Data Transformation & Aggregation: Aggregate Functions And GroupingFunctions

Sequential SQL

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Contents

Part I

Advanced Aggregate Functions

ADVANCED AGGREGATE FUNCTIONS take SQL's summarization capabilities to the next level. While basic aggregates like `SUM()` or `COUNT()` give you simple numerical summaries, advanced aggregates can construct complex data types like strings, arrays, or JSON objects from your grouped data, or perform sophisticated statistical analyses. They are your toolkit for transforming rows into rich, structured summaries or insightful metrics, all within the database.

1 What Are They? (Meanings & Values)

The Core Idea

Advanced Aggregate Functions[a] are SQL functions that operate on a set of rows (typically defined by a `GROUP BY` clause) and return a single, often complex, summary value for that set. Unlike basic aggregates that usually return a single number, these can produce:

- Concatenated strings of values from multiple rows.
- Arrays of values from multiple rows.
- JSON structures (arrays or objects) representing aggregated data.
- Statistical measures like percentiles, correlations, or regression parameters.

Think of them as smart condensers: they take many pieces of information and intelligently combine them into a more structured or analytically rich singular output per group. If your data had a voice, these functions would be its eloquent poets and statisticians.

[a] Before to read this you can see all the numerous functions for aggregating any data type in any way that you can imagine in the official postgresql documentation

2 Relations: How They Play with Others

Connections to Your SQL Journey So Far

Advanced aggregate functions don't live in a vacuum; they build upon and interact with concepts you've already mastered:

- ♢ `GROUP BY` **Clause (Intermediate SQL):** This is their natural habitat! Advanced aggregates compute their results for each group defined by `GROUP BY`. Without groups, they typically operate on the entire table (or result set from `WHERE`).
- ♢ **Basic Aggregators (`SUM`, `AVG`, `COUNT`, etc. - Intermediate SQL):** Advanced aggregates are their more sophisticated cousins. You might use basic aggregates alongside advanced ones in the same query.

- `FILTER` **Clause for Aggregates (Complementary SQL):** Just like basic aggregates, advanced aggregates can use the `FILTER (WHERE ...)` clause to consider only a subset of rows within each group for their calculation. This is super handy for conditional aggregation.
- `ORDER BY` **(Basic SQL & Advanced** `ORDER BY` **- Complementary SQL):** Several advanced aggregates (like `STRING_AGG`, `ARRAY_AGG`, `PERCENTILE_CONT`) have their own internal `ORDER BY` clause that dictates the order of elements within the aggregated result (e.g., the order of items in a concatenated string or array, or the sorting needed for percentile calculation). This is distinct from the final `ORDER BY` of the query.
- **Joins (Intermediate & Complementary SQL):** You'll often join tables first to bring together the data you want to aggregate. The advanced aggregate then operates on the result of these joins.
- **CTEs (Common Table Expressions - Advanced SQL):** CTEs are fantastic for preparing or pre-processing data. You can define a CTE to shape your data and then apply advanced aggregates in a subsequent part of the query, making complex logic easier to manage. "With a CTE's grace, data finds its place, for aggregates to embrace!"
- **Data Types &** `CAST` **(Intermediate SQL):** Be mindful of the input types for these functions and the output types they produce (e.g., `TEXT`, `ARRAY`, `JSONB`, `NUMERIC`). You might need to `CAST` data to the correct type before aggregation.
- **String Functions (**`CONCAT`**,** `SUBSTRING`**, etc. - Complementary SQL):** The expressions fed into `STRING_AGG` might involve string manipulations. The output of `STRING_AGG` is a string.
- `DISTINCT` **(Intermediate SQL):** Some advanced aggregates, like `STRING_AGG` and `ARRAY_AGG`, can aggregate only `DISTINCT` values.
- **Null Handling (**`COALESCE`**,** `IS NULL` **- Intermediate SQL):** How these functions handle `NULL` inputs varies. Statistical functions often ignore `NULL`s. For construction functions like `STRING_AGG`, `NULL`s might be skipped. You might use `COALESCE` on their output (e.g., `COALESCE(STRING_AGG(...), 'None')`).
- `CASE` **Expressions (Intermediate & Complementary SQL):** `CASE` can be used within the expression being aggregated to perform conditional logic before the aggregation happens. Example: `ARRAY_AGG(CASE WHEN status = 'active' THEN itemID ELSE NULL END)`.

They extend what's possible, making SQL a more powerful tool for data transformation directly within the database.

3 How to Use Them: Structures & Syntax

Advanced aggregate functions are typically used in the `SELECT` list of a query, often in conjunction with a `GROUP BY` clause. Some, like `PERCENTILE_CONT`, have a unique `WITHIN GROUP` syntax.

3.1 String & Array Construction Functions

STRING_AGG(expression, separator [ORDER BY ...])

Concatenates values from an expression across multiple rows within a group into a single string, with a specified separator.

- **Meaning:** Builds a delimited string from a group of values.
- **Value:** A single string (TEXT type).
- **Rhyme:** "Names in a row, with commas they flow, `STRING_AGG` makes it so!"

