Query Language and Groupings

Aggregate Operators and SQL Clauses

Computer Science - IIS Fermi Sacconi Ceci

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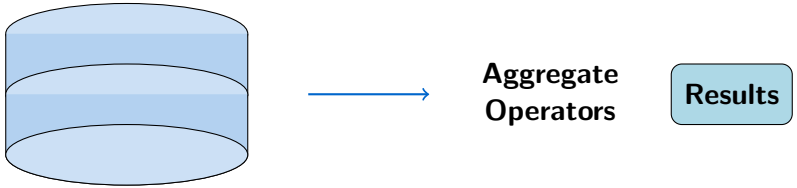

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Aggregate Operators

SQL Extension

Compared to relational algebra, the most important extension introduced by SQL is that of **aggregate operators**.

Main characteristics:

- Aggregate multiple table rows
- Perform operations at *relation* level, not tuple level
- Return a **single aggregate value**
- Do not select a subset of rows, but calculate values

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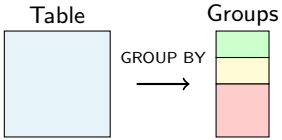
Aggregate Operators

Functionality

Aggregation operations allow you to:

- **Group** tuples
- Perform **specific calculations** (sums, counts, statistics)
- **Divide** the table into subsets
- Group tuples with **same values** for specific attributes



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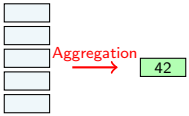
Aggregate Operators

Fundamental difference

Aggregation operators, unlike mathematical operators that act only on the tuple being processed:

Can be applied to multiple tuples of the table and are characterized by:

- Returning a **unique value**
- Operating on a **group of values**
- Working on values that form a **column**



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Aggregate Operators

Main aggregation operators

`AVG(field)` Calculates the **arithmetic mean**

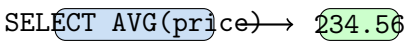
`COUNT(expr|*)` **Counts** rows

`MAX(expr)` Calculates the **maximum** value

`MIN(expr)` Calculates the **minimum** value

`SUM(field)` Calculates the **total sum**

`STDDEV(field)` Calculates the **standard deviation**



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Aggregate Operators

GROUP BY Clause

Specifies which fields to perform groupings on.

Important

Aggregate operators can only appear after these clauses:

- `SELECT`
- `HAVING`

```
SELECT category, COUNT(*) AS number
FROM products
GROUP BY category;
```


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The HAVING Clause

How it works

The `HAVING` clause allows you to insert a constraint on the data resulting from the `GROUP BY` grouping operation.

Difference with WHERE:

- `WHERE` operates on **database fields** (before grouping)
- `HAVING` operates on **fields resulting from groupings** (after)

```
SELECT department, AVG(salary) AS average
FROM employees
GROUP BY department
HAVING AVG(salary) > 30000;
```

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COUNT Operator

Syntax

```
COUNT(expression | *)
```

```
SELECT COUNT(*) AS total_cars
FROM cars;
```

total_cars
12

Note: `COUNT(*)` counts all rows, including duplicates.

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COUNT Operator

Result

The result is **12**: all records that make up the table and are not NULL are counted, regardless of their content.

Important

`COUNT` is the only aggregation operator that considers null values in the calculation.

To count distinct values:

```
SELECT COUNT(DISTINCT brand) AS
   different_brands
FROM cars;
```

different_brands
8

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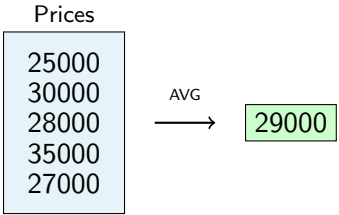
AVG Operator

Arithmetic Mean

Calculates the average of values in a numeric column.

```sql
SELECT AVG(price) AS average_price
FROM cars;
```



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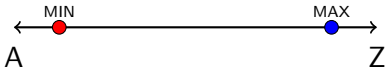
MIN and MAX Operators

How they work

`MAX` and `MIN` return the highest and lowest values contained within a column.

Behavior by data type:

- **Numeric fields:** returns the numeric value
- **Text fields:** identifies the field that, in alphabetical order, is last (MAX) or first (MIN)
- Ordering according to the **ASCII** code table
- **Lexicographic** ordering



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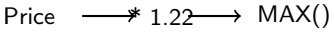
MIN and MAX Operators

Mathematical expressions

It is possible to use mathematical expressions as arguments for the `MIN` and `MAX` operators.

```
SELECT MAX(price * 1.22) AS max_price_vat
FROM cars;
```

```
SELECT MIN(price - discount) AS
   min_price_discounted
FROM cars;
```



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MIN and MAX Operators

```sql
SELECT MIN(salary) AS minimum_salary
FROM employees;
```

