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SQL for Data Science

SQL Window Functions

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> Example dataset

We will use a dataset on the sales of bicycles as a sample. This dataset includes:

The [product] table

The product table contains the types of bicycles sold, their model year, and list price.

product_id	product_name	model_year	list_price
1	Treak 820 - 2016	2016	379.99
2	Ritchey Timberwolf Frameset - 2016	2016	749.99
3	Surly Wednesday Frameset - 2016	2016	999.99
4	Trek Fuel EX 8 29 - 2016	2016	2899.99
5	Heller Shagamaw Frame - 2016	2016	1320.99

The [order] table

The order table contains the order_id and its date.

order_id	order_date
1	2016-01-01T00:00:00.000Z
2	2016-01-01T00:00:00.000Z
3	2016-01-02T00:00:00.000Z
4	2016-01-03T00:00:00.000Z
5	2016-01-03T00:00:00.000Z

The [order_items] table

The order_items table lists the orders of a bicycle store. For each order_id, there are several products sold (product_id). Each product_id has a discount value.

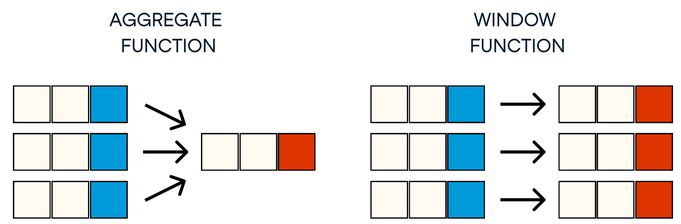
order_id	product_id	discount
1	20	0.2
1	8	0.07
1	10	0.05
1	16	0.05
1	4	0.2
2	20	0.07

What are Window Functions?

A window function makes a calculation across multiple rows that are related to the current row. For example, a window function allows you to calculate.

- Running totals (i.e. sum values from all the rows before the current row)
- 7-day moving averages (i.e. average values from 7 rows before the current row)
- Rankings

Similar to an aggregate function (GROUP BY), a window function performs the operation across multiple rows. Unlike an aggregate function, a window function does not group rows into one single row.



> Syntax

Windows can be defined in the SELECT section of the query.

```
SELECT
 window_function() OVER(
      PARTITION BY partition_expression
      ORDER BY order_expression
      window_frame_extent
 ) AS window_column_alias
 FROM table_name
```

To reuse the same window with several window functions, define a named window using the WINDOW keyword. This appears in the query after the HAVING section and before the ORDER BY section.

```
SELECT
 window_function() OVER(window_name)
 FROM table_name
 [HAVING ...]
 WINDOW window_name AS (
      PARTITION BY partition_expression
      ORDER BY order_expression
      window_frame_extent
 )
 [ORDER BY ...]
```

> Order by

ORDER BY is a subclause within the OVER clause. ORDER BY changes the basis on which the function assigns numbers to rows.

It is a must-have for window functions that assign sequences to rows, including RANK and ROW_NUMBER. For example, if we ORDER BY the expression `price` on an ascending order, then the lowest-priced item will have the lowest rank.

Let's compare the following two queries which differ only in the ORDER BY clause.

```
/* Rank price from LOW->HIGH */
SELECT
    product_name,
    list_price,
    RANK() OVER
       (ORDER BY list_price ASC) rank
FROM products
```

product_name	list_price	rank
Strider Classic 12 Balance Bike - 2018	89.99	1
Sun Bicycles Lil Kitt'n - 2017	109.99	2
Trek Boy's Kickster - 2015/2017	149.99	3

```
/* Rank price from HIGH->LOW */
SELECT
    product_name,
    list_price,
    RANK() OVER
       (ORDER BY list_price ASC) rank
FROM products
```

product_name	list_price	rank
Trek Domane SLR 9 Disc - 2018	11999.99	1
Trek Domane SLR 8 Disc - 2018	7499.99	2
Trek Domane SL Frameset - 2018	6499.99	3

> Partition by

We can use PARTITION BY together with OVER to specify the column over which the aggregation is performed.

Comparing PARTITION BY with GROUP BY, we find the following similarity and difference:

- Just like GROUP BY, the OVER subclause splits the rows into as many partitions as there are unique values in a column.
- However, while the result of a GROUP BY aggregates all rows, the result of a window function using PARTITION BY aggregates each partition independently. Without the PARTITION BY clause, the result set is one single partition.