Syntax & Usage:

```sql
SELECT
    d.departmentName,
    STRING_AGG(e.firstName, ', ' ORDER BY e.hireDate) AS
    employeesInOrderOfHire
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
GROUP BY d.departmentName;

-- With FILTER clause
SELECT
    d.departmentName,
    STRING_AGG(e.firstName, '; ')
        FILTER (WHERE e.salary > 70000) AS highEarnerNames
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
GROUP BY d.departmentName;
```

Listing 1: Concatenate employee first names per department

Notes:

- The `ORDER BY` clause within `STRING_AGG` is optional but highly recommended for predictable output.
- `NULL` values in the expression are typically ignored (not added to the string).
- If the group is empty or all expression values are `NULL`, it returns `NULL`. Use `COALESCE` to provide a default, e.g., `COALESCE(STRING_AGG(...), 'No matching employees')`.

ARRAY_AGG(expression [ORDER BY ...])

Collects values from an expression across multiple rows within a group into an array.

- **Meaning:** Builds an array from a group of values.
- **Value:** An array of the expression's data type.
- **Rhyme:** "Skills in a set, an array you'll get, `ARRAY_AGG` hasn't failed yet!"

Syntax & Usage:

```sql
SELECT
```

```sql
    d.departmentName,
    ARRAY_AGG(DISTINCT skill ORDER BY skill) AS departmentSkills --
    Assuming 'skills' is unnested
FROM Departments d
JOIN Employees e ON d.departmentId = e.departmentId,
UNNEST(e.skills) AS skill -- Previous concept 'unnest' for arrays
GROUP BY d.departmentName;

-- Aggregating employee IDs for each project
SELECT
    p.projectName,
    ARRAY_AGG(ep.employeeId ORDER BY ep.employeeId) AS teamMemberIds
FROM Projects p
JOIN EmployeeProjects ep ON p.projectId = ep.projectId
GROUP BY p.projectName;
```

Listing 2: Collect all skills for employees in each department

Notes:

- The `ORDER BY` clause within `ARRAY_AGG` is optional.
- `NULL` values in the expression *are* included in the array by default. You might want to filter them using a `WHERE` clause before grouping or `FILTER (WHERE expression IS NOT NULL)`.
- If the group is empty, it returns `NULL`.

3.2 JSON Construction Functions

`JSON_AGG(expression [ORDER BY ...])` **or** `JSONB_AGG`

Aggregates values from an expression across multiple rows within a group into a JSON array. PostgreSQL offers both `JSON_AGG` (for `json` type) and `JSONB_AGG` (for `jsonb` type, usually preferred for efficiency and features).

- **Meaning:** Builds a JSON array from a group of values.
- **Value:** A JSON array.
- **Rhyme:** "Data so neat, in a JSON sweet, `JSON_AGG` can't be beat!"

Syntax & Usage: To create meaningful JSON objects within the array, the 'expression' often involves functions like `JSON_BUILD_OBJECT` or `ROW_TO_JSON` (which are part of "JSON and Array Functions", a topic subsequent to this one. However, their use is often implied for `JSON_AGG` to be powerful, as seen in typical examples and even the user's previous problem set). For simplicity here, we show aggregation of simpler values, and one example with `JSON_BUILD_OBJECT` for illustration, assuming its basic use can be introduced here.

```sql
SELECT
    d.departmentName,
    JSONB_AGG(e.salary ORDER BY e.salary DESC) AS salariesJsonArray
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
GROUP BY d.departmentName;

```

```sql
-- Create a JSON array of employee objects (firstName, email) per department
SELECT
    d.departmentName,
    JSONB_AGG(
        JSON_BUILD_OBJECT(
            'firstName', e.firstName,
            'email', e.email
        ) ORDER BY e.lastName -- Order of objects in the array
    ) AS employeesAsJson
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
GROUP BY d.departmentName;
```

Listing 3: Create a JSON array of employee salaries per department

Notes:

- The input 'expression' can be a simple value, a column, or a more complex JSON structure itself (e.g., constructed by `JSON_BUILD_OBJECT`).
- The `ORDER BY` clause within `JSON_AGG` is optional and controls the order of elements in the resulting JSON array.
- `NULL` values in the expression are converted to JSON `null` by default.

3.3 Statistical & Analytical Functions

`PERCENTILE_CONT(fraction) WITHIN GROUP (ORDER BY sort_expression)`

Calculates a percentile based on a continuous distribution of the `sort_expression` values within a group. It interpolates between adjacent input items if necessary.

- **Meaning:** Finds the value at a specific percentile (e.g., 0.5 for median) within an ordered set of values, potentially interpolating.
- **Value:** A numeric value, same type as `sort_expression`.
- **Rhyme:** "Median's quest, put `PERCENTILE_CONT` to the test, it finds the value best!"

Syntax & Usage:

```sql
SELECT
    d.departmentName,
    PERCENTILE_CONT(0.25) WITHIN GROUP (ORDER BY e.salary) AS salaryP25,
    PERCENTILE_CONT(0.50) WITHIN GROUP (ORDER BY e.salary) AS medianSalary,
    PERCENTILE_CONT(0.75) WITHIN GROUP (ORDER BY e.salary) AS salaryP75
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
GROUP BY d.departmentName;
```

Listing 4: Calculate 25th 50th (median) and 75th percentiles of salary per department

Notes:

- 'fraction' must be between 0 and 1.

- The `WITHIN GROUP (ORDER BY ...)` clause is mandatory.
- `PERCENTILE_DISC(fraction) WITHIN GROUP (ORDER BY ...)` is a related function that returns an actual value from the set (discrete percentile), rather than interpolating. "If a real value you must pick, `PERCENTILE_DISC` does the trick!"
- Both ignore `NULL`s in the `sort_expression`.

`CORR(Y_expression, X_expression)`

Calculates the Pearson correlation coefficient between two sets of numeric expressions (Y and X) within a group.

