

SQL QUERIES

CS121: Introduction to Relational Database Systems
Fall 2016 – Lecture 5

SQL Queries

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- SQL queries use the **SELECT** statement

- General form is:

```
SELECT  $A_1, A_2, \dots$   
      FROM  $r_1, r_2, \dots$   
      WHERE  $P;$ 
```

- r_i are the relations (tables)
 - A_i are attributes (columns)
 - P is the selection predicate
- Equivalent to: $\Pi_{A_1, A_2, \dots}(\sigma_P(r_1 \times r_2 \times \dots))$

Ordered Results

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- 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_1, A_2, \dots ”
 - Tuples are sorted by specified attributes
 - Results are sorted by A_1 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)

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

```
SELECT account_number, balance
FROM account
WHERE balance < 700;
```

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

- Order results in increasing order of bank balance:

```
SELECT account_number, balance
FROM account
WHERE balance < 700
ORDER BY balance;
```

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

- Default order is ascending order

Ordered Results (3)

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- 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

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- 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

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- Find average balance of accounts at Perryridge branch

```
SELECT AVG(balance) FROM account
WHERE branch_name = 'Perryridge';
```

+	-----	+
	AVG(balance)	
+	-----	+
	650.000000	
+	-----	+

- 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)

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- 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:

```
SELECT MIN(amount) AS min_amt,  
       MAX(amount) AS max_amt  
FROM loan;
```

+	-----+	-----+
	min_amt	max_amt
+	-----+	-----+
	500.00	7500.00
+	-----+	-----+

Eliminating Duplicates

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- 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

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- 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

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- Can also perform grouping on a relation before computing aggregates
 - ▣ Specify a **GROUP BY A_1, A_2, \dots** 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	570.000000
Downtown	1250.000000
Mianus	500.000000
North Town	7500.000000
Perryridge	1400.000000
Redwood	2000.000000
Round Hill	900.000000

Grouping and Aggregates (2)

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- 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)

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- Note the difference between relational algebra notation and SQL syntax

- Relational algebra syntax:

$$G_1, G_2, \dots, G_n \mathcal{G}_{F_1(A_1), F_2(A_2), \dots, F_m(A_m)}(E)$$

- ▣ Grouping attributes only appear on left of \mathcal{G}

- SQL syntax:

SELECT $G_1, G_2, \dots, F_1(A_1), F_2(A_2), \dots$
FROM r_1, r_2, \dots **WHERE** P
GROUP BY G_1, G_2, \dots

- ▣ Frequently, grouping attributes are specified in both the **SELECT** clause and **GROUP BY** clause

Grouping and Aggregates (4)

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- SQL doesn't require 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     $r_1, r_2, \dots$  WHERE P  
GROUP BY  $G_1, G_2, \dots$ 
```
- 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

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- The **WHERE** clause is applied *before* any grouping occurs

```
SELECT   $G_1, G_2, \dots, F_1(A_1), F_2(A_2), \dots$   
FROM     $r_1, r_2, \dots$  WHERE P  
GROUP BY  $G_1, G_2, \dots$ 
```

- ▣ Translates into relational algebra expression:

$$\Pi_{\dots(G_1, G_2, \dots)} \mathcal{G}_{F_1(A_1), F_2(A_2), \dots} (\sigma_P(r_1 \times r_2 \times \dots))$$

- ▣ A **WHERE** clause constrains the set of tuples that grouping and aggregation are applied to

Filtering Results

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- 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  $G_1, G_2, \dots, F_1(A_1), F_2(A_2), \dots$   
FROM  $r_1, r_2, \dots$  WHERE  $P_W$   
GROUP BY  $G_1, G_2, \dots$   
HAVING  $P_H$ 
```

- ▣ Translates into:

$$\Pi_{\dots}(\sigma_{P_H}(G_1, G_2, \dots G_{F_1(A_1), F_2(A_2), \dots}(\sigma_{P_W}(r_1 \times r_2 \times \dots))))$$

The HAVING Clause

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- 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;
```

customer_name	num_loans
Smith	3

Nested Subqueries

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- 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

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- Some subqueries produce only a single result
`SELECT MAX(assets) FROM branch;`
 - ▣ Called a scalar subquery
 - ▣ 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

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- 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

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- 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);`

```
+-----+  
| branch_name |  
+-----+  
| Pownal      |  
+-----+
```

Set Membership Tests

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- 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)

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- **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

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- 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)

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“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

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“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 correlated subquery
 - ▣ The inner query must be evaluated once *for each tuple* considered by the enclosing query
 - ▣ Generally to be avoided! *Very slow.*

Correlated Subqueries (2)

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- 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

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- 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)

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- 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)

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□ Example:

“Find branches with assets greater than *all* branches in Brooklyn.”

```
SELECT branch_name FROM branch
WHERE assets > ALL (
    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

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- Can test whether a nested query generates any duplicate tuples
 - ▣ **UNIQUE (...)**
 - ▣ **NOT UNIQUE (...)**
- 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

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

HAVING vs. Nested Query

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“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

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- 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)
      AS counts (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

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- 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

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- Always 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 one level of aggregation
- Need a second **SELECT** to find the maximum total
- Unfortunately, MySQL accepts this and returns bogus result

More Data Manipulation Operations

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- 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

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- 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

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- 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)

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- 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;
```


Review

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- SQL query syntax is *very* rich
 - ▣ Can state a wide range of complex queries
 - ▣ Many ways to state a particular query
- SQL supports nested queries
 - ▣ Often essential for computing particular results
 - ▣ Can sometimes be *very* inefficient
- SQL also provides similar capability for inserting, deleting, and updating tables

Next Time

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- **NULL** values in SQL
- Additional SQL join operations
 - ▣ Natural join
 - ▣ Outer joins
- SQL views