BIRZEIT UNIVERSITY

Faculty of Engineering and Tecnology

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SQL

Chapter 5

SQL – Introduction

- Standard DML/DDL for relational DB’s
  - DML = “Data Manipulation Language” (queries, updates)
  - DDL = “Data Definition Language” (create tables, indexes, …)
- Also includes:
  - view definition
  - security
  - integrity constraints
  - transactions
- History:
  - System R project at IBM: “SEQUEL”
  - later, becomes standard: Structured Query Language

Banking Example

branch (branch-name, branch-city, assets)

customer (customer-name, customer-street, customer-other)

account (account-number, branch-name, balance)

loan (loan-number, branch-name, amount)

depositor (customer-name, account-number)

borrower (customer-name, loan-number)

A Simple SELECT-FROM-WHERE Query

bname	lno	amt
Downtown	L-170	3000
Redwood	L-230	4000
Perry	L-260	1700
Redwood	L-450	3000

```
SELECT  bname
FROM     loan
WHERE   amt > 1000
```

Similar to:

$$\pi_{\text{bname}} (\sigma_{\text{amt}>1000} \text{(loan)})$$

But not quite….

bname
Downtown
Redwood
Perry
Redwood

Duplicates are retained, i.e. result not a set

Why preserve duplicates?

- eliminating them is costly
- often, users don’t care
- can also write:

```
SELECT DISTINCT bname
FROM    loan
WHERE  amt> 1000
```

Another query

```
SELECT cname, balance
FROM     depositor, account
WHERE  depositor.acct_no = account.acct_no
```

depositor (customer-name, account-number)
account (account-number, branch-name, balance)

Similar to :

$$\pi_{\text{cname, balance}}\ (\text{depositor} \bowtie \text{account})$$

cname	balance
Johnson	500
Smith	400
Turner	350
Smith	300
Jones	240
Smith	300

Note: you can also write

```
SELECT cname, balance
FROM     depositor  AS d, account AS a
WHERE  d.acct_no = a.acct_no
```

In general

```
SELECT   A1, A2, …, An
FROM     r1, r2, …, rm
[WHERE  P]
```

- WHERE clause optional (missing WHERE clause means WHERE is true)

<u>Conceptual Algorithm:</u>

1. <u>FROM</u> clause: cartesian product (X)
   - $t1 \leftarrow r1 \text{ x } r2 \text{ x } \ldots \text{ x } rm$
2. <u>WHERE</u> clause: selection (s)
   - $t2 \leftarrow \sigma_{P} (t1)$
3. <u>SELECT</u> clause: projection (p)
   - $result \leftarrow \pi_{A1, A2, \ldots., An} \; (t2)$

Note: will never be implemented with product (X) !

The SELECT clause

equivalent to projection, despite name

can use “*” to get all attributes

e.g.,

```
SELECT *
FROM   loan
```

can write SELECT DISTINCT to eliminate duplicates

can write SELECT ALL to preserve duplicate (default)

can include arithmetic expressions

e.g.,
```
SELECT bname, acct_no, balance*1.05
FROM   account
```

The WHERE clause

- equivalent to selection, despite name…

- WHERE predicate can be:
  - Simple:

    attribute   relop attribute or constant

    (relop: <,>,=,£, ^{3}, ^{1})
  - Complex: using AND, OR, NOT, BETWEEN
- e.g.

```
SELECT lno
FROM     loan
WHERE  amt BETWEEN
                    9000 AND  10000
```

```
SELECT lno
FROM     loan
WHERE  amt >= 9000 AND  amt <= 10000
```

Formal Semantics of SQL

- RA can only express SELECT DISTINCT queries
- to express SQL, must extend to a bag algebra ,

a bag (aka: multiset) like sets, but can have duplicates

e.g. { 4, 5, 4, 6}

e.g.

balances =

cname	balance
Johnson	500
Smith	400
Turner	350
Smith	300
Jones	240
Smith	300

The FROM clause

- Equivalent to cartesian product (X)