Name	Salary
Mario Rossi	28000
Laura Bianchi	32000
Giuseppe Verdi	**25000**
Anna Neri	35000

minimum_salary
25000

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MIN and MAX Operators

```sql
SELECT MAX(salary) AS maximum_salary
FROM employees;
```

Name	Salary
Mario Rossi	28000
Laura Bianchi	32000
Giuseppe Verdi	25000
Anna Neri	**35000**

maximum_salary
35000

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MIN and MAX Operators

```sql
SELECT MAX(surname) AS max_surname
FROM employees;
```

Surname
Bianchi
Neri
Rossi
Verdi

max_surname
Verdi

Alphabetical order: B ¡ N ¡ R ¡ V

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MIN and MAX Operators

```sql
SELECT MIN(surname) AS min_surname
FROM employees;
```

Surname
Bianchi
Neri
Rossi
Verdi

min_surname
Bianchi

Alphabetical order: B ¡ N ¡ R ¡ V

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MIN and MAX Operators

Complex expressions

Let's see how to apply arithmetic operators in the query. To know the difference between minimum and maximum employee salaries, expressed as a percentage:

```
SELECT
(MAX(salary) - MIN(salary)) /
MAX(salary) * 100 AS percentage_diff
FROM employees;
```

percentage_diff
28.57

The difference between maximum and minimum salary is 28.57%

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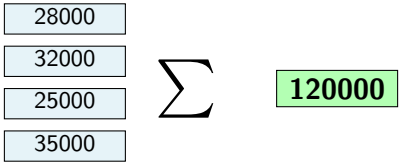
SUM Operator

Total sum

Calculates the sum of all values in a numeric column.

```sql
SELECT SUM(salary) AS total_salaries
FROM employees;
```



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SUM Operator

```sql
SELECT
SUM(amount) AS total_sales,
SUM(quantity) AS total_pieces
FROM sales
WHERE year = 2024;
```

total_sales	total_pieces
158750.50	1243

Note

`SUM` ignores NULL values in the calculation.

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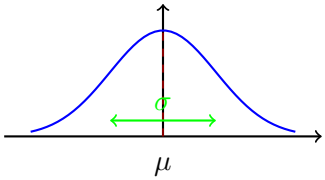
AVG and STDDEV Operators

```sql
SELECT
AVG(salary) AS average_salary,
STDDEV(salary) AS standard_deviation
FROM employees;
```

average_salary	standard_deviation
30000.00	4082.48



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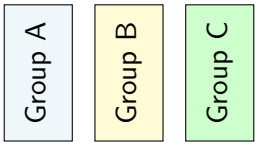
The GROUP BY Clause

Function

The `GROUP BY` clause is used to group and process uniformly different rows that have equal values in a specific column in the source table.

Syntax:

```sql
SELECT column1, aggregate_function(column2)
FROM table
WHERE condition
GROUP BY column1;
```



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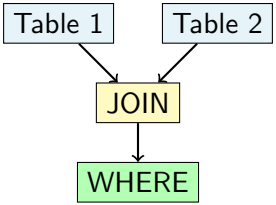
The GROUP BY Clause

Execution order

Taking into account the following considerations, let's clarify the priorities during the execution of a selection with grouping.

Processing phases:

1. Execution of the `JOIN`, if present
2. Selection on tuples with the condition after `WHERE`



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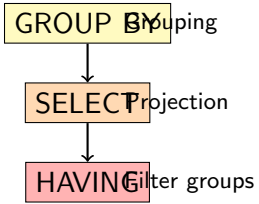
The GROUP BY Clause

Processing phases (continued):

3. Grouping based on fields specified after `GROUP BY`
4. List of values specified after `SELECT` (target list)
5. Selection of tuples that satisfy the condition after `HAVING`



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The GROUP BY Clause

```sql
SELECT department, COUNT(*) AS
    number_employees
FROM employees
GROUP BY department;
```

Original table:

Name	Department
Mario	Sales
Laura	IT
Giuseppe	Sales
Anna	IT
Carlo	Marketing

Result:

department	number_employees
Sales	2
IT	2
Marketing	1

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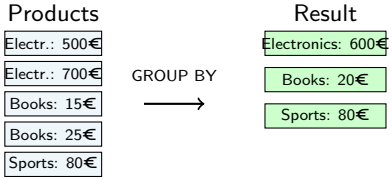
The GROUP BY Clause

```sql
SELECT category, AVG(price) AS average_price
FROM products
GROUP BY category;
```



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The GROUP BY Clause

```sql
SELECT
year,
month,
SUM(sales) AS total_sales
FROM monthly_sales
GROUP BY year, month
ORDER BY year, month;
```

year	month	total_sales
2023	1	45000
2023	2	52000
2024	1	48000
2024	2	55000

Grouping on **multiple columns**

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The GROUP BY Clause

```sql
SELECT
city,
COUNT(*) AS number_customers,
SUM(orders) AS total_orders
FROM customers
GROUP BY city;
```

city	number_customers	total_orders
Rome	15	234
Milan	22	387
Naples	8	145
Turin	12	198