- **Meaning:** Measures the strength and direction of a linear relationship between two variables.
- **Value:** A numeric value between -1 and 1.
- **Rhyme:** "Do X and Y dance in a line? `CORR` gives a telling sign."

Syntax & Usage:

```sql
SELECT
    CORR(performanceScore, salary) AS salaryPerfScoreCorrelation
FROM Employees;

-- Per department (if it makes sense)
SELECT
    d.departmentName,
    CORR(e.performanceScore, e.salary) AS deptSalaryPerfCorrelation
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
GROUP BY d.departmentName
HAVING COUNT(e.performanceScore) > 1 AND COUNT(e.salary) > 1; -- CORR
    needs at least 2 pairs
```

Listing 5: Correlation between salary and performanceScore overall

Notes:

- Returns `NULL` if it cannot compute (e.g., variance of one variable is zero, or too few non-null pairs).
- Ignores pairs where either Y or X (or both) is `NULL`.
- A value near +1 indicates a strong positive linear correlation, near -1 a strong negative linear correlation, and near 0 little to no linear correlation.

`REGR_SLOPE(Y_expression, X_expression)`

Calculates the slope of the linear regression line fitting the (X, Y) pairs within a group. (Y is dependent, X is independent).

- **Meaning:** Estimates how much Y changes for a one-unit change in X, assuming a linear model.

- **Value:** A numeric value representing the slope.
- **Rhyme:** "For X's climb, what's Y's paradigm? `REGR_SLOPE` tells the gradient, every time."

Syntax & Usage:

```sql
SELECT
    d.departmentName,
    REGR_SLOPE(e.performanceScore, e.salary) AS perfVsSalarySlope,
    REGR_INTERCEPT(e.performanceScore, e.salary) AS
    perfVsSalaryIntercept,
    REGR_R2(e.performanceScore, e.salary) AS perfVsSalaryRsquared
FROM Employees e
JOIN Departments d ON e.departmentId = d.departmentId
WHERE e.performanceScore IS NOT NULL AND e.salary IS NOT NULL
GROUP BY d.departmentName
HAVING COUNT(*) > 1; -- Regression functions typically need at least 2
    points
```

Listing 6: Slope of performanceScore (Y) vs salary (X) per department

Notes:

- Other related regression functions:
  - `REGR_INTERCEPT(Y,X)`: Y-intercept of the regression line.
  - `REGR_R2(Y,X)`: Coefficient of determination (R-squared), indicates goodness of fit.
  - `REGR_COUNT(Y,X)`: Number of non-null pairs used.
  - `REGR_AVGX(Y,X)`, `REGR_AVGY(Y,X)`: Averages of X and Y.
- Ignores pairs where Y or X is `NULL`.

Practice Ground: pgAdmin4 and Beyond

All these functions can be practiced effectively in PostgreSQL using tools like **pgAdmin4**. Most modern SQL databases (SQL Server, Oracle, MySQL, etc.) support these or very similar functions, though syntax might vary slightly (e.g., SQL Server's `STRING_AGG`, Oracle's `LISTAGG`). MySQL has `GROUP_CONCAT` for string aggregation and window functions for percentiles. Always check your specific database's documentation!

4 Why Use Them? (Advantages)

Why Use This? (Advantages)

✓ **Conciseness & Power in SQL:** Achieve complex data shaping and analysis directly in SQL. This often means less application-level code for data manipulation. Your SQL queries become more expressive. "Why write loops galore, when SQL offers more, right at the data's core?"

- ✓ **Performance:** Database systems are highly optimized for aggregations. Performing these operations in the database is generally faster than fetching raw data and processing it in an application, especially for large datasets. Reduces data transfer too!
- ✓ **Reduced Data Transfer:** By summarizing and structuring data on the server, you send less data over the network to your application. This is a win for speed and efficiency.
- ✓ **Standardized Calculations:** Functions like `PERCENTILE_CONT`, `CORR`, `REGR_SLOPE` provide standard statistical calculations, ensuring consistency and correctness without reimplementing complex formulas.
- ✓ **Direct Rich Data Structures:** `ARRAY_AGG` and `JSON_AGG` allow you to construct arrays and JSON directly, which is incredibly useful for APIs or when your application expects data in these formats.
- ✓ **Readability (once understood):** While the syntax might seem new at first, once familiar, these functions make the *intent* of the query clearer than complex workarounds using only basic constructs.

5 Watch Out! (Disadvantages)

Watch Out! (Disadvantages)

- × `STRING_AGG` **Size Limits & Parsing:**
  - Concatenated strings can become very long, potentially exceeding system limits or being truncated. ”A string too vast, might not always last.”
  - Parsing information back out of a long delimited string in SQL or application code can be clumsy and inefficient compared to working with normalized data or arrays/JSON.
- × `ARRAY_AGG` **&** `JSON_AGG` **Memory/Performance:**
  - Aggregating huge numbers of items or very large items into arrays or JSON objects can consume significant server memory and CPU.
  - Transmitting and parsing very large arrays/JSON objects on the client-side can also be a bottleneck. ”A JSON so grand, needs a strong server hand.”
- × **JSON Schema-lessness:** While `JSON_AGG` helps create JSON, SQL doesn’t enforce the internal schema of the JSON content. Type safety and structure validation become the application’s responsibility.
- × `PERCENTILE_CONT` **Interpolation:** The continuous percentile might return a value that doesn’t actually exist in your dataset. For discrete data (like ratings 1-5), `PERCENTILE_DISC` might be more intuitive if you need an existing data point. ”A made-up middle, solves a statistical riddle.”
- × `CORR` **&** `REGR_SLOPE` **Interpretation:**
  - These functions only measure *linear* relationships. A low correlation doesn’t mean no relationship; it could be non-linear.

