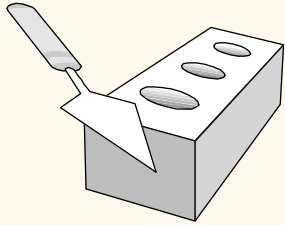
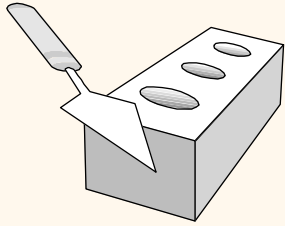


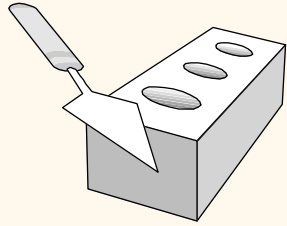
SQL: Queries, Constraints, Triggers

Chapter 5



The SQL Query Language

- Developed by IBM (system R) in the 1970s
- *The* most widely used language for creating, manipulating, and querying relational DBMS.
- Need for a standard since it is used by many vendors
- Standards:
  - SQL-86
  - SQL-89 (minor revision)
  - SQL-92 (major revision)
  - SQL-99 (major extensions, current standard)



Example Instances

- We will use these instances of the Sailors and Reserves relations in our examples.

S1

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

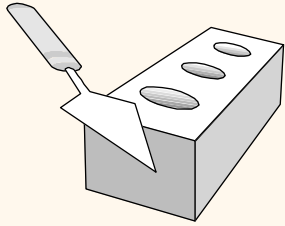
R1

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

S2

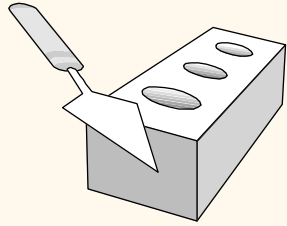
sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

Basic SQL Query



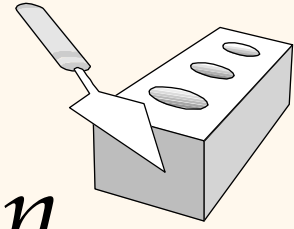
SELECT	[DISTINCT] *target-list*
FROM	*relation-list*
WHERE	*qualification*

- *relation-list* A list of relation names
- *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:
  1. Compute the cross-product of *relation-list*.
  2. Discard resulting tuples if they fail *qualifications*.
  3. Delete attributes that are not in *target-list*.
  4. 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*.

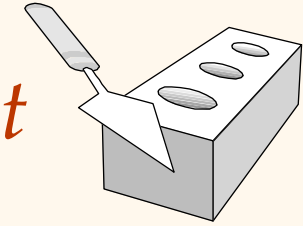


Example of Conceptual Evaluation

```
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

Find sailors who've reserved at least one boat



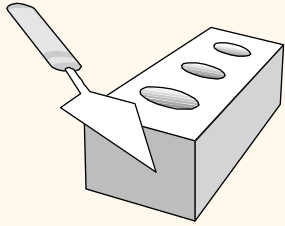
```
SELECT  S.sid
FROM  Sailors S, Reserves R
WHERE  S.sid=R.sid
```

- 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?

Find the names of sailors who have reserved a red boat

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

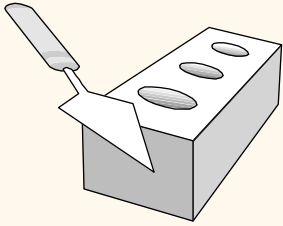
Expressions and Strings



```
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 and names of sailors who've reserved a red or a green boat

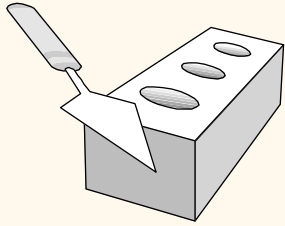


- UNION: Can be used to compute the union of any two *union-compatible* sets of tuples (which are themselves the result of SQL queries).
- If we replace OR by AND in the first version, what do we get?
- Also available: EXCEPT (What do we get if we replace UNION by EXCEPT?)

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

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



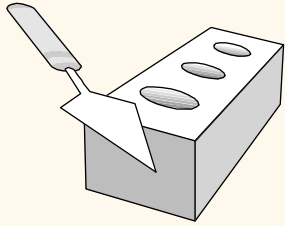
- INTERSECT: Can be used to compute the intersection of any two *union-compatible* sets of tuples.
- Included in the SQL/92 standard, but some systems don't support it.
- Contrast symmetry of the UNION and INTERSECT queries with how much the other versions differ.

```
SELECT  S.sid, S.sname
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'
```

Key field!

