#### SQL QUERIES

CS121: Relational Databases Fall 2018 – Lecture 5

#### **SQL** Queries

- □ SQL queries use the SELECT statement
- General form is:
  - SELECT  $A_1$ ,  $A_2$ , ... FROM  $r_1$ ,  $r_2$ , ... WHERE P;
  - $\square$   $r_i$  are the relations (tables)
  - A<sub>i</sub> are attributes (columns)
  - P is the selection predicate
- $\Box$  Equivalent to:  $\Pi_{A_1, A_2, \dots}(\sigma_P(r_1 \times r_2 \times \dots))$

#### **Ordered Results**

- SQL query results can be ordered by particular attributes
- Two main categories of query results:
  - "Not ordered by anything"
    - Tuples can appear in any order
  - "Ordered by attributes A<sub>1</sub>, A<sub>2</sub>, ..."
    - Tuples are sorted by specified attributes
    - Results are sorted by A<sub>1</sub> first
    - Within each value of  $A_1$ , results are sorted by  $A_2$
    - etc.
- Specify an ORDER BY clause at end of SELECT statement

# Ordered Results (2)

4

□ Find bank accounts with a balance under \$700:

SELECT account\_number, balance
FROM account
WHERE balance < 700;</pre>

- Order results in increasing order of bank balance:
  - SELECT account\_number, balance
    FROM account
    WHERE balance < 700
    ORDER BY balance;</pre>

Default order is ascending order

+	++
account_number	balance
A-102   A-101   A-444   A-305	400.00     500.00     625.00     350.00
+	++

+	++
account_number	balance
A-305	350.00
A-102	400.00
A-101	500.00
A-444	625.00
+	++

## Ordered Results (3)

- 5
- Say ASC or DESC after attribute name to specify order
  - **ASC** is redundant, but can improve readability in some cases
- □ Can list multiple attributes, each with its own order
  - "Retrieve a list of all bank branch details, ordered by branch city, with each city's branches listed in reverse order of holdings."
    - SELECT \* FROM branch
      - ORDER BY branch\_city ASC, assets DESC;

+		++
branch_name	branch_city	assets
Pownal	Bennington	400000.00
Brighton	Brooklyn	7000000.00
Downtown	Brooklyn	900000.00
Round Hill	Horseneck	8000000.00
Perryridge	Horseneck	1700000.00
Mianus	Horseneck	400200.00
Redwood	Palo Alto	2100000.00
	•••	

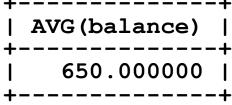
## Aggregate Functions in SQL

- SQL provides grouping and aggregate operations, just like relational algebra
- Aggregate functions:
  - **SUM** sums the values in the collection
  - **AVG** computes average of values in the collection
  - **COUNT** counts number of elements in the collection
  - MIN returns minimum value in the collection
  - **MAX** returns maximum value in the collection
- SUM and AVG require numeric inputs (obvious)

#### Aggregate Examples

7

Find average balance of accounts at Perryridge branch SELECT AVG(balance) FROM account WHERE branch\_name = 'Perryridge';



Find maximum amount of any loan in the bank
 SELECT MAX (amount) AS max\_amt FROM loan;
 Can name computed values, like usual
 max\_amt |
 7500.00 |

# Aggregate Examples (2)

- This query produces an error: SELECT branch\_name, MAX(amount) AS max\_amt FROM loan;
- Aggregate functions compute a single value from a multiset of inputs
  - Doesn't make sense to combine individual attributes and aggregate functions like this
- □ This does work:

## **Eliminating Duplicates**

- Sometimes need to eliminate duplicates in SQL queries
  - Can use DISTINCT keyword to eliminate duplicates
- Example:
  - "Find the number of branches that currently have loans." SELECT COUNT (branch\_name) FROM loan;
  - Doesn't work, because branches may have multiple loans
  - Instead, do this:
    - SELECT COUNT(DISTINCT branch\_name) FROM loan;
  - Duplicates are eliminated from input multiset before aggregate function is applied

## **Computing Counts**

Can count individual attribute values COUNT (branch\_name) COUNT (DISTINCT branch name)

- Can also count the total number of tuples COUNT (\*)
  - If used with grouping, counts total number of tuples in each group
  - If used without grouping, counts total number of tuples
- Counting a specific attribute is useful when:
  - Need to count (possibly distinct) values of a particular attribute
  - Cases where some values in input multiset may be NULL
    - As before, COUNT ignores NULL values (more on this next week)

## Grouping and Aggregates

Can also perform grouping on a relation before computing aggregates

□ Specify a GROUP BY A<sub>1</sub>, A<sub>2</sub>, . . . clause at end of query

Example:

"Find the average loan amount for each branch."

