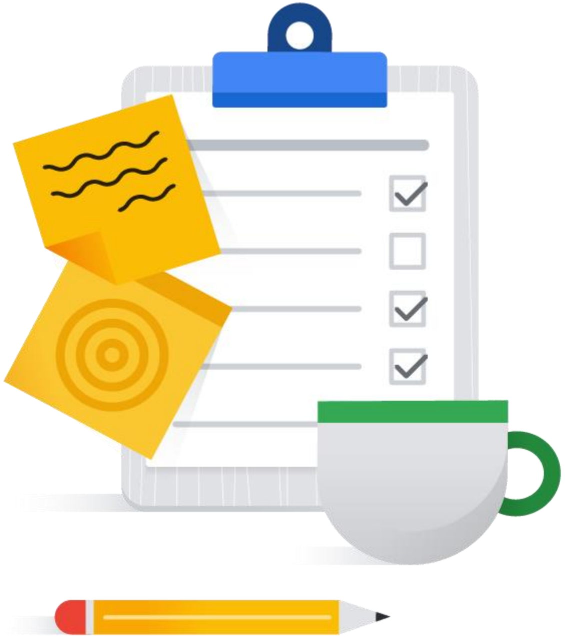
Query Processing and Optimization

06

Google Cloud

Topics

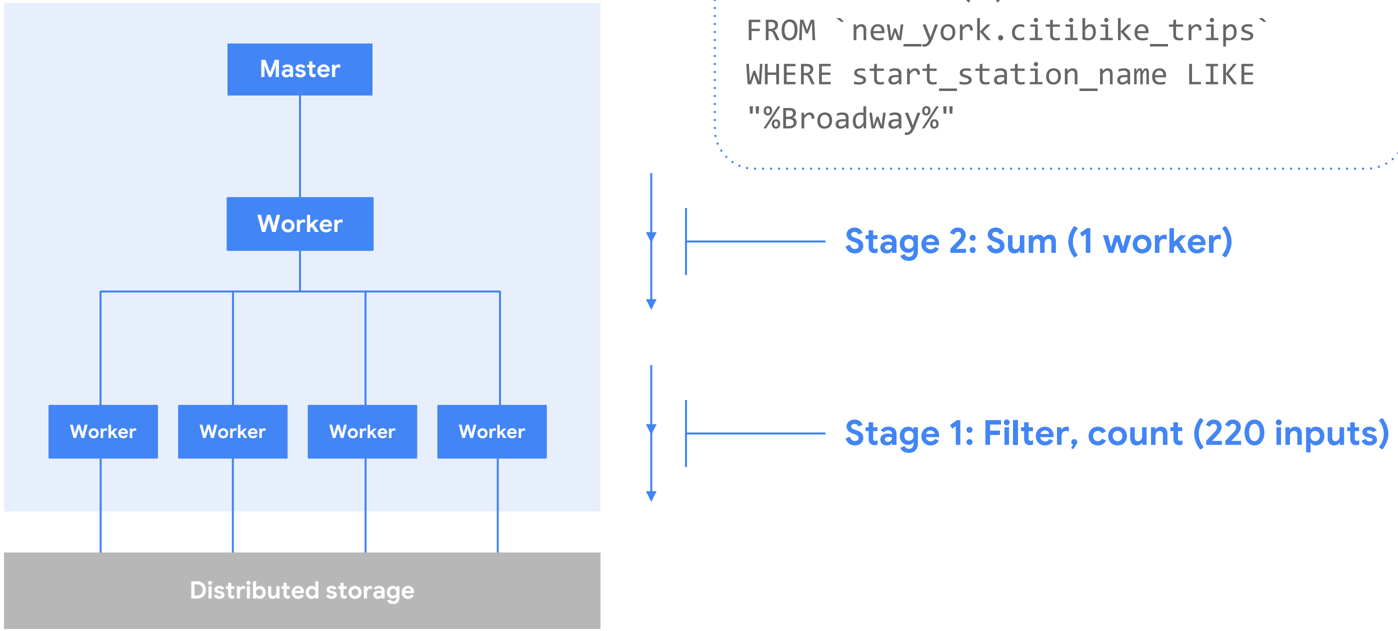
01	Simple Query Execution
02	SELECTs and Aggregation
03	JOINs and Skewed JOINs
04	Filtering and Ordering
05	Best Practices for Functions



01

Simple Query Execution

Simple query execution




```
SELECT COUNT(*)
FROM `new_york.citibike_trips`
WHERE start_station_name LIKE
"%Broadway%"
```

Demo

Simple query execution

Query plan, stages, and metrics

Interpreting the query plan

- **Is there a significant difference between avg and max time?**
  - There is probably a data skew; use APPROX_TOP_COUNT to check.
  - Filter early to work around.
- **Most time is spent reading from intermediate stages.**
  - Consider filtering earlier in the query.
- **Most time is spent on CPU tasks.**
  - Consider approximate functions, inspect UDF usage, filter earlier.