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

Find sid's and names of sailors who've reserved red boats but not green boats

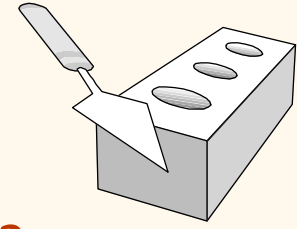


```
SELECT  S.sid, S.sname
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid AND B.color='red'
EXCEPT
SELECT  S.sid, S.sname
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid AND B.color='green'
```

- EXCEPT: Can be used to compute the difference of any two *union-compatible* sets of tuples

- Many systems recognize the keyword MINUS instead of EXCEPT

Nested Queries

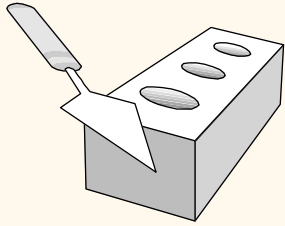


Find names of sailors who've reserved boat #103

```
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 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.*

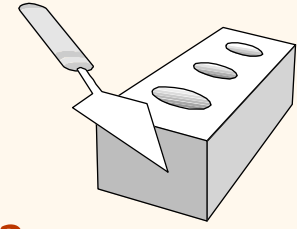
Nested Queries



Find names of sailors who've not reserved a red boat

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

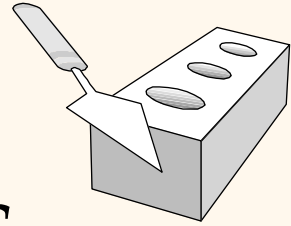
Nested Queries with Correlation



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.
- Illustrates why, in general, subquery must be re-computed for each Sailors tuple.

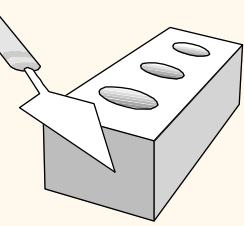


More on Set-Comparison Operators

- 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 >, <, =, ≥, ≤, ≠
- 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

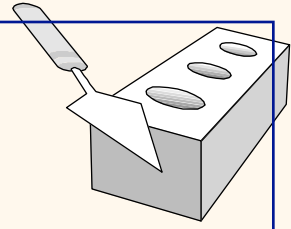


Find sid of sailors who've reserved both a red and a green boat:

```
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.
- Useful if your system does not support INTERSECT or EXCEPT

Division in SQL



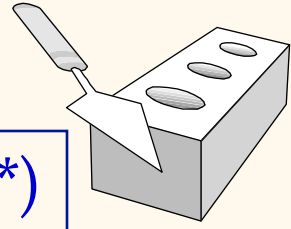
```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS
          ((SELECT  B.bid
            FROM  Boats B)
           EXCEPT
            (SELECT  R.bid
             FROM  Reserves R
             WHERE  R.sid=S.sid))
```

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
                    WHERE  NOT EXISTS  (SELECT  R.bid
                                        FROM  Reserves R
                                        WHERE  R.bid=B.bid
                                          AND R.sid=S.sid))
```

Aggregate Operators



- Significant extension of relational algebra.

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

sid	sname	rating	age
28	Bob	10	35
31	Bob	10	20
44	guppy	5	50
58	rusty	10	35

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

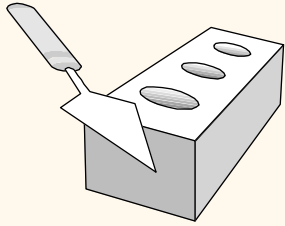
```
SELECT  AVG (S.age)
FROM  Sailors S
WHERE  S.rating=10
```

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

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

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

Find name and age of the oldest sailor(s)



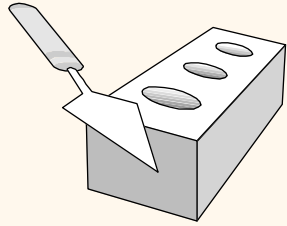
- The first query is illegal! (We'll look into the reason a bit later, when we discuss GROUP BY.)
- The third query is equivalent to the second query, and is allowed in the SQL/92 standard, but is not supported in some systems.