For example, using GROUP BY, we can calculate the average price of bicycles per model year using the following query.

```
  SELECT
  model_year,
  AVG(list_price) avg_price
FROM products
GROUP BY model_year
```

model_year	avg_price
2016	980.29923
2017	1279.931176
2018	1658.470441
2019	2583.323333

What if we want to compare each product's price with the average price of that year? To do that, we use the AVG() window function and PARTITION BY the model year, as such.

```
  SELECT
  model_year,
  product_name,
  list_price,
  AVG(list_price) OVER
    (PARTITION BY model_year)
  avg_price
  FROM products
```

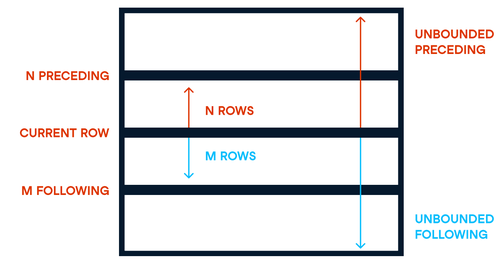
model_year	product_name	list_price	avg_price
2018	Electra Amsterdam Fashion 3i Ladies' - 2017/2018	899.99	1658.470441
2017	Electra Amsterdam Fashion 7i Ladies' - 2017	1099.99	1279.931176
2017	Electra Amsterdam Original 3i - 2015/2017	659.99	1279.931176

Notice how the avg_price of 2018 is exactly the same whether we use the PARTITION BY clause or the GROUP BY clause.

> Window frame extent

A window frame is the selected set of rows in the partition over which aggregation will occur. Put simply, they are a set of rows that are somehow related to the current row.

A window frame is defined by a lower bound and an upper bound relative to the current row. The lowest possible bound is the first row, which is known as UNBOUNDED PRECEDING. The highest possible bound is the last row, which is known as UNBOUNDED FOLLOWING. For example, if we only want to get 5 rows before the current row, then we will specify the range using 5 PRECEDING.



> Accompanying Material

You can use this https://bit.ly/3scZtOK to run any of the queries explained in this cheat sheet.

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> Ranking window functions

There are several window functions for assigning rankings to rows. Each of these functions requires an ORDER BY sub-clause within the OVER clause.

The following are the ranking window functions and their description:

Function Syntax	Function Description	Additional notes
`ROW_NUMBER()`	Assigns a sequential integer to each row within the partition of a result set.	Row numbers are not repeated within each partition.
`RANK()`	Assigns a rank number to each row in a partition.	• Tied values are given the same rank. • The next rankings are skipped.
`PERCENT_RANK()`	Assigns the rank number of each row in a partition as a percentage.	• Tied values are given the same rank. • Computed as the fraction of rows less than the current row, i.e., the rank of row divided by the largest rank in the partition.
`NTILE(n_buckets)`	Distributes the rows of a partition into a specified number of buckets.	• For example, if we perform the window function NTILE(5) on a table with 100 rows, they will be in bucket 1, rows 21 to 40 in bucket 2, rows 41 to 60 in bucket 3, et cetera.
`CUME_DIST()`	The cumulative distribution: the percentage of rows less than or equal to the current row.	• It returns a value larger than 0 and at most 1. • Tied values are given the same cumulative distribution value.

We can use these functions to rank the product according to their prices.

```
   /* Rank all products by price */
SELECT
   product_name,
   list_price,
   ROW_NUMBER() OVER (ORDER BY list_price) AS row_num,
   DENSE_RANK() OVER (ORDER BY list_price) AS dense_rank,
   RANK() OVER (ORDER BY list_price) AS rank,
   PERCENT_RANK() OVER (ORDER BY list_price) AS pct_rank,
   NTILE(75) OVER (ORDER BY list_price) AS ntile,
   CUME_DIST() OVER (ORDER BY list_price) AS cume_dist
FROM products
```

product_name	list_price	row_num	dense_rank	rank	pct_rank	ntile	cume_dist
Strider Classic 12 Balance Bike - 2018	89.99	1	1	1	0	1	0.0031152648
Sun Bicycles Lil Kitt'n - 2017	109.99	2	2	2	0.003125	1	0.0062305296
Trek Boy's Kickster - 2015/2017	149.99	3	3	3	0.00625	1	0.0124610592
Trek Girl's Kickster - 2017	149.99	4	3	3	0.00625	1	0.0124610592
Trek Kickster - 2018	159.99	5	4	5	0.0125	1	0.015576324
Trek Precaliber 12 Boys - 2017	189.99	6	5	6	0.015625	2	0.0218068536
Trek Precaliber 12 Girls - 2017	189.99	7	5	6	0.015625	2	0.0218068536

> Value window functions

FIRST_VALUE() and LAST_VALUE() retrieve the first and last value respectively from an ordered list of rows, where the order is defined by ORDER BY.

Value window function	Function
`FIRST_VALUE(value_to_return) OVER (ORDER BY value_to_order_by)`	Returns the first value in an ordered set of values
`LAST_VALUE(value_to_return) OVER (ORDER BY value_to_order_by)`	Returns the last value in an ordered set of values
`NTH_VALUE(value_to_return, n) OVER (ORDER BY value_to_order_by)`	Returns the nth value in an ordered set of values.