  - Correlation does not imply causation! ”They move as one, but who fired the starting gun?”
  - `REGR_SLOPE` gives you the slope, but you need other functions (like `REGR_R2`) to understand the goodness-of-fit or significance of that slope.

× **Portability:** While concepts are similar, exact function names and syntax details (especially for JSON and advanced statistics) can vary between database systems (e.g., `LISTAGG` in Oracle, `GROUP_CONCAT` in MySQL).

× **Complexity for Beginners:** The syntax, especially `WITHIN GROUP`, can be initially confusing. It's a step up from basic aggregates.

Part II

Advanced Grouping Operations

ADVANCED GROUPING OPERATIONS like ROLLUP, CUBE, and GROUPING SETS are SQL's answer to complex reporting needs that require multiple levels of aggregation in a single query. Instead of writing many separate queries with different GROUP BY clauses and then UNIONing them, these operations let you define all desired grouping levels at once. The database can then optimize the generation of these subtotals and grand totals efficiently. They are the Swiss Army knives for summary reports!

6 What Are They? (Meanings & Values)

The Core Idea

Advanced Grouping Operations extend the GROUP BY clause to allow calculation of aggregate values for multiple sets of grouping columns (grouping sets) in a single SQL statement.

- ROLLUP (a, b, c): Generates grouping sets for hierarchical summaries. It produces subtotals for (a,b,c), then (a,b), then (a), and finally a grand total (). Think of it as "rolling up" the data from the most detailed level to the grand total, following the specified column order.
- CUBE (a, b, c): Generates grouping sets for all possible combinations of the specified columns. For (a,b,c), it produces subtotals for (a,b,c), (a,b), (a,c), (b,c), (a), (b), (c), and (). It's for multi-dimensional analysis where any combination is of interest.
- GROUPING SETS ((a,b), (a), (c), ()): The most flexible option. It allows you to explicitly specify exactly which grouping sets you want. ROLLUP and CUBE are essentially shorthands for specific GROUPING SETS definitions.

Value: The result is a single result set containing rows for each specified grouping level. Columns not part of a particular grouping set's aggregation level will appear as NULL in those summary rows. The GROUPING() function is crucial for distinguishing these NULLs (indicating a subtotal) from actual NULL values in the data.

7 Relations: How They Play with Others

Connections to Your SQL Journey So Far

These advanced grouping operations are deeply integrated with concepts you've already encountered:

- ♢ GROUP BY **Clause (Intermediate SQL):** These are direct extensions of GROUP BY. You use them *within* the GROUP BY clause.
- ♢ **Basic Aggregators (**SUM**,** AVG**,** COUNT**, etc. - Intermediate SQL):** These are

what you calculate for each generated grouping set. For every subtotal row produced by `ROLLUP`, `CUBE`, or `GROUPING SETS`, you'll be applying functions like `SUM(salesAmount)`, `COUNT(orders)`, etc.

- ♢ `HAVING` **(Intermediate SQL):** Can be used to filter the resulting groups, including the subtotal/grand total rows generated by these operations.
- ♢ `ORDER BY` **(Basic SQL & Advanced** `ORDER BY` **- Complementary SQL):** Essential for presenting the multi-level results in a logical and readable way. Often, you'll order by the grouping columns, and potentially by the `GROUPING()` function's output, to ensure subtotals appear in the correct places. `NULLS LAST` or `NULLS FIRST` might be used on grouping columns in `ORDER BY` because subtotals have `NULL`s.
- ♢ **Null Handling (**`COALESCE`**,** `IS NULL` **- Intermediate SQL):** Rows representing subtotals or grand totals will have `NULL` values in the columns that are "rolled up" or not part of that specific grouping set. `COALESCE` is vital for replacing these `NULL`s with meaningful labels (e.g., 'All Departments', 'Grand Total'). The `GROUPING()` function helps differentiate these "super-aggregate `NULL`s" from actual data `NULL`s.
- ♢ `CASE` **Expressions (Intermediate & Complementary SQL):** Frequently used with the `GROUPING()` function in the `SELECT` list to provide descriptive labels for subtotal rows.
- ♢ **CTEs (Common Table Expressions - Advanced SQL):** Useful for preparing the base data set before applying complex grouping logic, enhancing readability and modularity.
- ♢ **Joins (Intermediate & Complementary SQL):** Data from multiple tables is typically joined first; then these advanced grouping operations are applied to the resulting dataset.
- ♢ `UNION ALL` **(Set Operations - Complementary SQL):** Advanced grouping operations are often a more efficient and cleaner alternative to manually constructing multiple aggregation levels using separate queries combined with `UNION ALL`. "No more `UNION`'s plight, `GROUPING SETS` make your queries bright!"

Intra-topic Relations:

- ○ `GROUPING SETS` is the most fundamental. `ROLLUP` and `CUBE` are convenient shorthands for common patterns of `GROUPING SETS`.
- ○ The `GROUPING(col1 [, col2...])` function is used alongside all three (`ROLLUP`, `CUBE`, `GROUPING SETS`) to help identify the level of aggregation for each row.

