with age  $\geq 18$ , for each rating with at least 2 such sailors and with every sailor under 60.

HAVING COUNT (\*) > 1 AND EVERY (S.age <=60)



What is the result of changing EVERY to ANY?

Find age of the youngest sailor with age  $\geq 18$ , for each rating with at least 2 sailors between 18 and 60.

```
SELECT S.rating, MIN (S.age)
                        AS minage
FROM   Sailors S
WHERE  S.age >= 18 AND S.age <= 60
GROUP BY S.rating
HAVING COUNT (*) > 1
```

*Sailors instance:*

<u>sid</u>	sname	rating	age
22	dustin	7	45.0
29	brutus	1	33.0
31	lubber	8	55.5
32	andy	8	25.5
58	rusty	10	35.0
64	horatio	7	35.0
71	zorba	10	16.0
74	horatio	9	35.0
85	art	3	25.5
95	bob	3	63.5
96	frodo	3	25.5

*Answer relation:*

rating	minage
3	25.5
7	35.0
8	25.5

Find age of the youngest sailor with age > 18,  
for each rating with at least 2 sailors (of any age)

```
SELECT S.rating, MIN (S.age)
FROM Sailors S
WHERE S.age > 18
GROUP BY S.rating
HAVING 1 < (SELECT COUNT (*)
             FROM Sailors S2
             WHERE S.rating=S2.rating)
```

- Shows HAVING clause can also contain a subquery.
- Compare this with the query where we considered only ratings with 2 sailors over 18!
- What if HAVING clause is replaced by HAVING COUNT(\*) >1?

Find those ratings for which the average age is the minimum over all ratings

- Aggregate operations cannot be nested! **WRONG:**

```
SELECT S.rating
FROM Sailors S
WHERE S.age = (SELECT MIN (AVG (S2.age)) FROM Sailors S2)
```

❖ Correct solution (in SQL/92):

```
SELECT Temp.rating, Temp.average
FROM (SELECT S.rating, AVG (S.age) AS average
      FROM Sailors S
      GROUP BY S.rating) AS Temp
WHERE Temp.average = (SELECT MIN (Temp.average)
                     FROM Temp)
```

# Null Values

- Field values in a tuple are sometimes *unknown* (e.g., a rating has not been assigned) or *inapplicable* (e.g., no spouse's name).
  - SQL provides a special value *null* for such situations.
- The presence of *null* complicates many issues. E.g.:
  - Special operators needed to check if value is/is not *null*.
  - Is *rating*>8 true or false when *rating* is equal to *null*? What about *AND*, *OR* and *NOT* connectives?
  - We need a 3-valued logic (true, false and *unknown*).
  - Meaning of constructs must be defined carefully. (e.g., WHERE clause eliminates rows that don't evaluate to true.)
  - New operators (in particular, *outer joins*) possible/needed.

# Integrity Constraints (Review)

- An IC describes conditions that every *legal instance* of a relation must satisfy.
  - Inserts/deletes/updates that violate IC's are disallowed.
  - Can be used to ensure application semantics (e.g., *sid* is a key), or prevent inconsistencies (e.g., *sname* has to be a string, *age* must be  $< 200$ )
- Types of IC's: Domain constraints, primary key constraints, foreign key constraints, general constraints.
  - *Domain constraints*: Field values must be of right type. Always enforced.

# General Constraints

- Useful when more general ICs than keys are involved.
- Can use queries to express constraint.
- Constraints can be named.

```
CREATE TABLE Sailors
( sid INTEGER,
  sname CHAR(10),
  rating INTEGER,
  age REAL,
  PRIMARY KEY (sid),
  CHECK ( rating >= 1
        AND rating <= 10 )
```

```
CREATE TABLE Reserves
( sname CHAR(10),
  bid INTEGER,
  day DATE,
  PRIMARY KEY (bid,day),
  CONSTRAINT noInterlakeRes
  CHECK (`Interlake' <>
        ( SELECT B.bname
          FROM Boats B
          WHERE B.bid=bid)))
```

# Constraints Over Multiple Relations

- Awkward and wrong!
- If Sailors is empty, the number of Boats tuples can be anything!
- ASSERTION is the right solution; not associated with either table.

```
CREATE TABLE Sailors
( sid INTEGER,
  sname CHAR(10),
  rating INTEGER,
  age REAL,
  PRIMARY KEY (sid),
  CHECK
  ( (SELECT COUNT (S.sid) FROM Sailors S)
    + (SELECT COUNT (B.bid) FROM Boats B) < 100 )
```

*Number of boats  
plus number of  
sailors is < 100*

```
CREATE ASSERTION smallClub
CHECK
( (SELECT COUNT (S.sid) FROM Sailors S)
  + (SELECT COUNT (B.bid) FROM Boats B) < 100 )
```



# Triggers

- Trigger: procedure that starts automatically if specified changes occur to the DBMS
- Three parts:
  - Event (activates the trigger)
  - Condition (tests whether the triggers should run)
  - Action (what happens if the trigger runs)

# Triggers - syntax

```
<trigger definition> ::=  
    CREATE TRIGGER <trigger name>  
        <trigger action time> <trigger event>  
        ON <table name> [ REFERENCING <old or new values alias list> ]  
        <triggered action>
```

```
<trigger action time> ::=  
    BEFORE  
    | AFTER
```

```
<trigger event> ::=  
    INSERT  
    | DELETE  
    | UPDATE [ OF <trigger column list> ]
```

```
<trigger column list> ::= <column name list>
```

```
<triggered action> ::=  
    [ FOR EACH { ROW | STATEMENT } ]  
    [ WHEN <left paren> <search condition> <right paren> ]  
    <triggered SQL statement>
```

# Triggers - syntax

```
<triggered SQL statement> ::=  
    <SQL procedure statement>  
    | BEGIN ATOMIC  
      { <SQL procedure statement> <semicolon> }...  
    END
```

```
<old or new values alias list> ::=  
    <old or new values alias>...
```

```
<old or new values alias> ::=  
    OLD [ROW ][AS ]<old values correlation name>  
    | NEW [ROW ][AS ]<new values correlation name>  
    | OLD TABLE [ AS ] <old values table alias>  
    | NEW TABLE [ AS ] <new values table alias>
```

# Triggers: Example (SQL3)

```
CREATE TRIGGER youngSailorUpdate
  AFTER INSERT ON SAILORS
  REFERENCING NEW TABLE NewSailors
  FOR EACH STATEMENT
  INSERT
    INTO YoungSailors(sid, name, age, rating)
  SELECT sid, name, age, rating
  FROM NewSailors N
  WHERE N.age <= 18
```

# Summary

- SQL was an important factor in the early acceptance of the relational model; more natural than earlier, procedural query languages.
- Relationally complete; in fact, significantly more expressive power than relational algebra.
- Even queries that can be expressed in RA can often be expressed more naturally in SQL.
- Many alternative ways to write a query; optimizer should look for most efficient evaluation plan.
  - In practice, users need to be aware of how queries are optimized and evaluated for best results.

# Summary (Contd.)

- NULL for unknown field values brings many complications
- SQL allows specification of rich integrity constraints
- Triggers respond to changes in the database