SELECT branch\_name, AVG(amount) AS avg\_amt
FROM loan GROUP BY branch\_name;

- First, tuples in loan are grouped by branch\_name
- Then, aggregate functions are applied to each group

branch_name	avg_amt
Central     Downtown     Mianus     North Town     Perryridge     Redwood     Round Hill	570.000000   1250.000000   500.000000   7500.000000   1400.000000   2000.000000   900.000000

# Grouping and Aggregates (2)

#### Can group on multiple attributes

Each group has unique values for the entire set of grouping attributes

#### Example:

- "How many accounts does each customer have at each branch?"
- Group by both customer name and branch name
- Compute count of tuples in each group
- Can write the SQL statement yourself, and try it out

# Grouping and Aggregates (3)

- Note the difference between relational algebra notation and SQL syntax
- Relational algebra syntax:
  - G<sub>1</sub>, G<sub>2</sub>, ..., G<sub>n</sub>G<sub>F1(A1)</sub>, F<sub>2(A2)</sub>, ..., F<sub>m(Am)</sub>(E) Grouping attributes only appear on left of G
- SQL syntax:
  - SELECT  $G_1, G_2, ..., F_1(A_1), F_2(A_2), ...$ FROM  $r_1, r_2, ...$  WHERE P GROUP BY  $G_1, G_2, ...$
  - Frequently, grouping attributes are specified in both the SELECT clause and GROUP BY clause

# Grouping and Aggregates (4)

- SQL doesn't <u>require</u> that you specify the grouping attributes in the SELECT clause
  - Only requirement is that the grouping attributes are specified in the GROUP BY clause
  - e.g. if you only want the aggregated results, could do this: SELECT  $F_1(A_1)$ ,  $F_2(A_2)$ , ...

FROM  $r_1, r_2, \ldots$  WHERE P

GROUP BY  $G_1, G_2, \ldots$ 

□ Also, can use expressions for grouping and aggregates

Example (very uncommon, but also valid): SELECT MIN(a + b) - MAX(c) FROM t GROUP BY d \* e;

## Filtering Tuples

- The WHERE clause is applied before any grouping occurs
  - SELECT  $G_1, G_2, ..., F_1(A_1), F_2(A_2), ...$ FROM  $r_1, r_2, ...$  WHERE P GROUP BY  $G_1, G_2, ...$
  - Translates into relational algebra expression: Π...(<sub>G1, G2</sub>, ..., G<sub>F1(A1)</sub>, F2(A2), ... (σP(r1 × r2 × ...)))
     A WHERE clause constrains the set of tuples that

grouping and aggregation are applied to

### Filtering Results

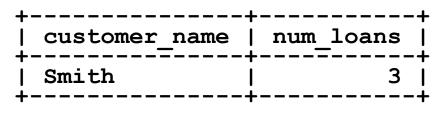
- To apply filtering to the results of grouping and aggregation, use a HAVING clause
  - Exactly like WHERE clause, except applied after grouping and aggregation
  - SELECT  $G_1, G_2, \ldots, F_1(A_1), F_2(A_2), \ldots$ FROM  $r_1, r_2, \ldots$  WHERE  $P_W$ GROUP BY  $G_1, G_2, \ldots$ HAVING  $P_H$

Translates into:

 $\Pi_{...}(\sigma_{\mathsf{P}_{\mathsf{H}}}(\sigma_{\mathsf{G}_{1},\mathsf{G}_{2},...}\mathcal{G}_{F_{1}(\mathsf{A}_{1}),F_{2}(\mathsf{A}_{2}),...}(\sigma_{\mathsf{P}_{\mathsf{W}}}(r_{1}\times r_{2}\times ...))))$ 

### The HAVING Clause

- The HAVING clause can use aggregate functions in its predicate
  - It's applied after grouping/aggregation, so those values are available
  - The WHERE clause cannot do this, of course
- Example:
  - "Find all customers with more than one loan."
    - SELECT customer\_name, COUNT(\*) AS num\_loans
      FROM borrower GROUP BY customer\_name
      HAVING COUNT(\*) > 1;



#### **Nested Subqueries**

- SQL provides broad support for nested subqueries
  - A SQL query is a "select-from-where" expression
  - Nested subqueries are "select-from-where" expressions embedded within another query
- □ Can embed queries in WHERE clauses
  - Sophisticated selection tests
- Can embed queries in FROM clauses
  - Issuing a query against a derived relation
- □ Can even embed queries in SELECT clauses!
  - Appeared in SQL:2003 standard; many DBs support this
  - Makes many queries easier to write, but can be slow too