8 How to Use Them: Structures & Syntax

```
GROUP BY ROLLUP (col1, col2, ...  colN)
```

Generates grouping sets for hierarchical summaries. It assumes a hierarchy from left to right among the listed columns.

- **Meaning:** Creates subtotals by progressively "rolling up" from the rightmost column.

- **Equivalent** `GROUPING SETS`**:** For `ROLLUP(a,b,c)`, it's like `GROUPING SETS ((a,b,c), (a,b), (a), ())`.
- **Rhyme:** "From detail to grand, `ROLLUP` lends a hand, summarizing across the land."

Syntax & Usage:

```
SELECT
    EXTRACT(YEAR FROM saleDate) AS saleYear,
    EXTRACT(QUARTER FROM saleDate) AS saleQuarter,
    EXTRACT(MONTH FROM saleDate) AS saleMonth,
    SUM(quantity * unitPrice) AS totalSales,
    GROUPING(EXTRACT(YEAR FROM saleDate), EXTRACT(QUARTER FROM saleDate
    ), EXTRACT(MONTH FROM saleDate)) AS groupingLevel
FROM Sales
GROUP BY ROLLUP (
    EXTRACT(YEAR FROM saleDate),
    EXTRACT(QUARTER FROM saleDate),
    EXTRACT(MONTH FROM saleDate)
)
ORDER BY saleYear NULLS LAST, saleQuarter NULLS LAST, saleMonth NULLS
    LAST;
```

Listing 7: Sales totals: by Year then by Year+Quarter then by Year+Quarter+Month

Output Interpretation:

- Rows where 'saleMonth' is 'NULL' are subtotals for that 'saleYear' and 'saleQuarter'.
- Rows where 'saleQuarter' and 'saleMonth' are 'NULL' are subtotals for that 'saleYear'.
- The row where 'saleYear', 'saleQuarter', and 'saleMonth' are all 'NULL' is the grand total.

`GROUP BY CUBE (col1, col2, ... colN)`

Generates grouping sets for all possible combinations of the specified columns, plus the grand total.

- **Meaning:** Creates subtotals for every permutation of grouping columns.
- **Equivalent** `GROUPING SETS`**:** For `CUBE(a,b)`, it's like `GROUPING SETS ((a,b), (a), (b), ())`. For 3 columns, it's $2^3 = 8$ grouping sets.
- **Rhyme:** "Slice it, dice it, every way you like it, `CUBE` will surely strike it!"

Syntax & Usage:

```
SELECT
    r.regionName,
    p.category AS productCategory,
    SUM(s.quantity) AS totalQuantity,
    GROUPING(r.regionName, p.category) AS groupingIndicator
FROM Sales s
JOIN Products p ON s.productId = p.productId
```

```sql
JOIN Regions r ON s.regionId = r.regionId
GROUP BY CUBE (r.regionName, p.category)
ORDER BY r.regionName NULLS LAST, p.category NULLS LAST;
```

Listing 8: Sales totals for all combinations of Region and Product Category

Output Interpretation: You'll get rows for:

- Each (regionName, productCategory)
- Each regionName (productCategory is NULL) - subtotal per region
- Each productCategory (regionName is NULL) - subtotal per category
- Grand total (both regionName and productCategory are NULL)

`GROUP BY GROUPING SETS ((set1), (set2), ...)`

The most explicit and flexible way to define multiple grouping criteria. You list exactly the combinations of columns you want to group by.

- **Meaning:** Specify exact combinations for grouping.
- **Rhyme:** "Pick and choose, no aggregation blues, `GROUPING SETS` lets you cruise!"

Syntax & Usage:

```sql
SELECT
    d.departmentName,
    r.regionName,
    SUM(s.amount) AS totalSales,
    GROUPING(d.departmentName, r.regionName) AS groupingIndicator
FROM Sales s
JOIN Employees e ON s.employeeId = e.employeeId
JOIN Departments d ON e.departmentId = d.departmentId
JOIN Regions r ON s.regionId = r.regionId
GROUP BY GROUPING SETS (
    (d.departmentName, r.regionName), -- Group by department and region
    (r.regionName),                   -- Group by region only
    ()                                -- Grand total
)
ORDER BY d.departmentName NULLS LAST, r.regionName NULLS LAST;
```

Listing 9: Sales totals: by (Department Region) and by (Region) and Grand Total

Notes:

- An empty parenthesis `()` denotes the grand total.
- Each set of parentheses within `GROUPING SETS` defines one level of aggregation.

`GROUPING(col1 [, col2 ...])` Function

Used in the `SELECT` list to determine if a specified column (or set of columns) has been aggregated (i.e., "rolled up" or is part of a subtotal/grand total calculation) in a given output row.

- **Meaning:** Indicates if a column is part of the current group's aggregation level.
- **Value:** Returns an integer. If a single column is passed, it returns 1 if the column is aggregated (value is `NULL` because it's a subtotal for that column), and 0 otherwise. If multiple columns are passed, it returns a bitmask.
- **Rhyme:** "Is this `NULL` real, or a subtotal's spiel? `GROUPING()` makes the truth reveal!"

