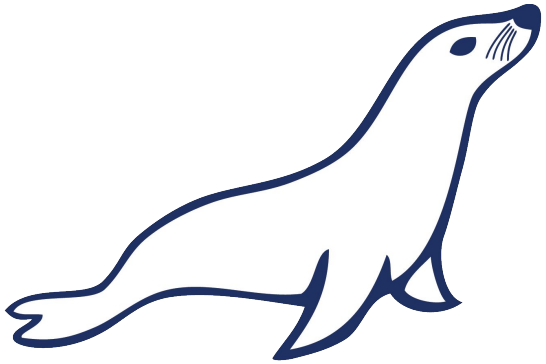

MariaDB®
FOUNDATION

Optimizer in 10.2 and 10.3

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What's new in MariaDB Optimizer

- Most features in 10.3 are additions over 10.2 features.
- Improved support / optimizations for CTEs and Window Functions

What are CTEs?

Syntax

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
)
SELECT *
FROM engineers
WHERE ...
```

What are CTEs?

Syntax

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
)
SELECT *
FROM engineers
WHERE ...
```

Keyword

What are CTEs?

Syntax

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
)
SELECT *
FROM engineers
WHERE ...
```

CTE Name

What are CTEs?

Syntax

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
)
SELECT *
FROM engineers
WHERE ...
```

CTE Body

What are CTEs?

Syntax

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
)
SELECT *
FROM engineers
WHERE ...
```

CTE Usage

What are CTEs?

CTEs are similar to derived tables.

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
)
SELECT *
FROM engineers
WHERE ...
```

```
SELECT *
FROM (SELECT *
      FROM employees
      WHERE dept=”Engineering”) AS engineers
WHERE ...
```

What are CTEs?

CTEs are more readable than derived tables.

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
),
eu_engineers AS (
      SELECT *
      FROM engineers
      WHERE country IN (”CN”,...)
)
SELECT *
FROM eu_engineers
WHERE ...
```

```
SELECT *
FROM (SELECT *
      FROM (SELECT *
            FROM employees
            WHERE dept=”Engineering”) AS engineers
      WHERE country IN (”CN”,...))
WHERE ...
```

What are CTEs?

CTEs are more readable than derived tables.

```
WITH engineers AS (
      SELECT *
      FROM employees
      WHERE dept=”Engineering”
),
eu_engineers AS (
      SELECT *
      FROM engineers
      WHERE country IN (”CN”,...)
)
SELECT *
FROM eu_engineers
WHERE ...
```

Linear View

```
SELECT *
FROM (SELECT *
      FROM (SELECT *
            FROM employees
            WHERE dept=”Engineering”) AS engineers
      WHERE country IN (”CN”,...))
WHERE ...
```

Nested View

What are CTEs?

Example: Year-over-year comparisons

```
WITH sales_product_year AS (
  SELECT
    product,
    year(ship_date) as year,
    SUM(price) as total_amt
  FROM
    item_sales
  GROUP BY
    product, year
)
```

```
SELECT *
FROM
  sales_product_year CUR,
  sales_product_year PREV,
WHERE
  CUR.product = PREV.product AND
  CUR.year = PREV.year + 1 AND
  CUR.total_amt > PREV.total_amt
```

Recursive CTEs

- MariaDB also supports recursive references to CTEs
- Makes SQL language Turing Complete
- Ability to express hierarchical queries
  - Ex. List all employees below CTO
  - We are working on supporting CONNECT BY syntax from Oracle

Recursive CTEs

```
with recursive ancestors as (
  select * from folks
  where name = 'Alex'     <--- Base (Anchor) part
  union [all]             <--- Keyword
  select f.*              <--- Recursive part
  from folks as f, ancestors AS a
  where
    f.id = a.father or f.id = a.mother
)
select * from ancestors;
```

Recursive CTEs

Step 1: Get table header and types from Anchor

```
with recursive ancestors as (
  select * from folks
  where name = 'Alex'
  union
  select f.*
  from folks as f, ancestors AS a
  where
    f.id = a.father or f.id = a.mother
)
select * from ancestors;
```

```
+------+--------------+--------+--------+
| id   | name         | father | mother |
+------+--------------+--------+--------+
```