To compare the price of a particular bicycle model with the cheapest (or most expensive) alternative, we can use the FIRST_VALUE (or LAST_VALUE).

```
   /* Find the difference in price from
the cheapest alternative */
SELECT
  product_name,
  list_price,
  FIRST_VALUE(list_price) OVER (
     ORDER BY list_price
     ROWS BETWEEN
         UNBOUNDED PRECEDING
         AND
         UNBOUNDED FOLLOWING
     ) AS cheapest_price,
FROM products
```

product_name	list_price	cheapest_price	diff
Strider Classic 12 Balance Bike - 2018	89.99	89.99	0
Sun Bicycles Lil Kitt'n - 2017	109.99	89.99	20
Trek Boy's Kickster - 2015/2017	149.99	89.99	60
Trek Girl's Kickster - 2017	149.99	89.99	60

```
   /* Find the difference in price from
the priciest alternative */
SELECT
   product_name,
   list_price,
   LAST_VALUE(list_price) OVER (
     ORDER BY list_price
     ROWS BETWEEN
        UNBOUNDED PRECEDING
        AND
        UNBOUNDED FOLLOWING
     ) AS highest_price
FROM products
```

product_name	list_price	highest_price	diff
Strider Classic 12 Balance Bike - 2018	89.99	11999.99	11910
Sun Bicycles Lil Kitt'n - 2017	109.99	11999.99	11890
Trek Boy's Kickster - 2015/2017	149.99	11999.99	11850

> Aggregate window functions

Aggregate functions available for GROUP BY, such as COUNT(), MIN(), MAX(), SUM(), and AVG() are also available as window functions.

Function Syntax	Function Description
`COUNT(expression) OVER (PARTITION BY partition_column)`	Count the number of rows that have a non-null expression in the partition.
`MIN(expression) OVER (PARTITION BY partition_column)`	Find the minimum of the expression in the partition.
`MAX(expression) OVER (PARTITION BY partition_column)`	Find the maximum of the expression in the partition.
`AVG(expression) OVER (PARTITION BY partition_column)`	Find the mean (average) of the expression in the partition.

Suppose we want to find the average, maximum and minimum discount for each product, we can achieve it as such.

```
SELECT
   order_id,
   product_id,
   discount,
   AVG(discount) OVER (PARTITION BY product_id) AS avg_discount,
   MIN(discount) OVER (PARTITION BY product_id) AS min_discount,
   MAX(discount) OVER (PARTITION BY product_id) AS max_discount
FROM order_items
```

order_id	product_id	discount	avg_discount	min_discount	max_discount
2	16	0.05	0.113191	0.05	0.2
2	20	0.07	0.11253	0.05	0.2
3	20	0.05	0.11253	0.05	0.2
3	3	0.05	0.105581	0.05	0.2

> LEAD, LAG

The LEAD and LAG locate a row relative to the current row.

Function Syntax	Function Description
`LEAD(expression [,offset[,default_value]]) OVER(ORDER BY columns)`	Accesses the value stored in a row after the current row.
`LAG(expression [,offset[,default_value]]) OVER(ORDER BY columns)`	Accesses the value stored in a row before the current row.

Both LEAD and LAG take three arguments:

- Expression: the name of the column from which the value is retrieved
- Offset: the number of rows to skip. Defaults to 1.
- Default_value: the value to be returned if the value retrieved is null. Defaults to NULL.

With LAG and LEAD, you must specify ORDER BY in the OVER clause.

LEAD and LAG are most commonly used to find the value of a previous row or the next row. For example, they are useful for calculating the year-on-year increase of business metrics like revenue.

Here is an example of using lag to compare this year's sales to last year's.

```
   /* Find the number of orders in a year */
WITH yearly_orders AS (
   SELECT
 year(order_date) AS year,
 COUNT(DISTINCT order_id) AS num_orders
 FROM sales.orders
 GROUP BY year(order_date)
)

/* Compare this year's sales to last year's */
SELECT
   *,
   LAG(num_orders) OVER (ORDER BY year) last_year_order,
   LAG(num_orders) OVER (ORDER BY year) - num_orders diff_from_last_year
FROM yearly_orders
```

year	num_orders	last_year_order	diff_from_last_year
2016	635	null	null
2017	688	635	-53
2018	292	688	396

Similarly, we can make a comparison of each year's order with the next year's.

```
   /* Find the number of orders in a year */
WITH yearly_orders AS (
   SELECT
 year(order_date) AS year,
 COUNT(DISTINCT order_id) AS num_orders
 FROM sales.orders
 GROUP BY year(order_date)
)

/* Compare the number of years compared to next year */
SELECT *,
   LEAD(num_orders) OVER (ORDER BY year) next_year_order,
   LEAD(num_orders) OVER (ORDER BY year) - num_orders diff_from_next_year
FROM yearly_orders
```

year	num_orders	next_year_order	diff_from_next_year
2016	635	688	53
2017	688	292	-396
2018	292	null	null