Syntax & Usage:

```
        SELECT
            CASE GROUPING(d.departmentName)
                WHEN 1 THEN 'All Departments Total'
                ELSE d.departmentName
            END AS department,
            CASE GROUPING(e.jobTitle)
                WHEN 1 THEN 'All Job Titles in Department'
                ELSE e.jobTitle
            END AS title,
            SUM(e.salary) AS totalSalary
        FROM Employees e
        JOIN Departments d ON e.departmentId = d.departmentId
        GROUP BY ROLLUP (d.departmentName, e.jobTitle)
        ORDER BY GROUPING(d.departmentName), d.departmentName, GROUPING
    (e.jobTitle), e.jobTitle;

```

Listing 10: Using GROUPING() to label subtotals

Why `GROUPING()` is important: A `NULL` in a grouping column in the output could mean two things:

1. The original data in that column for those rows was actually `NULL`.
2. The row is a subtotal/grand total, and that column was aggregated over (hence it appears `NULL`).

`GROUPING(columnName)` returns 1 for case (2) and 0 for case (1), allowing you to distinguish.

Examples:

```
        -- Example 1: ROLLUP with One Column
        -- Purpose: To calculate aggregate values (employee count,
    total salary) for each department
        --          and a grand total across all departments.
        -- `ROLLUP (d.departmentName)` creates two levels of
    aggregation:
        --   1. Per d.departmentName
        --   2. Grand total (d.departmentName is NULL in this grouping
    context)
        SELECT
            -- The CASE statement uses GROUPING(d.departmentName) to
    determine the label.
            -- GROUPING(d.departmentName) returns:
            --   0 if d.departmentName is part of the current grouping
    key (i.e., a specific department row).
            --   1 if d.departmentName is aggregated/rolled up (i.e.,
    the grand total row where d.departmentName is conceptually NULL).
```

```
            CASE GROUPING(d.departmentName)
                WHEN 1 THEN 'All Departments - Grand Total' -- Label for the grand total row
                ELSE d.departmentName                       -- Actual department name for department-specific rows
            END AS department_group,

            -- Explicitly showing the GROUPING() value for clarity.
            -- This helps understand how the CASE statement above works.
            GROUPING(d.departmentName) AS grouping_dept_name_value,

            COUNT(e.employeeId) AS employee_count,
            SUM(e.salary) AS total_salary
        FROM
            advanced_query_techniques.EmployeesI e
        JOIN
            advanced_query_techniques.DepartmentsI d ON e.departmentId = d.departmentId
        GROUP BY
            ROLLUP (d.departmentName) -- Generates subtotals for departmentName and a grand total.
        ORDER BY
            -- Sorts the grand total row (GROUPING=1) before individual department rows (GROUPING=0).
            GROUPING(d.departmentName),
            -- Then sorts individual departments alphabetically.
            d.departmentName;

```

Listing 11: Example 1: ROLLUP with One Column

```
-- Example 2: ROLLUP with Two Columns
-- Purpose: To calculate aggregates at multiple levels:
--          1. Per (departmentName, locationCity) - most granular.
--          2. Per departmentName (summing across its locationCities) - subtotal.
--          3. Grand total (summing across all departments and cities).
-- `ROLLUP (d.departmentName, d.locationCity)` follows a hierarchy:
--   (d.departmentName, d.locationCity)
--   (d.departmentName)  -- d.locationCity is rolled up
--   ()                  -- d.departmentName and d.locationCity are rolled up
SELECT
    -- Labeling for the department level.
    -- GROUPING(d.departmentName) = 1 only for the grand total row.
    CASE GROUPING(d.departmentName)
        WHEN 1 THEN 'All Departments & Cities - Grand Total'
        ELSE d.departmentName
    END AS department_group,

    -- Labeling for the city level.
    -- GROUPING(d.locationCity) = 1 if locationCity is rolled up. This happens for:
    --   a) Department subtotals (departmentName is present, city is rolled up).
    --   b) The grand total (both departmentName and city are rolled up).
    CASE GROUPING(d.locationCity)
        WHEN 1 THEN
            -- Further distinguish if this "All Cities" is for a
```

```
    specific department or the grand total.
25              CASE GROUPING(d.departmentName)
26                  WHEN 1 THEN '' -- For grand total, city part is implied
     by department's grand total.
27                  ELSE 'All Cities in Department' -- For department
    subtotal.
28              END
29          ELSE d.locationCity -- Actual city name if not rolled up.
30      END AS city_group,
31
32      -- Explicitly showing the GROUPING() values.
33      GROUPING(d.departmentName) AS grouping_dept_name_value,    -- 0 for
    specific dept, 1 for grand total.
34      GROUPING(d.locationCity) AS grouping_location_city_value, -- 0 for
    specific city, 1 if city is subtotaled/grandtotaled.
35
36      COUNT(e.employeeId) AS employee_count,
37      SUM(e.salary) AS total_salary
38  FROM
39      advanced_query_techniques.EmployeesI e
40  JOIN
41      advanced_query_techniques.DepartmentsI d ON e.departmentId = d.
    departmentId
42  GROUP BY
43      ROLLUP (d.departmentName, d.locationCity) -- Rolls up from right to
     left: (dept, city), (dept), ()
44  ORDER BY
45      -- Order ensures logical presentation: Grand total, then department
     subtotals, then city details.
46      GROUPING(d.departmentName),    -- Grand total first
47      d.departmentName,              -- Then by department name
48      GROUPING(d.locationCity), -- Department subtotals before specific
    cities within that dept
49      d.locationCity;                -- Then by city name
50
```