### Kinds of Subqueries

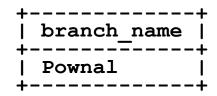
- Some subqueries produce only a single result SELECT MAX(assets) FROM branch;
  - Called a <u>scalar subquery</u>
  - Still a relation, just with one attribute and one tuple
- Most subqueries produce a relation containing multiple tuples
  - Nested queries often produce relation with single attribute
    - Very common for subqueries in WHERE clause
  - Nested queries can also produce multiple-attribute relation
    - Very common for subqueries in FROM clause
    - Can also be used in the WHERE clause in some cases

## Subqueries in WHERE Clause

- □ Widely used:
  - Direct comparison with scalar-subquery results
  - Set-membership tests: IN, NOT IN
  - Empty-set tests: EXISTS, NOT EXISTS
- Less frequently used:
  - Set-comparison tests: ANY, SOME, ALL
  - Uniqueness tests: UNIQUE, NOT UNIQUE
- (Can also use these in the HAVING clause)

#### Comparison with Subquery Result

- Can use scalar subqueries in WHERE clause comparisons
- Example:
  - Want to find the name of the branch with the smallest number of assets.
  - Can easily find the smallest number of assets: SELECT MIN(assets) FROM branch;
  - This is a scalar subquery; can use it in WHERE clause: SELECT branch\_name FROM branch WHERE assets = (SELECT MIN(assets) FROM branch);



## Set Membership Tests

- Can use IN (...) and NOT IN (...) for set membership tests
- Example:
  - Find customers with both an account and a loan.
  - Before, did this with a INTERSECT operation

Can also use a set-membership test:
 "Select all customer names from depositor relation, that also appear somewhere in borrower relation."
 SELECT DISTINCT customer\_name FROM depositor
 WHERE customer\_name IN (
 SELECT customer name FROM borrower)

DISTINCT necessary because a customer might appear multiple times in depositor

# Set Membership Tests (2)

- 23
- IN (...) and NOT IN (...) support subqueries that return multiple columns (!!!)
- Example: "Find the ID of the largest loan at each branch, including the branch name and the amount of the loan."
  - First, need to find the largest loan at each branch SELECT branch\_name, MAX(amount)
     FROM loan GROUP BY branch\_name
  - Use this result to identify the rest of the loan details SELECT \* FROM loan
    - WHERE (branch\_name, amount) IN (
       SELECT branch\_name, MAX(amount)
       FROM loan GROUP BY branch\_name);

### **Empty-Set Tests**

- Can test whether or not a subquery generates any results at all
  - EXISTS (...)
  - NOT EXISTS (...)
- Example:
  - "Find customers with an account but not a loan."
    - SELECT DISTINCT customer\_name FROM depositor d WHERE NOT EXISTS (
      - SELECT \* FROM borrower b
      - WHERE b.customer\_name = d.customer\_name);
  - Result includes every customer that appears in depositor table, that doesn't also appear in the borrower table.

# Empty-Set Tests (2)

25

"Find customers with an account but not a loan."
 SELECT DISTINCT customer\_name FROM depositor d
 WHERE NOT EXISTS (
 SELECT \* FROM borrower b
 WHERE b.customer\_name = d.customer\_name);
 Inner query refers to an attribute in outer query's relation

- In general, nested subqueries can refer to enclosing queries' relations.
- However, enclosing queries cannot refer to the nested queries' relations.

#### **Correlated Subqueries**

26

"Find customers with an account but not a loan."
 SELECT DISTINCT customer\_name FROM depositor d
 WHERE NOT EXISTS (
 SELECT \* FROM borrower b
 WHERE b.customer\_name = d.customer\_name);

- When a nested query refers to an enclosing query's attributes, it is a <u>correlated subquery</u>
  - The inner query must be evaluated once for each tuple considered by the enclosing query
  - Generally to be avoided! Very slow.

# Correlated Subqueries (2)

- Many correlated subqueries can be restated using a join or a Cartesian product
  - Often the join operation will be much faster
  - More advanced DBMSes will automatically decorrelate such queries, but some can't...
- Certain conditions, e.g. EXISTS/NOT EXISTS, usually indicate presence of a correlated subquery
- □ If it's easy to decorrelate the subquery, do that! ☺
- □ If not, test the query for its performance.
  - If the database can decorrelate it, you're done!
  - If the database can't decorrelate it, may need to come up with an alternate formulation.

### Set Comparison Tests

- Can compare a value to a set of values
  - Is a value larger/smaller/etc. than some value in the set?
- Example:

"Find all branches with assets greater than at least one branch in Brooklyn."

