Histogram Support in MySQL 8.0

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Program Agenda

1. Motivating example
2. Quick start guide
3. How are histograms used?
4. Query example
5. Some advice
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Motivating Example

JOIN Query

EXPLAIN SELECT *
FROM orders JOIN customer ON o_custkey = c_custkey
WHERE o_orderdate < '1993-01-01' AND c_acctbal < -1000;

<table>
<thead>
<tr>
<th>id</th>
<th>select type</th>
<th>table</th>
<th>type</th>
<th>possible keys</th>
<th>key</th>
<th>key len</th>
<th>ref</th>
<th>rows</th>
<th>filtered</th>
<th>extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SIMPLE</td>
<td>orders</td>
<td>ALL</td>
<td>i_o_orderdate, i_o_custkey</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>15000000</td>
<td>31.19</td>
<td>Using where</td>
</tr>
<tr>
<td>1</td>
<td>SIMPLE</td>
<td>customer</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>4</td>
<td>dbt3.orders.o_custkey</td>
<td>1</td>
<td>33.33</td>
<td>Using where</td>
</tr>
</tbody>
</table>
Motivating Example

Reverse join order

EXPLAIN SELECT /*+ JOIN_ORDER(customer, orders) */ *
FROM orders JOIN customer ON o_custkey = c_custkey
WHERE o_orderdate < '1993-01-01' AND c_acctbal < -1000;

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<td>orders</td>
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<td>i_o_orderdate, i_o_custkey</td>
<td>i_o_custkey</td>
<td>5</td>
<td>dbt3. customer. c_custkey</td>
<td>15</td>
<td>31.19</td>
<td>Using where</td>
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</table>
Comparing Join Order

Performance

Query Execution Time (seconds)

- orders → customer
- customer → orders
Histograms

Create histogram to get a better plan

ANALYZE TABLE customer UPDATE HISTOGRAM ON c_acctbal WITH 1024 BUCKETS;

EXPLAIN SELECT *
FROM orders JOIN customer ON o_custkey = c_custkey
WHERE o_orderdate < '1993-01-01' AND c_acctbal < -1000;

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Histograms

Column statistics

• Information about value distribution for a column
• Data values group in buckets
  – Frequency calculated for each bucket
  – Maximum 1024 buckets
• May use sampling to build histogram
  – Sample rate depends on available memory
• Automatically chooses between two histogram types:
  – Singleton: One value per bucket
  – Equi-height: Multiple values per bucket
Singleton Histogram

- One value per bucket
- Each bucket stores:
  - Value
  - Cumulative frequency
- Well suited to estimate both equality and range predicates
Equi-Height Histogram

- Multiple values per bucket
- Not quite equi-height
  - Values are not split across buckets
    ⇒ Frequent values in separate buckets
- Each bucket stores:
  - Minimum value
  - Maximum value
  - Cumulative frequency
  - Number of distinct values
- Best suited for range predicates
Usage

• Create or refresh histogram(s) for column(s):

  \texttt{ANALYZE TABLE table UPDATE HISTOGRAM ON column [, column] WITH n BUCKETS;}
  
  – Note: Will only update histogram, not other statistics

• Drop histogram:

  \texttt{ANALYZE TABLE table DROP HISTOGRAM ON column [, column];}

• Based on entire table or sampling:

  – Depends on avail. memory: \texttt{histogram\_generation\_max\_mem\_size} (default: 20 MB)

• New storage engine API for sampling

  – Default implementation: Full table scan even when sampling
  – Storage engines may implement more efficient sampling
Storage

• Stored in a JSON column in data dictionary
• Can be inspected in Information Schema table:

```sql
SELECT JSON_PRETTY(histogram)
FROM information_schema.column_statistics
WHERE schema_name = 'dbt3_sf1'
  AND table_name = 'lineitem'
  AND column_name = 'l_linenumber';
```
Histogram content

```json
{
  "buckets": [[1, 0.24994938524948698], [2, 0.46421066400720523], [3, 0.6427401784471978], [4, 0.7855470933802572], [5, 0.8927398868395817], [6, 0.96423707532558], [7, 1]],
  "data-type": "int",
  "null-values": 0.0,
  "collation-id": 8,
  "last-updated": "2018-02-03 21:05:21.690872",
  "sampling-rate": 0.20829115437457252,
  "histogram-type": "singleton",
  "number-of-buckets-specified": 1024
}```
Strings

• Max. 42 characters considered
• Base64 encoded

```
SELECT FROM_BASE64(SUBSTR(v, LOCATE(':', v, 10) + 1)) value, c cumulfreq
FROM information_schema.column_statistics,
  JSON_TABLE(histogram->'$.buckets', '[$*']
    COLUMNS(v VARCHAR(60) PATH '$[0]',
             c double PATH '$[1]')
  ) hist
WHERE column_name = 'o_orderstatus';
```

| value | cumulfreq |
|-------+-----------|
| F     | 0.4862529264385756 |
| O     | 0.974029654577566  |
| P     | 0.9999999999999999 |

16
Calculate Bucket Frequency

Use window function