Listing 12: ROLLUP with Two Columns

```
1  -- Example 3: CUBE with Two Columns
2  -- Purpose: To calculate aggregates for all possible combinations of
       grouping sets
3  --          from the specified columns (d.departmentName, d.
       locationCity).
4  -- `CUBE (d.departmentName, d.locationCity)` generates:
5  --    1. (d.departmentName, d.locationCity) - most granular.
6  --    2. (d.departmentName) - subtotal per department (locationCity
       rolled up).
7  --    3. (d.locationCity) - subtotal per city (departmentName rolled up)
       . *This is what CUBE adds over ROLLUP*.
8  --    4. () - grand total (both rolled up).
9  SELECT
10     -- Label for department based on whether d.departmentName is rolled
        up.
11     -- GROUPING(d.departmentName) = 1 if departmentName is aggregated (
       for city subtotals or grand total).
12     CASE GROUPING(d.departmentName)
13         WHEN 1 THEN 'Overall (All Departments Aggregate)'
14         ELSE d.departmentName
15     END AS department_group,
16
17     -- Label for city based on whether d.locationCity is rolled up.
```

```
    -- GROUPING(d.locationCity) = 1 if locationCity is aggregated (for department subtotals or grand total).
    CASE GROUPING(d.locationCity)
        WHEN 1 THEN 'Overall (All Cities Aggregate)'
        ELSE d.locationCity
    END AS city_group,

    -- Explicitly showing GROUPING() values.
    GROUPING(d.departmentName) AS grouping_dept_name_value,
    GROUPING(d.locationCity) AS grouping_location_city_value,

    COUNT(e.employeeId) AS employee_count,
    SUM(e.salary) AS total_salary
FROM
    advanced_query_techniques.EmployeesI e
JOIN
    advanced_query_techniques.DepartmentsI d ON e.departmentId = d.departmentId
GROUP BY
    CUBE (d.departmentName, d.locationCity) -- Generates all combinations of groupings.
ORDER BY
    -- Order to make the output more readable.
    GROUPING(d.departmentName),
    d.departmentName,
    GROUPING(d.locationCity),
    d.locationCity;

```

Listing 13: CUBE with Two Columns

```
-- Example 4: GROUPING SETS to Define Custom Aggregation Levels
-- Purpose: To explicitly define the exact combinations of columns for which subtotals are needed.
--          This provides fine-grained control over the aggregation levels.
-- Here, we're replicating the behavior of CUBE for two columns by specifying all sets.
SELECT
    -- This complex CASE structure creates descriptive labels for 'department_label'
    -- by checking the GROUPING status of both departmentName and locationCity.
    CASE
        -- Level 1: Most granular (departmentName, locationCity)
        WHEN GROUPING(d.departmentName) = 0 AND GROUPING(d.locationCity) = 0 THEN d.departmentName
        -- Level 2: Subtotal for departmentName (locationCity is aggregated)
        WHEN GROUPING(d.departmentName) = 0 AND GROUPING(d.locationCity) = 1 THEN d.departmentName
        -- Level 3: Subtotal for locationCity (departmentName is aggregated)
        WHEN GROUPING(d.departmentName) = 1 AND GROUPING(d.locationCity) = 0 THEN 'All Departments for this City'
        -- Level 4: Grand Total (both are aggregated)
        WHEN GROUPING(d.departmentName) = 1 AND GROUPING(d.locationCity) = 1 THEN 'Grand Total'
    END AS department_label,

    -- Similar complex CASE for 'city_label'.
```

```
    CASE
        WHEN GROUPING(d.departmentName) = 0 AND GROUPING(d.locationCity) = 0 THEN d.locationCity
        WHEN GROUPING(d.departmentName) = 0 AND GROUPING(d.locationCity) = 1 THEN 'All Cities in this Dept'
        WHEN GROUPING(d.departmentName) = 1 AND GROUPING(d.locationCity) = 0 THEN d.locationCity
        WHEN GROUPING(d.departmentName) = 1 AND GROUPING(d.locationCity) = 1 THEN 'All Cities Overall'
    END AS city_label,

    -- Explicit GROUPING values for inspection.
    GROUPING(d.departmentName) AS g_dept_val,
    GROUPING(d.locationCity) AS g_city_val,

    COUNT(e.employeeId) AS employee_count,
    SUM(e.salary) AS total_salary
FROM
    advanced_query_techniques.EmployeesI e
JOIN
    advanced_query_techniques.DepartmentsI d ON e.departmentId = d.departmentId
GROUP BY
    GROUPING SETS (
        (d.departmentName, d.locationCity), -- Group by both department and city.
        (d.departmentName),                 -- Group by department only (subtotal for department).
        (d.locationCity),                   -- Group by city only (subtotal for city).
        ()                                  -- Grand total (group by nothing).
    )
ORDER BY
    -- Ordering to make the various grouping sets appear in a logical sequence.
    g_dept_val, department_label, g_city_val, city_label;

```

Listing 14: GROUPING SETS to Define Custom Aggregation Levels

```
-- Example 5: Using the Bitmask Property of GROUPING()
-- Purpose: To demonstrate how GROUPING(colA, colB, ...) returns a single integer (bitmask)
--          representing the aggregation status of all specified columns.
-- The bitmask is formed as:
--   ... + (GROUPING(colA) * 2^N) + ... + (GROUPING(colY) * 2^1) + (GROUPING(colZ) * 2^0)
-- For GROUPING(d.departmentName, d.locationCity):
--   Bit 0 (value 1) is for d.locationCity.
--   Bit 1 (value 2) is for d.departmentName.
SELECT
    -- Displaying the original columns. These will be NULL if the column is aggregated for that row.
    d.departmentName,
    d.locationCity,

    -- The bitmask value itself.
    GROUPING(d.departmentName, d.locationCity) AS grouping_bitmask,