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The GROUP BY Clause

```sql
SELECT
brand,
model,
COUNT(*) AS units_sold,
AVG(price) AS average_price
FROM cars_sold
GROUP BY brand, model
ORDER BY units_sold DESC;
```

brand	model	units	price
Fiat	Panda	45	12500
Volkswagen	Golf	38	22000
Ford	Fiesta	32	15000

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The GROUP BY Clause

```sql
SELECT
YEAR(sale_date) AS year,
MONTH(sale_date) AS month,
COUNT(*) AS number_transactions,
SUM(amount) AS revenue
FROM transactions
GROUP BY YEAR(sale_date), MONTH(sale_date);
```

year	month	transactions	revenue
2024	10	152	45200.00
2024	11	178	52800.00
2024	12	201	68500.00

Grouping with **functions** in columns

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The HAVING Clause

```sql
SELECT department, AVG(salary) AS
    average_salary
FROM employees
GROUP BY department
HAVING AVG(salary) > 30000;
```

All groups:

department	average_salary
Sales	28000
IT	35000
Marketing	27000
Production	32000

Result with HAVING:

department	average_salary
IT	35000
Production	32000

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The HAVING Clause

```sql
SELECT category, COUNT(*) AS number_products
FROM products
GROUP BY category
HAVING COUNT(*) >= 5;
```

category	number_products
Electronics	12
Clothing	8
Home	6

Note

`HAVING` filters groups **after** aggregation, while `WHERE` filters rows **before**.

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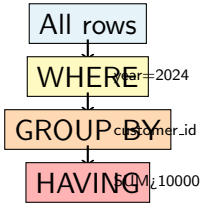
The HAVING Clause

```sql
SELECT
customer_id,
SUM(amount) AS total_purchases
FROM orders
WHERE year = 2024
GROUP BY customer_id
HAVING SUM(amount) > 10000;
```



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The HAVING Clause

```sql
SELECT
city,
COUNT(*) AS number_orders,
AVG(amount) AS average_amount
FROM orders
GROUP BY city
HAVING COUNT(*) > 10 AND AVG(amount) > 500;
```

city	number_orders	average_amount
Milan	25	675.50
Rome	18	820.30

Multiple conditions in HAVING

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The HAVING Clause

```
SELECT
brand,
COUNT(*) AS models,
MIN(price) AS min_price,
MAX(price) AS max_price
FROM automobiles
GROUP BY brand
HAVING MAX(price) - MIN(price) > 20000;
```

brand	models	min_price	max_price
BMW	8	35000	85000
Mercedes	6	40000	95000

HAVING with **expressions** between aggregations

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Limiting Result Tuples

LIMIT Clause

Allows you to limit the number of rows returned by the query.

Syntax:

```
SELECT columns
FROM table
WHERE condition
ORDER BY column
LIMIT number;
```

Common uses:

- Display only the first N results
- Implement pagination
- Optimize query performance

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Limiting Result Tuples

```sql
SELECT name, surname, salary
FROM employees
ORDER BY salary DESC
LIMIT 5;
```

Top 5 highest salaries:

name	surname	salary
Anna	Neri	45000
Mario	Rossi	42000
Laura	Bianchi	38000
Giuseppe	Verdi	35000
Carlo	Gialli	33000

Returns only the first 5 ordered rows

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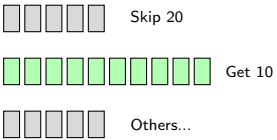
Limiting Result Tuples

Pagination with OFFSET

`OFFSET` allows you to skip a specified number of rows.

```sql
SELECT name, price
FROM products
ORDER BY price DESC
LIMIT 10 OFFSET 20;
```



Useful for pagination: page 3 = LIMIT 10 OFFSET 20

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Limiting Result Tuples

```sql
SELECT
product,
sales,
revenue
FROM sales_statistics
ORDER BY revenue DESC
LIMIT 3;
```

Top 3 products by revenue:

product	sales	revenue
Laptop Pro	234	234000 €
Smartphone X	456	182400 €
Tablet Plus	198	99000 €

Best Practice

Always use `ORDER BY` with `LIMIT` for consistent results.

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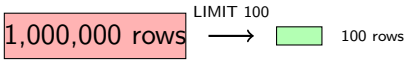
Limiting Result Tuples

Advantages of LIMIT

- **Performance:** reduces database load
- **Memory:** transfers less data
- **Usability:** improves user experience
- **Testing:** useful for testing queries on large datasets

```sql
-- Test query on large table
SELECT * FROM event_logs
WHERE date >= '2024-01-01'
LIMIT 100;
```



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