```
+------+--------------+--------+--------+
| id   | name         | father | mother |
+------+--------------+--------+--------+
|  100 | Alex         |     20 |     30 |
|   20 | Dad          |     10 |   NULL |
|   30 | Mom          |   NULL |   NULL |
|   10 | Grandpa Bill |   NULL |   NULL |
|   98 | Sister Amy   |     20 |     30 |
+------+--------------+--------+--------+
```

Recursive CTEs

Step 2: Get values for anchor

```
with recursive ancestors as (
  select * from folks
  where name = 'Alex'
  union
  select f.*
  from folks as f, ancestors AS a
  where
    f.id = a.father or f.id = a.mother
)
select * from ancestors;
```

```
+------+--------------+--------+--------+
| id   | name         | father | mother |
+------+--------------+--------+--------+
```

id	name	father	mother
100	Alex	20	30
20	Dad	10	NULL
30	Mom	NULL	NULL
10	Grandpa Bill	NULL	NULL
98	Sister Amy	20	30

Recursive CTEs

Step 2: Get values for anchor

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with recursive ancestors as (
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+------+--------------+--------+--------+
```

```
+------+--------------+--------+--------+
| id   | name         | father | mother |
+------+--------------+--------+--------+
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+------+--------------+--------+--------+
```

Recursive CTEs

Step 3: Compute recursive iteration

```
with recursive ancestors as (
  select * from folks
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)
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|  100 | Alex         |     20 |     30 |
+------+--------------+--------+--------+
```

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| id   | name         | father | mother |
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Recursive CTEs

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Recursive CTEs

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Recursive CTEs

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30	Mom	NULL	NULL
10	Grandpa Bill	NULL	NULL
98	Sister Amy	20	30

id	name	father	mother
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20	Dad	10	NULL
30	Mom	NULL	NULL

Recursive CTEs

Step 3: Compute recursive iteration

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| id   | name         | father | mother |
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+------+--------------+--------+--------+
```

```
+------+--------------+--------+--------+
| id   | name         | father | mother |
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+------+--------------+--------+--------+
```

Recursive CTEs

Step 3: Compute recursive iteration

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)
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Recursive CTEs

Step 3: Compute recursive iteration

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with recursive ancestors as (
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  where name = 'Alex'
  union
  select f.*
  from folks as f, ancestors AS a
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    f.id = a.father or f.id = a.mother
)
select * from ancestors;
```

```
+------+--------------+--------+--------+
| id   | name         | father | mother |
+------+--------------+--------+--------+
|  100 | Alex         |     20 |     30 |
|   20 | Dad          |     10 |   NULL |
|   30 | Mom          |   NULL |   NULL |
|   10 | Grandpa Bill |   NULL |   NULL |
+------+--------------+--------+--------+
```

```
+------+--------------+--------+--------+
| id   | name         | father | moth   |
+------+--------------+--------+--------+
|  100 | Alex         |     20 |        |
|   20 | Dad          |     10 |   NULL |
|   30 | Mom          |   NULL |   NULL |
|   10 | Grandpa Bill |   NULL |   NULL |
|   98 | Sister Amy   |     20 |     30 |
+------+--------------+--------+--------+
```

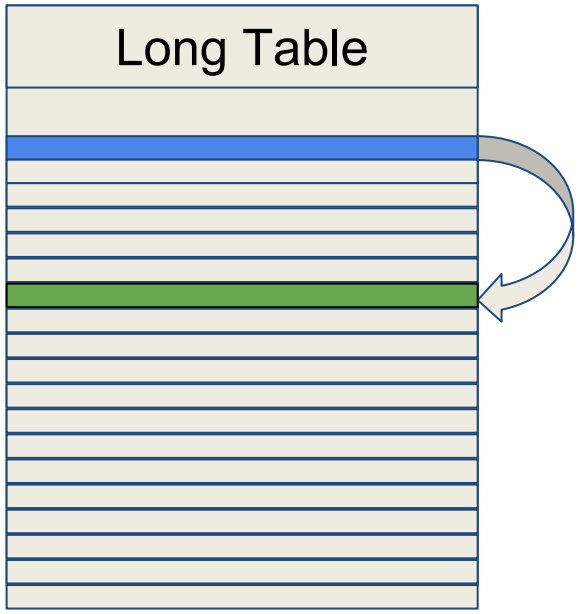
No new rows!
Done!