```
SELECT FROM_BASE64(SUBSTR(v, LOCATE(': ', v, 10) + 1)) value, c cumulfreq,
   c - LAG(c, 1, 0) over () freq
FROM information_schema.column_statistics,
    JSON_TABLE(histogram->'$.buckets', '[$*]'  
      COLUMNS(v VARCHAR(60) PATH '$[0]',
               c double PATH '$[1]')) hist
WHERE column_name = 'o_orderstatus';
```

<table>
<thead>
<tr>
<th>value</th>
<th>cumulfreq</th>
<th>freq</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>0.4862529264385756</td>
<td>0.4862529264385756</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0.974029654577566</td>
<td>0.48777672813899037</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.9999999999999999</td>
<td>0.025970345422433927</td>
<td></td>
</tr>
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When are Histograms useful?

Estimate cost of join

- \( t_x \) JOIN \( t_{x+1} \)

- \( \text{records}(t_{x+1}) = \text{records}(t_x) \times \text{condition_filter_effect} \times \text{records_per_key} \)
How to Calculate Condition Filter Effect, MySQL 5.7

```
SELECT *
FROM office JOIN employee ON office.id = employee.office_id
WHERE office_name = 'San Francisco' AND
    employee.name = 'John' AND age > 21 AND
    hire_date BETWEEN '2014-01-01' AND '2014-06-01';
```

Filter estimate based on what is available:

1. Range estimate
2. Index statistics
3. Guesstimate

<table>
<thead>
<tr>
<th>Condition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>0.1</td>
</tr>
<tr>
<td>&lt;=, &lt;, &gt;, &gt;=</td>
<td>1/3</td>
</tr>
<tr>
<td>BETWEEN</td>
<td>1/9</td>
</tr>
<tr>
<td>NOT &lt;op&gt;</td>
<td>1 – SEL(&lt;op&gt;)</td>
</tr>
<tr>
<td>AND</td>
<td>P(A and B) = P(A) * P(B)</td>
</tr>
<tr>
<td>OR</td>
<td>P(A or B) = P(A) + P(B) – P(A and B)</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
How to Calculate Condition Filter Effect, MySQL 5.7

Filter estimate based on what is available:

1. Range estimate
2. Index statistics
3. Histograms
4. Guesstimate

SELECT *
FROM office JOIN employee ON office.id = employee.office_id
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= 0.1
<=,<,>,>= 1/3
BETWEEN 1/9
NOT <op> 1 - SEL(<op>)
AND P(A and B) = P(A) * P(B)
OR P(A or B) = P(A) + P(B) - P(A and B)
...
...
Calculating Condition Filter Effect for Tables

Example without histograms

SELECT *
FROM office JOIN employee ON office.id = employee.office_id
WHERE office_name = 'San Francisco' AND
  employee.name = 'John' AND age > 21 AND
  hire_date BETWEEN '2014-01-01' AND '2014-06-01';

Condition filter effect for tables:
- office: 0.03
- employee: 0.29 * 0.1 * 0.33 ≈ 0.01
Calculating Condition Filter Effect for Tables

Example with histogram

```sql
SELECT *
FROM office JOIN employee ON office.id = employee.office_id
WHERE office_name = 'San Francisco' AND
  employee.name = 'John' AND age > 21 AND
  hire_date BETWEEN '2014-01-01' AND '2014-06-01';
```

Condition filter effect for tables:

- office: 0.03
- employee: $0.29 \times 0.1 \times 0.95 \approx 0.03$
Computing Selectivity From Histogram

Example

- age <= 21
  Selectivity = 0.203 + (0.306 – 0.203) * 5/8 = 0.267

- age > 21
  Selectivity = 1 - 0.267 = 0.733
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DBT-3 Query 7
Volume Shipping Query

SELECT supp_nation, cust_nation, l_year, SUM(volume) AS revenue
FROM (SELECT n1.n_name AS supp_nation, n2.n_name AS cust_nation,
     EXTRACT(YEAR FROM l_shipdate) AS l_year,
     l_extendedprice * (1 - l_discount) AS volume
     FROM supplier, lineitem, orders, customer, nation n1, nation n2
     WHERE s_suppkey = l_suppkey AND o_orderkey = l_orderkey
     AND c_custkey = o_custkey AND s_nationkey = n1.n_nationkey
     AND c_nationkey = n2.n_nationkey
     AND ((n1.n_name = 'RUSSIA' AND n2.n_name = 'FRANCE')
     OR (n1.n_name = 'FRANCE' AND n2.n_name = 'RUSSIA'))
     AND l_shipdate BETWEEN '1995-01-01' AND '1996-12-31') AS shipping
GROUP BY supp_nation, cust_nation, l_year
ORDER BY supp_nation, cust_nation, l_year;
DBT-3 Query 7

Query plan without histogram
DBT-3 Query 7
Query plan with histogram
DBT-3 Query 7

Performance

Query Execution Time (seconds)

- Without histogram
- With histogram
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Some advice

Which columns to create histograms for?

• Histograms are useful for columns that are
  – not the first column of any index, and
  – used in WHERE conditions of
    • JOIN queries
    • Queries with IN-subqueries
    • ORDER BY ... LIMIT queries

• Best fit
  – Low cardinality columns (e.g., gender, orderStatus, dayOfWeek, enums)
  – Columns with uneven distribution (skew)
  – Stable distribution (do not change much over time)
Some more advice

• When not to create histograms:
  – First column of an index
  – Never used in WHERE clause
  – Monotonically increasing column values (e.g. date columns)
    • Histogram will need frequent updates to be accurate
    • Consider to create index

• How many buckets?
  – If possible, enough to get a singleton histogram
  – For equi-height, 100 buckets should be enough
More information

• MySQL Server Team blog
  – http://mysqlserverteam.com/

• My blog:
  – http://oysteing.blogspot.com/

• MySQL forums:
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