```
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



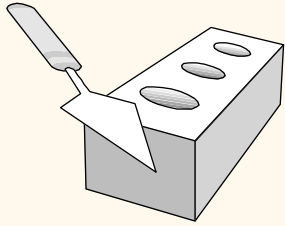
- So far, we've applied aggregate operators to all (qualifying) tuples. Sometimes, we want to apply them to each of several *groups* of tuples.
- Consider: *Find the age of the youngest sailor for each rating level.*
  - Suppose we know that rating values go from 1 to 10; we can write 10 queries that look like this (!):

For i = 1, 2, ... , 10:

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

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

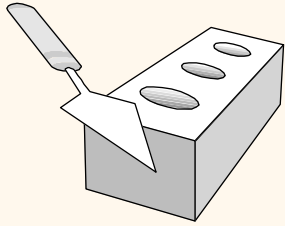
Queries With GROUP BY and HAVING



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

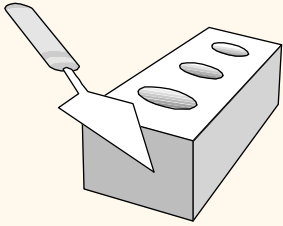
- The *target-list* contains (i) attribute names (ii) terms with aggregate operations (e.g., MIN (*S.age*)).
  - The attribute list (i) must be a subset of *grouping-list*. Intuitively, each answer tuple corresponds to a *group*, and these attributes must have a single value per group. (A *group* is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

Conceptual Evaluation



1. Compute the cross-product of *relation-list*.
2. Discard resulting tuples if they fail *qualifications*.
3. Delete attributes that are not in *target-list*.
4. The remaining tuples are partitioned into groups by the value of attributes in *grouping-list*.
5. The *group-qualification* is applied to eliminate some groups.
6. One answer tuple is generated per qualifying group.
7. If DISTINCT is specified, eliminate duplicate rows.

Find age and rating of the youngest sailor with age ≥ 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
```

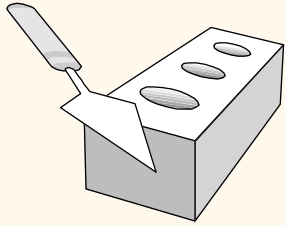
Answer relation:

rating	minage
3	25.5
7	35.0
8	25.5

Sailors instance:

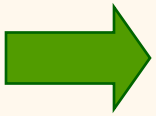
sid	sname	rating	age
22	dustin	7	45.0
29	brutus	1	33.0
31	lubber	8	55.5
32	andy	8	25.5
58	rusty	10	35.0
64	horatio	7	35.0
71	zorba	10	16.0
74	horatio	9	35.0
85	art	3	25.5
95	bob	3	63.5
96	frodo	3	25.5

- What if we do not have the condition age >18
- What if we only need the age

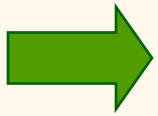


Find age of the youngest sailor with age ≥ 18, for each rating with at least 2 such sailors.

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

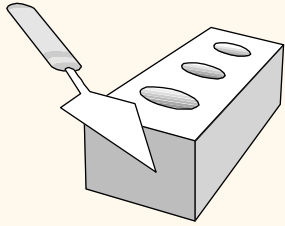


rating	age
1	33.0
3	25.5
3	63.5
3	25.5
7	45.0
7	35.0
8	55.5
8	25.5
9	35.0
10	35.0



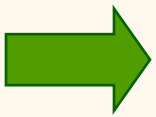
rating	minage
3	25.5
7	35.0
8	25.5

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

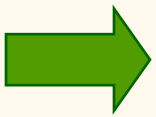


HAVING COUNT (*) > 1 AND EVERY (S.age <=60)

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

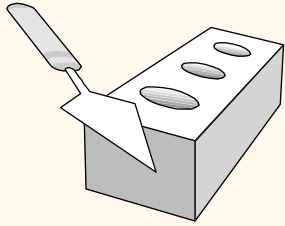


rating	age
1	33.0
3	25.5
3	63.5
3	25.5
7	45.0
7	35.0
8	55.5
8	25.5
9	35.0
10	35.0



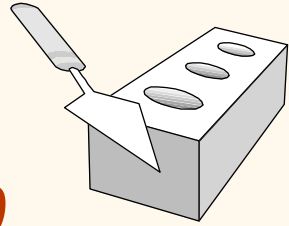
rating	minage
7	35.0
8	25.5

For each red boat, find the number of reservations for this boat



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

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



Find age of the youngest sailor with age ≥ 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
```

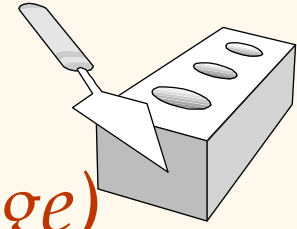
Answer relation:

rating	minage
3	25.5
7	35.0
8	25.5

Sailors instance:

sid	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

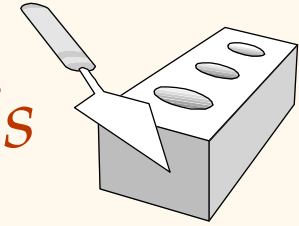
Find age of the youngest sailor with age > 18, for each rating with at least 2 sailors (of any age)



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