SELECT branch\_name FROM branch
WHERE assets > SOME (
 SELECT assets FROM branch
 WHERE branch\_name='Brooklyn');

# Set Comparison Tests (2)

#### General form of test:

- attr compare\_op SOME ( subquery )
- Can use any comparison operation
  - = SOME is same as IN
- **ANY** is a synonym for **SOME**
- Can also compare a value with all values in a set
  - Use ALL instead of SOME
    - <> ALL is same as NOT IN

## Set Comparison Tests (3)

#### Example:

"Find branches with assets greater than all branches in Brooklyn." SELECT branch\_name FROM branch WHERE assets > <u>ALL</u> ( SELECT assets FROM branch WHERE branch\_name='Brooklyn');

Could also write this with a scalar subquery

SELECT branch\_name FROM branch

WHERE assets >

(SELECT MAX(assets) FROM branch

WHERE branch name='Brooklyn');

#### Uniqueness Tests

- Can test whether a nested query generates any duplicate tuples
  - □ UNIQUE (...)
  - **D**NOT UNIQUE  $(\ldots)$
- Not widely implemented
  - Expensive operation!
- Can emulate in a number of ways
  - GROUP BY ... HAVING COUNT(\*) = 1 or GROUP BY ... HAVING COUNT(\*) > 1 is one approach

## Subqueries in FROM Clause

- Often need to compute a result in multiple steps
- Can query against a subquery's results
  - Called a <u>derived relation</u>
- □ A trivial example:
  - A HAVING clause can be implemented as a nested query in the FROM clause

#### HAVING vs. Nested Query

33

"Find all cities with more than two customers living in the city."

SELECT customer\_city, COUNT(\*) AS num\_customers
FROM customer GROUP BY customer\_city
HAVING COUNT(\*) > 2;

Or, can write:

SELECT customer\_city, num\_customers
FROM (SELECT customer\_city, COUNT(\*)
 FROM customer GROUP BY customer\_city)
 AS counts (customer\_city, num\_customers)
WHERE num\_customers > 2;

Grouping and aggregation is computed by inner query

Outer query selects desired results generated by inner query

### **Derived Relation Syntax**

- 34
- Subquery in FROM clause must be given a name
  - Many DBMSes also require attributes to be named SELECT customer\_city, num\_customers FROM (SELECT customer\_city, COUNT(\*) FROM customer GROUP BY customer\_city) <u>AS counts</u> (customer\_city, num\_customers) WHERE num\_customers > 2;
  - Nested query is called counts, and specifies two attributes
  - Syntax varies from DBMS to DBMS...
    - MySQL requires a name for derived relations, but doesn't allow attribute names to be specified.

#### **Using Derived Relations**

- More typical is a query against aggregate values
- **Example:**

"Find the largest total account balance of any branch."

Need to compute total account balance for each branch first. SELECT branch\_name, SUM(balance) AS total\_bal FROM account GROUP BY branch name;

Then we can easily find the answer: SELECT MAX(total\_bal) AS largest\_total FROM (SELECT branch\_name, SUM(balance) AS total\_bal FROM account GROUP BY branch\_name) AS totals (branch\_name, tot\_bal);

# Aggregates of Aggregates

<u>Always</u> take note when computing aggregates of aggregates!

"Find the largest total account balance of any branch."

- Two nested aggregates: max of sums
- □ A very common mistake:
  - SELECT branch\_name, SUM(balance) AS tot\_bal
    FROM account GROUP BY branch\_name
    HAVING tot bal = MAX(tot bal)
  - A SELECT query can only perform <u>one</u> level of aggregation
  - Need a second SELECT to find the maximum total
  - Unfortunately, MySQL accepts this and returns bogus result

#### More Data Manipulation Operations

- SQL provides many other options for inserting, updating, and deleting tuples
- All commands support SELECT-style syntax
- Can insert individual tuples into a table: INSERT INTO table VALUES (1, 'foo', 50);
- Can also insert the result of a query into a table: INSERT INTO table SELECT ...;
  - Only constraint is that generated results must have a compatible schema

## **Deleting Tuples**

- SQL DELETE command can use a WHERE clause DELETE FROM table;
  - Deletes all rows in the table
  - DELETE FROM table WHERE ...;
  - Only deletes rows that satisfy the conditions
  - The WHERE clause can use anything that SELECT's WHERE clause supports
    - Nested queries, in particular!

## **Updating Tables**

- SQL also has an UPDATE command for modifying existing tuples in a table
- General form:
  - UPDATE table

```
SET attr1=val1, attr2=val2, ...
```

```
WHERE condition;
```

- Must specify the attributes to update
- Attributes being modified *must* appear in table being updated (obvious)
- The WHERE clause is optional! If unspecified, all rows are updated.
- **WHERE** condition can contain nested queries, etc.

# Updating Tables (2)

- Values in UPDATE can be arithmetic expressions
  - Can refer to any attribute in table being updated
- Example:
  - Add 2% interest to all bank account balances with a balance of \$500 or less.

```
UPDATE account
SET balance = balance * 1.02
WHERE balance <= 500;
```

#### Next Time

NULL values in SQL

#### Additional SQL join operations

- Natural join
- Outer joins
- SQL views