```

```sql
    -- Manually deciphering the bitmask using bitwise AND to check individual bits.
    -- This shows what the single GROUPING(colA, colB) call implicitly combines.
    -- (grouping_bitmask & 2) > 0 means the bit for departmentName (position 1, value 2) is set.
    CASE WHEN (GROUPING(d.departmentName, d.locationCity) & 2) > 0 THEN 1 ELSE 0 END AS is_dept_name_aggregated_from_mask,
    -- (grouping_bitmask & 1) > 0 means the bit for locationCity (position 0, value 1) is set.
    CASE WHEN (GROUPING(d.departmentName, d.locationCity) & 1) > 0 THEN 1 ELSE 0 END AS is_location_city_aggregated_from_mask,

    -- Using the bitmask directly in a CASE statement for labeling.
    CASE GROUPING(d.departmentName, d.locationCity)
        WHEN 0 THEN 'Detail: (' || COALESCE(d.departmentName, 'N/A') || ', ' || COALESCE(d.locationCity, 'N/A') || ')' -- Binary 00: Both not aggregated (d.deptName active, d.locCity active)
        WHEN 1 THEN 'Subtotal for Dept: ' || d.departmentName || ' (City Aggregated)'           -- Binary 01: d.locCity aggregated (d.deptName active)
        WHEN 2 THEN 'Subtotal for City: ' || d.locationCity || ' (Dept Aggregated)'             -- Binary 10: d.deptName aggregated (d.locCity active)
        WHEN 3 THEN 'Grand Total (Both Dept & City Aggregated)'
                                -- Binary 11: Both aggregated
    END AS aggregation_level_description,

    COUNT(e.employeeId) AS employee_count,
    SUM(e.salary) AS total_salary
FROM
    advanced_query_techniques.EmployeesI e
JOIN
    advanced_query_techniques.DepartmentsI d ON e.departmentId = d.departmentId
GROUP BY
    CUBE (d.departmentName, d.locationCity) -- CUBE is used here as it generates all 2^N combinations
                                            -- that map directly to the bitmask values from 0 to 2^N - 1.
ORDER BY
    grouping_bitmask, -- Order by the bitmask to see the levels clearly.
    d.departmentName, -- Secondary sort for readability within each bitmask level.
    d.locationCity;   -- Tertiary sort.

```

Listing 15: Using the Bitmask Property of GROUPING()

Practice Ground: pgAdmin4 and Other Databases

`ROLLUP`, `CUBE`, and `GROUPING SETS` are standard SQL features and well-supported in PostgreSQL (test them in pgAdmin4!), SQL Server, Oracle, and DB2. MySQL supports `ROLLUP` (as `WITH ROLLUP`) but has historically had different or more limited support for `CUBE` and explicit `GROUPING SETS`, often requiring workarounds or relying on window functions for similar outcomes. Always consult your database's documentation.

9 Why Use Them? (Advantages)

Why Use This? (Advantages)

- ✓ **Efficiency (Huge!):** The database can often generate all requested aggregation levels much more efficiently in a single pass or with a more optimized plan than if you wrote multiple queries and `UNION ALL`'ed them. "One query to rule them all, makes performance stand tall!"
- ✓ **Query Simplicity & Readability:** For complex reports, a single query with `GROUPING SETS`, `ROLLUP`, or `CUBE` is usually much cleaner, shorter, and easier to understand and maintain than many separate `GROUP BY` queries combined.
- ✓ **Reduced Code Complexity:** Less SQL to write means less chance of errors and easier maintenance.
- ✓ **Completeness for Analysis:**
  - `ROLLUP` is perfect for hierarchical reports (e.g., Year -¿ Quarter -¿ Month).
  - `CUBE` ensures you get all possible cross-tabular summaries, excellent for exploratory data analysis.
- ✓ **Standardization:** These are standard SQL features, making your knowledge portable across many database systems that implement the standard.

10 Watch Out! (Disadvantages)

Watch Out! (Disadvantages)

- × **Complexity of Output Interpretation:** The result set contains rows at different aggregation levels. You *must* understand how to use the `NULL`s in grouping columns and the `GROUPING()` function to correctly interpret and label these rows. Otherwise, your report might be misleading. "A `NULL` surprise, if you don't use your eyes, or `GROUPING()` as your guide!"
- × `CUBE` **Output Size:** `CUBE(c1, c2, ..., cN)` generates 2^N grouping sets. If N is large, the number of rows in the output can explode, leading to performance issues and an unwieldy result set. If you only need specific combinations, `GROUPING SETS` is better. "With `CUBE`'s mighty hand, results may expand, more than you planned!"
- × `ROLLUP` **Rigidity:** `ROLLUP` is strictly hierarchical based on the order of columns specified. If you need non-hierarchical subtotals (e.g., total by (Year, Product) and total by (Region, Product) from `ROLLUP(Year, Region, Product)`), `ROLLUP` alone won't give it; you'd need `GROUPING SETS`.
- × **Initial Learning Curve:** The concepts of grouping sets and interpreting their output can be challenging for those new to them.
- × **Query Performance for Very Complex Groupings:** While generally more efficient than `UNION ALL`, extremely complex `GROUPING SETS` definitions on very large tables can still be resource-intensive. The optimizer does its best, but there are limits.

× **Portability Nuances:** While largely standard, there can be minor differences or levels of support across different SQL database systems, especially for older versions or less common combinations. MySQL's historic handling is a key example.