3. User Interfaces and SQL Language

(2/4)

Aggregate Operators

- Significant extension of relational algebra.
  - COUNT (*)
  - COUNT ([DISTINCT] A)
  - SUM ([DISTINCT] A)
  - AVG ([DISTINCT] A)
  - MAX (A)
  - MIN (A)
- *A* is single column

Examples of Aggregate Operators

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

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

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

```
SELECT  AVG (DISTINCT 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)
```

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, ... , 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
```

- 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 fact, 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 age 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
```

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

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 <u>such</u> 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

What is the result of changing EVERY to ANY?

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 (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  S2.rating = S.rating)
```

rating	minage
3	25.5
7	35.0
8	25.5
10	35.5

- Shows HAVING clause can also contain a sub-query.
- 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
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)
```

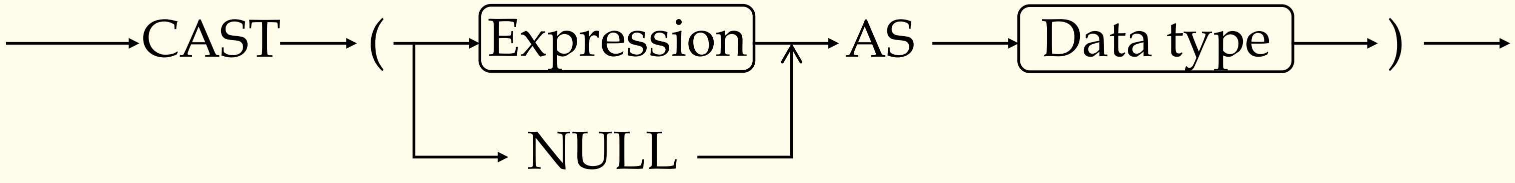
Null Values

- 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.

Some New Features of SQL

- **CAST expression**
- CASE expression
- Sub-query
- Outer Join
- Recursion

CAST Expression



- Change the expression to the target data type
- Valid target type
- Use
  - Match function parameters

    substr(string1, CAST(x AS Integer), CAST(y AS Integer))
  - Change precision while calculating

    CAST (elevation AS Decimal (5,0))
  - Assign a data type to NULL value

CAST Expression

- Example:

  Students (name, school)

  Soldiers (name, service)

```
CREATE VIEW prospects (name, school, service) AS
      SELECT name, school, CAST(NULL AS Varchar(20))
      FROM Students
UNION
      SELECT name, CAST(NULL AS Varchar(20)), service
      FROM Soldiers ;
```

Some New Features of SQL

- CAST expression
- **CASE expression**
- Sub-query
- Outer Join
- Recursion

CASE Expression

- Simple form :

  Officers (name, status, rank, title)

```
SELECT name, CASE status
                         WHEN 1 THEN ‘Active Duty’
                         WHEN 2 THEN ‘Reserve’
                         WHEN 3 THEN ‘Special Assignment’
                         WHEN 4 THEN ‘Retired’
                         ELSE ‘Unknown’
                   END AS status
FROM Officers ;
```

CASE Expression

- General form (use searching condition):

  Machines (serialno, type, year, hours_used, accidents)

- *Find the rate of the accidents of "chain saw" in the whole accidents :*

```
SELECT sum (CASE
                    WHEN type='chain saw' THEN accidents
                    ELSE 0e0
             END) / sum (accidents)
FROM Machines;
```

CASE Expression

- *Find the average accident rate of every kind of equipment :*

```
SELECT type, CASE
                        WHEN sum(hours_used)>0 THEN
                                  sum(accidents)/sum(hours_used)
                        ELSE NULL
                END AS accident_rate
FROM Machines
GROUP BY type;
```

(Because some equipments maybe not in use at all, their hours_used is 0. Use CASE can prevent the expression divided by 0.)

CASE Expression

- Compared with

```
SELECT type, sum(accidents)/sum(hours_used)
FROM Machines
GROUP BY type
HAVING sum(hours_used)>0;
```