Summary so far

- CTEs are essentially “query local views”
- Allow for greater optimization potential than views
- Can express hierarchical queries using recursion

What can window functions do?

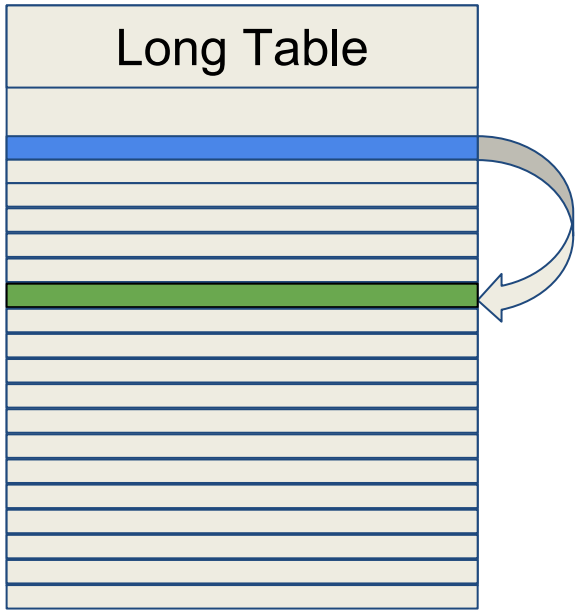
- Can access multiple rows from the current row.



What can window functions do?

- Can access multiple rows from the current row.

- Eliminate self-joins.

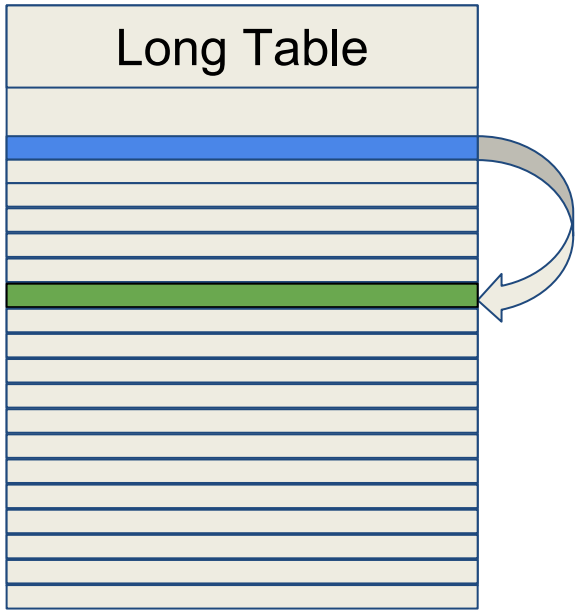


What can window functions do?

- Can access multiple rows from the current row.

- Eliminate self-joins.

- Get faster running queries.



What are window functions?

- Similar to aggregate functions
  - Computed over a sequence of rows
- But they provide one result per row
  - Like regular functions!
- Identified by the OVER clause.

What are window functions?

Similar to regular functions

```
SELECT

      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

```
+-------------------------+------------+-----------+--------------+
| email                   | first_name | last_name | account_type |
+-------------------------+------------+-----------+--------------+
| admin@boss.org          | Admin      | Boss      | admin        |
| bob.carlsen@foo.bar     | Bob        | Carlsen   | regular      |
| eddie.stevens@data.org  | Eddie      | Stevens   | regular      |
| john.smith@xyz.org      | John       | Smith     | regular      |
| root@boss.org           | Root       | Chief     | admin        |
+-------------------------+------------+-----------+--------------+
```

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over () as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

```
+------+-------------------------+------------+-----------+--------------+
| rnum | email                   | first_name | last_name | account_type |
+------+-------------------------+------------+-----------+--------------+
|    1 | admin@boss.org          | Admin      | Boss      | admin        |
|    2 | bob.carlsen@foo.bar     | Bob        | Carlsen   | regular      |
|    3 | eddie.stevens@data.org  | Eddie      | Stevens   | regular      |
|    4 | john.smith@xyz.org      | John       | Smith     | regular      |
|    5 | root@boss.org           | Root       | Chief     | admin        |
+------+-------------------------+------------+-----------+--------------+
```

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over () as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

This order is not deterministic!

rnum	email	first_name	last_name	account_type
1	admin@boss.org	Admin	Boss	admin
2	bob.carlsen@foo.bar	Bob	Carlsen	regular
3	eddie.stevens@data.org	Eddie	Stevens	regular
4	john.smith@xyz.org	John	Smith	regular
5	root@boss.org	Root	Chief	admin

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over () as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

This is also valid!

