Efficient Mergeable Quantile Sketches using Moments

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Analytics on Heterogeneous Data

Per-device streams
Aggregation over time
5-minute windows

Efficient Mergeable Quantile Sketches

Quantile query
Aggregation over devices

- Monitoring: Users want to model distributions
- Billions of events daily, and hundreds of thousands of device types
- Advanced queries are bottlenecked on the ability to aggregate results over specific subgroups

Existing sketches: slow (microsecond) merges, accumulates over millions of merges

Query Model

**Aggregate Quantile Queries:**

\[
\text{select percentile(latency, 99)}
\]

from requests where app_version = "v7" and dt > date_sub(date(), 2 week)

\[
t_{\text{query}} = t_{\text{merge}} \cdot n_{\text{merge}} + t_{\text{est}}
\]

**Aggregate Threshold Queries:**

\[
\text{select percentile(latency, 99) AS p99}
\]

from requests where p99 > 100 group by app_version, hw_model

\[
t_{\text{query}} = t_{\text{merge}} \cdot n_{\text{merge}} + t_{\text{est}} \cdot n_{\text{groups}}
\]

Sketching Moments

\[
\min \quad \max \quad \text{count} \quad \sum x \quad \sum x^2 \quad \ldots \quad \sum \ln(x) \quad \ldots
\]

- \(k_a\) Moments
- \(k_b\) Log Moments

Efficient Quantile Estimation

Given: Moments

Estimate: Distribution

Maximum Entropy Principle:

Solve for least-informative distribution given constraints

\[
f(x) = \exp \left(\sum_{i=0}^{k_a} \lambda_i x^i + \sum_{i=1}^{k_b} \lambda_i \log(x^i)\right)
\]

Convex optimization problem can be solved in < 30 ms:

- Chebyshev polynomials for stability
- Fast numeric integration => Fast Newton’s method

Cascades for Threshold Queries:

When estimating over many groups, use progressively more expensive estimates:

- Markov
- Racz (Chebyshev-Stieltjes)
- Difference Detection*
- Max Entropy

Results

Merge throughput c.f. sketches with similar error:

Druid In-memory database Integration:

- Pre-aggregate groups of 100 rows
- Quantile query time over whole population