(or ⋈ depending on the WHERE clause)

- binds tuples in relations to variable names
- e.g.: FROM borrower, loan
  - computes: borrower x loan
  - identifies borrower, loan columns (attrs) in the results

    e.g. allowing one to write:

    WHERE borrower.lno = loan.lno

```
FROM     borrower  b,  loan  l
WHERE  b.lno = l.lno
```

•Simplifies the expression
•Needed for self-joins

More SQL: Range variables

1. Using AS in FROM clause

introduces tuple variables

e.g.:

```
SELET DISTINCT T.bname
FROM  branch AS T, branch AS S
WHERE T.assets > S.assets
```

2. Using AS in SELECT clause

renames columns in result (ρ)

e.g.:

```
SELET bname, acct_no, balance*1.05 AS newbal
FROM  account
```

bname	acct_no	newbal
Downtown	A-170	450
Redwood	A-230	400

SQL - String Operations

- SQL includes a string-matching operator
- percent (%): zero or more characters.
- underscore (_): exactly one character.
- E.g. Find the names of all customers whose street includes the substring “Main”.

```
SELECT customer-name
FROM   customer
WHERE cstreet LIKE ‘%Main%’
```

- E.g. Find the names of all customers whose names begin with A and end with b and consists at least three characters.

```
SELECT customer-name
FROM   customer
WHERE customer-name  LIKE ‘A_%B’
```

More SQL: Set operations

Example Queries:

```
(SELECT cname FROM depositor)

?

(SELECT cname FROM borrower)
```

? = UNION

- returns names of customers with saving accts, loans, or both

? = INTERSECT

- returns names of customers with saving accts AND loans

? = EXCEPT

- returns names of customers with saving accts but NOT loans

Order by

Example: List in alphabetical order, the names of all customers with loans at Kenmore branch:

```
SELECT   DISTINCT cname
FROM      borrower b, loan l
WHERE    b.lno = l.lno  AND  bname = “Kenmore”
ORDER  BY  cname
```

Result:

cname
Adams
Byers
Smith
.....

can also write:

```
ORDER BY cname DESC   or
ORDER BY cname  ASC (default)
```

like SELECT DISTINCT, very expensive...

Aggregate Operators

- Aggregate Operators:

AVG (col): average of values in col
MIN (col) : minimum value in col
MAX (col): maximum value in col
SUM (col): sum of values in col
COUNT (col): number of values in col

Examples:

account (acct_no, bname, bal)

1. Find the average acct balance @ Perry:

```
SELECT AVG (bal)
FROM     account
WHERE  bname = “Perry”
```

2. Find the number of tuples in customer:

```
SELECT COUNT(*)
FROM  customer
```

3. Find the number of depositors

```
SELECT COUNT( DISTINCT cname)
FROM     depositor
```

COUNT, SUM, AVG
have a DISTINCT version

Aggregates and Group By

- Usually, aggregates used with "Group By"
- E.g.

```
SELECT      bname, COUNT (DISTINCT cname)
FROM         depositor d, account  a
WHERE       d.acct_no = a.acct_no
GROUP BY bname
```

depositor (customer-name, account-number)
account (account-number, branch-name, balance)

```
Result:    bname        COUNT
           --------------------------
           Downtown          2
           Mianus            5
           Perry             1
           Brighton          5
           Kenmore           7
```

Aggregates and Group By

Intuition behind “Group By”

```
SELECT      bname, COUNT (DISTINCT cname)
FROM         depositor d, account  a
WHERE       d.acct_no = a.acct_no
GROUP BY  bname
```

Step 1: “Group “ results of join

bname	a.acct_no	balance	cname	d.acct_no
Downtown	A-101	500	Johnson	A-101
Mianus	A-215	700	Smith	A-215
Perry	A-102	400	Hayes	A-102
Brighton	A-202	900	Johnson	A-202
Brighton	A-217	800	Jones	A-217
Kenmore	A-305	700	Smith	A-305
Kenmore	A-232	600	Lindsay	A-232