```
+------+-----------------------+------------+-----------+--------------+
| rnum | email                 | first_name | last_name | account_type |
+------+-----------------------+------------+-----------+--------------+
|    2 | admin@boss.org        | Admin      | Boss      | admin        |
|    1 | bob.carlsen@foo.bar   | Bob        | Carlsen   | regular      |
|    3 | eddie.stevens@data.org| Eddie      | Stevens   | regular      |
|    5 | john.smith@xyz.org    | John       | Smith     | regular      |
|    4 | root@boss.org         | Root       | Chief     | admin        |
+------+-----------------------+------------+-----------+--------------+
```

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over () as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

And this one...

```
+------+-----------------------+------------+-----------+--------------+
| rnum | email                 | first_name | last_name | account_type |
+------+-----------------------+------------+-----------+--------------+
|    5 | admin@boss.org        | Admin      | Boss      | admin        |
|    4 | bob.carlsen@foo.bar   | Bob        | Carlsen   | regular      |
|    3 | eddie.stevens@data.org| Eddie      | Stevens   | regular      |
|    2 | john.smith@xyz.org    | John       | Smith     | regular      |
|    1 | root@boss.org         | Root       | Chief     | admin        |
+------+-----------------------+------------+-----------+--------------+
```

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over (ORDER BY email) as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

Now only this one is valid!

```
+------+-----------------------+------------+-----------+--------------+
| rnum | email                 | first_name | last_name | account_type |
+------+-----------------------+------------+-----------+--------------+
|    1 | admin@boss.org        | Admin      | Boss      | admin        |
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```

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over (ORDER BY email) as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY email;
```

How do we "group" by account type?

rnum	email	first_name	last_name	account_type
1	admin@boss.org	Admin	Boss	admin
2	bob.carlsen@foo.bar	Bob	Carlsen	regular
3	eddie.stevens@data.org	Eddie	Stevens	regular
4	john.smith@xyz.org	John	Smith	regular
5	root@boss.org	Root	Chief	admin

What are window functions?

Let's start with a "function like" example

```
SELECT
      row_number() over (PARTITION BY account_type ORDER BY email) as rnum,
      email, first_name,
      last_name, account_type
FROM users
ORDER BY account_type, email;
```

row_number() resets for every partition

```
+------+-----------------------+------------+-----------+--------------+
| rnum | email                 | first_name | last_name | account_type |
+------+-----------------------+------------+-----------+--------------+
|    1 | admin@boss.org        | Admin      | Boss      | admin        |
|    2 | root@boss.org         | Root       | Chief     | admin        |
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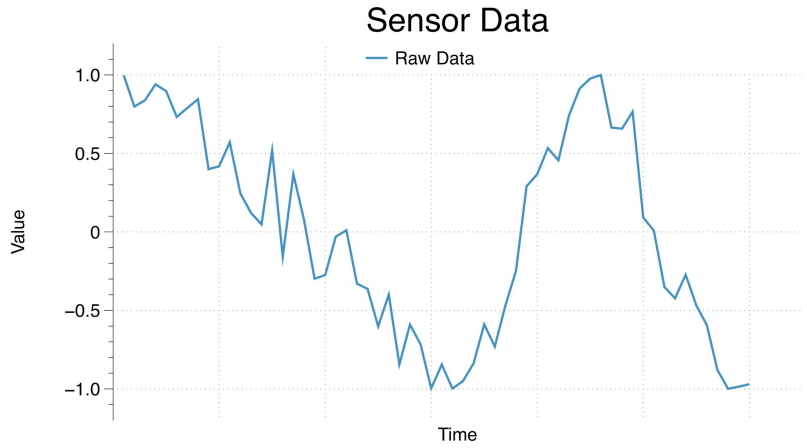
+------+-----------------------+------------+-----------+--------------+
```

What are window functions?

How about that aggregate similarity?

