SQL: Queries, Constraints, Triggers

Chapter 5

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Apache ResilientDB Incubating

ExpoLab Creativity Unfolded

Example Instances

R1

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

S1

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

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

- 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?

Basic SQL Query

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

- *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*.

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

S1

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

R1

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!

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

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

```
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!

INTERSECT: Can be used to compute the intersection of any two *union-compatible* sets of tuples.

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.
- Illustrates why, in general, sub-query 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, 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')
```

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))
```

Sailors S such that ...

there is no boat B without ...

a Reserves tuple showing S reserved B

Aggregate Operators

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

single column

- Significant extension of relational algebra.

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

```
SELECT  *
  FROM  S
WHERE column = (SELECT …  FROM  R)
```

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

```
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 $i = 1, 2, \ldots, 10$:

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

Queries With GROUP BY *and* HAVING

```
   SELECT  [DISTINCT]  attribute-list, aggregate operations
     FROM  relation-list
    WHERE  qualification
 GROUP BY  grouping-list
   HAVING  group-qualification
```

- 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*.)
- Terms with aggregate operations are of form MIN (*S.age*)), for example

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 <u>*single value per group*</u>!
  - 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 age of the youngest sailor with age ≥18, for each rating with at least 2 <u>such</u> 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 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

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: Example (SQL:1999)

```
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