Step 2: aggregate on groups and project on result

```
bname        COUNT
--------------------------
Downtown          1
Mianus            1
Perry             1
Brighton           2
Kenmore            2
```

Group By

- Another example:

branch(bname, bcity, assets)

```
SELECT      bname, SUM(assets) as total
FROM        branch
GROUP BY  bcity
```

Result ??

bname	total
Redwood	2.1M
Pownal	0.3M
N. Town	3.7M
????	2M
?????	10.1M

Above query is NOT allowed

Non-aggregated values in SELECT clause (e.g., bname) must also appear in GROUP BY clause

```
SELECT     A1, A2, ..., Ak, Agg1(), ...., Aggi()
FROM         ..........
WHERE      ...........
GROUP BY A1, A2, ..., Ak, Ak+1, ..., An
```

HAVING

WHERE :: FROM as HAVING :: GROUP BY

- HAVING P: selects rows from result of GROUP BY
- Optional (missing HAVING means TRUE)

Example: Find names of branches and the average account balance for those branches having average account balance > $1200

```
SELECT  bname, AVG(balance) AS avg
FROM    account
GROUP BY bname
HAVING  avg > 1200
```

NULLs

can be a value for any attribute

e.g. :

branch2=

bname	bcity	assets
Downtown	Boston	9M
Perry	Horse	1.7M
Mianus	Horse	.4M
Kenmore	Boston	NULL

What does this mean?

- We don’t know Kenmore’s assets?
- Kenmore has no assets?
- ....

Effect on Queries:

SELECT * FROM branch2
WHERE assets = NULL

bname	bcity	assets

SELECT * FROM branch2
WHERE assets IS NULL

bname	bcity	assets
Kenmore	Boston	NULL

NULLs

- Arithmetic with nulls:
  - n op null = null

    op : + , - , *, /

```
SELECT   ..........
FROM     ............
WHERE boolexpr IS UNKNOWN
```

- Booleans with nulls: One can write:

3-valued logic (true, false, unknown)

What expressions evaluate to UNKNOWN?

1. Comparisons with NULL (e.g. assets = NULL)
2. FALSE OR UNKNOWN (but: TRUE OR UNKNOWN = TRUE)
3. TRUE AND UNKNOWN
4. UNKNOWN AND/OR UNKNOWN

NULLs

Given:

branch2=

bname	bcity	assets
Downtown	Boston	9M
Perry	Horse	1.7M
Mianus	Horse	.4M
Kenmore	Boston	NULL

Aggregate operations:

```
SELECT SUM(assets)
FROM   branch2
```

returns →

```
SUM
--------
11.1M
```

NULL is ignored
Same for AVG, MIN, MAX

But.... COUNT(assets) retunrs 4!

Let branch3 an empty relation

```
Then:   SELECT SUM(assets)
        FROM   branch3        returns     NULL
```

but COUNT(<empty rel>) = 0

Review - Summary

account (acct_no, bname, balance)
branch(bname, bcity, assets)

```
SELECT      bcity, sum(balance) AS totalbalance
FROM        branch b, account a
WHERE       b.bname=a.bname  AND assets >= 1M
GROUP BY  bcity
HAVING      totalbalance > 700
ORDER BY  bcity DESC
```

Steps 1,2 : FROM, WHERE

b.bname	bcity	assets	a.bname	acct_no	balance
Downtown	Bkln	9M	Downtown	A-101	500
Redwood	Palo Alto	2.1M	Redwood	A-215	700
Perry	Horse	1.7M	Perry	A-102	400
RH	Horse	8M	RH	A-202	350
Brighton	Bkln	7.1M	Brighton	A-305	900
Brighton	Bkln	7.1M	Brighton	A-217	750