```
SELECT
      time, value
FROM data_points
ORDER BY time;
```



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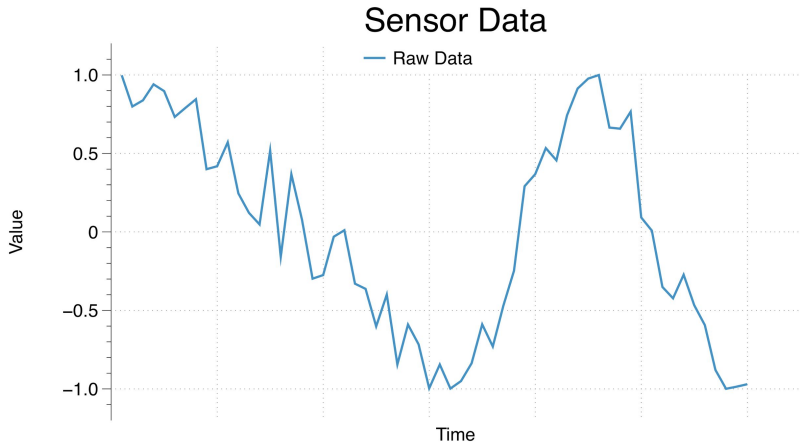
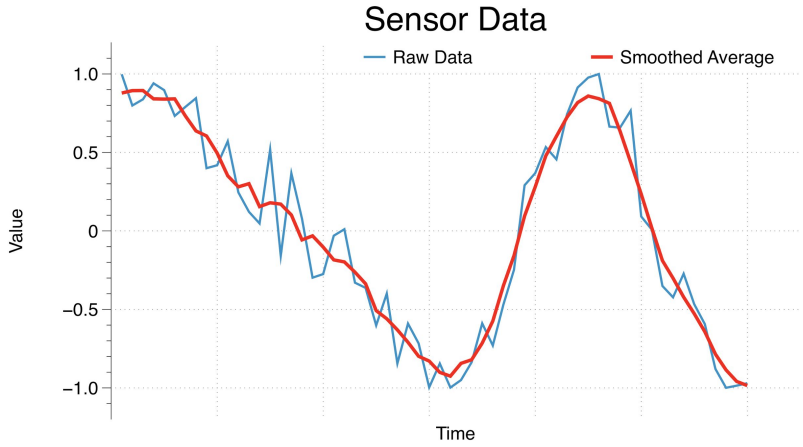



```
SELECT
      time, value
      avg(value) over (ORDER BY time
                                      ),
FROM data_points
ORDER BY time;
```



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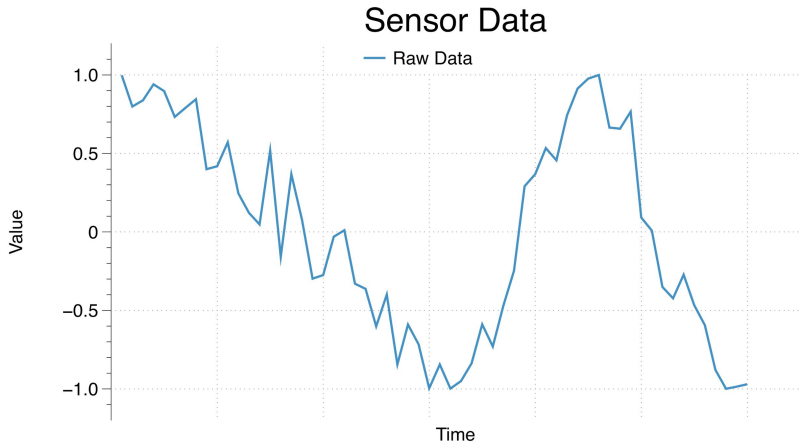
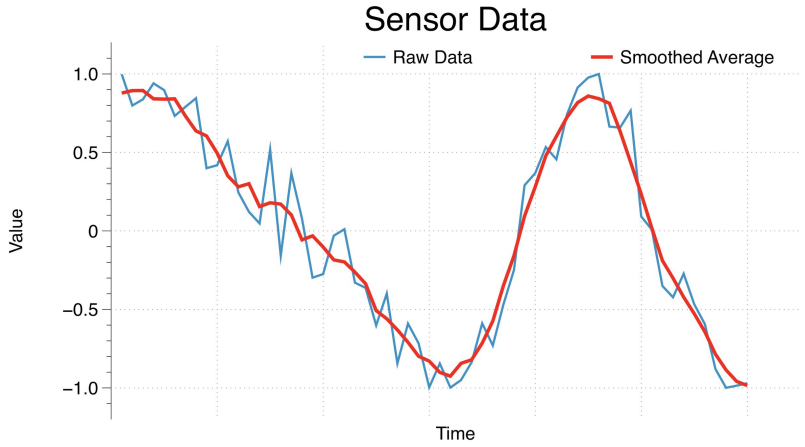


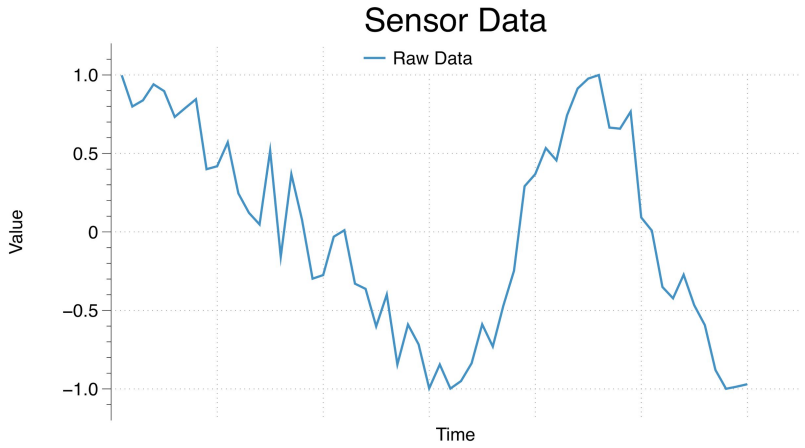

```
SELECT
      time, value
      avg(value) over (ORDER BY time
                       ROWS BETWEEN 3 PRECEDING
                                AND 3 FOLLOWING),
FROM data_points
ORDER BY time;
```



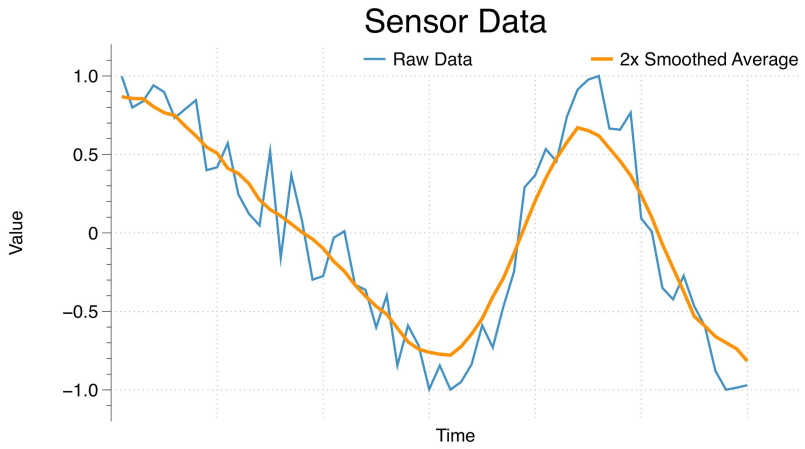
What are window functions?

How about that aggregate similarity?

```
SELECT
      time, value
FROM data_points
ORDER BY time;
```




```
SELECT
      time, value
      avg(value) over (ORDER BY time
                       ROWS BETWEEN 6 PRECEDING
                                AND 6 FOLLOWING),
FROM data_points
ORDER BY time;
```



Window Functions in MariaDB

- We support in 10.2:
  - ROW_NUMBER, RANK, DENSE_RANK, PERCENT_RANK, CUME_DIST, NTILE
  - FIRST_VALUE, LAST_VALUE, NTH_VALUE, LEAD, LAG
  - All regular aggregate functions except GROUP_CONCAT

Window Functions in MariaDB

- In 10.3 we (will) support:
  - Advanced window functions such as: PERCENTILE_CONT, PERCENTILE_DISC, MEDIAN
  - Feature parity with ColumnStore engine.
  - Performance optimizations for MIN/MAX when result sets are already ordered. (To be pushed before 10.3 is Beta)