Summary thus far

Steps 3,4 : GROUP BY, SELECT

bcity	totalbalance
Bkln	2150
Palo Alto	700
Horse	750

Steps 5 : HAVING

bcity	totalbalance
Bkln	2150
Horse	750

Steps 6 : ORDER BY

bcity	totalbalance
Horse	750
Bkln	2150

Summary thus far

Clause	Evaluation Order	Semantics (RA)
-----------	-----------	----------
SELECT[DISTINCT]	4	π
FROM	1	X
WHERE	2	σ
INTO	7	←
GROUP BY	3	Can’t express
HAVING	5	σ
ORDER BY	6	Can’t express

Find sailors who’ ve reserved at least one boat

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

- **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 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).**

```
SELECT R.sid
   FROM Boats B,Reserves R
WHERE R.bid=B.bid AND
(B.color=‘red’OR B.color=‘green’)
```

Vs.

```
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’
```

Find sid’s of sailors who’ve reserved a red but did not reserve 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’
EXCEPT
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 the sailors who are older than any sailor named Ahmad ordered in descending

```
Select *
From Sailor s
Where s.age > (     select s2.age
                     from sailor s2
                     where s2.sname LIKE ‘Ahmad%’)
ORDER BY sname DESC, age ASC
```

- *Find the average age of sailors with a rating of 10.*
-

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

Find the name and age of the oldest sailor

- (S.age)

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

- If the SELECT clause uses aggregate operators, then it must use only aggregate operators unless the query contains a GROUP BY clause

Find the names of sailors who are older than the oldest sailor with a rating of 10.

```
SELECT S.sname
FROM Sailors S
WHERE S.age > ( SELECT MAX ( S2.age ) FROM Sailors S2
                WHERE S2.rating = 10 )
```

Find the age of the youngest sailor for each rating level

- SELECT s.rating, MIN(s.age)
- FROM sailors s
- GROUP BY s.rating

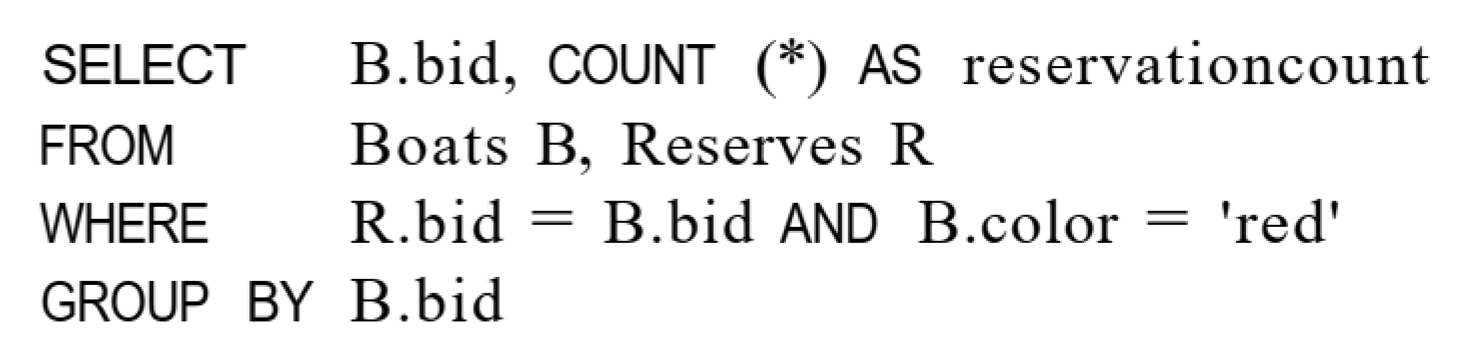
Find the age of the youngest sailor who is eligible to vote (i.e., is at least 18 years old) for each rating level with at least two such sailors.

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

How this query evaluated

1. Cross-product for tables in from-list
2. Apply WHERE
3. Eliminate unwanted columns not mentioned in select-list
4. Sort the table according to GROUP BY clause
5. Apply HAVING
6. Apply aggregate operators

Find number of reservations for each red boat



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

```
SELECT                              AS reservationcount
FROM                                R
WHERE
GROUP BY
HAVING
```