How do you optimize queries?

Less work ⟶ Faster query

What is **work** for a query?

- **I/O** — How many bytes did you read?
- **Shuffle** — How many bytes did you pass to the next stage?
- **Grouping** — How many bytes do you pass to each group?
- **Materialization** — How many bytes did you write?
- **CPU work** — User-defined functions (UDFs), functions

02

SELECTs and Aggregations

SELECTs

Optimization: Necessary columns only

Original code

```
select
  *
from
`dataset.table`
```

Optimized

```
select
  * EXCEPT (dim1, dim2)
from
`dataset.table`
```

Reasoning

Only select the columns necessary, especially in inner queries. **SELECT** * is cost-inefficient and may also hurt performance.

If the number of columns to return is large, consider using **SELECT** * **EXCEPT** to exclude unneeded columns.

In some use cases, **SELECT** * **EXCEPT** may be necessary.

Recap: Auto-pruning with partitioning and clustering

Partitioned table

Table info

Table ID	fh-bigquery:wikipedia_v2.pageviews_2017
Table size	2.2 TB
Long-term storage size	2.2 TB
Number of rows	54,489,325,868
Created	Feb 27, 2018, 1:54:41 AM
Table expiration	Never
Last modified	Feb 27, 2018, 4:47:50 AM
Data location	US
Table type	Partitioned
Partitioned by	Day
Partitioned on field	datehour
Partition filter	Required

Partitioned and clustered table

Table info

Table ID	fh-bigquery:wikipedia_v3.pageviews_2017
Table size	2.2 TB
Long-term storage size	2.2 TB
Number of rows	54,489,325,868
Created	Aug 1, 2018, 1:24:57 AM
Table expiration	Never
Last modified	Aug 2, 2018, 8:50:32 PM
Data location	US
Table type	Partitioned
Partitioned by	Day
Partitioned on field	datehour
Partition filter	Required
Clustered by	wiki, title

Recap: Auto-pruning with partitioning and clustering

Partitioned table by datehour

```
SELECT *
FROM `fh-bigquery.wikipedia_v2.pageviews_2017`
WHERE DATE(datehour) BETWEEN '2017-06-01'
AND '2017-06-30'
LIMIT 1
```

1.7 sec elapsed, 180 GB processed

Partitioned table by datehour
Clustered table by wiki, title

```
SELECT *
FROM `fh-bigquery.wikipedia_v3.pageviews_2017`
WHERE DATE(datehour) BETWEEN '2017-06-01'
AND '2017-06-30'
LIMIT 1
```

1.8 sec elapsed, 16 MB processed

Nest repeated data

- **Customers often default to “flat” denormalization even if it is not the most beneficial.**
  - Requires a GROUP BY to analyze data.

- **Example: Orders table with a row for each line item**
  - `{order_id1, item_id1}, {order_id1, item_id2}, …`

- **If you model one order per row and nest line items in a nested field, GROUP BY is no longer required.**
  - `{order_id1, [ {item_id1}, {item_id2} ] }`

Query cache

Hash of

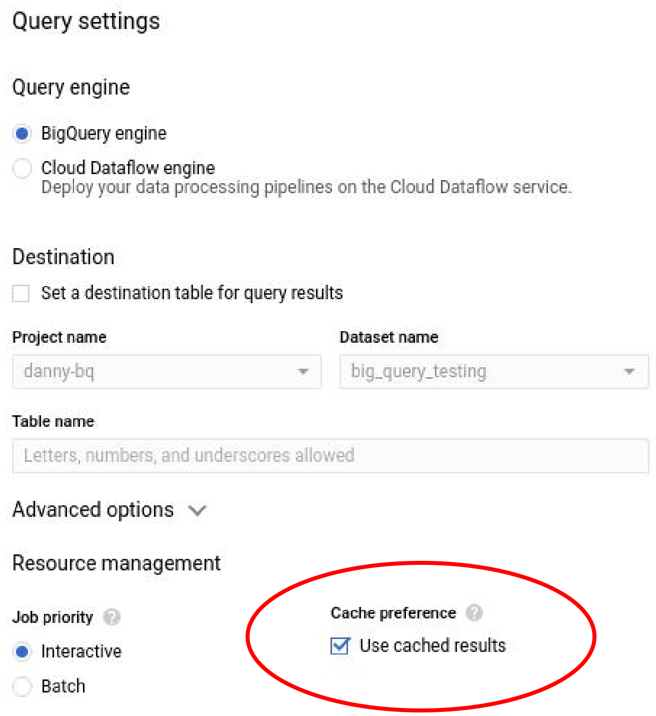
- Data modification times
- Tables used
- Query string

Cache skipped if

- Referenced tables or views have changed
- Non-deterministic function used (e.g., NOW())
- Permanent result table requested
- Source tables have streaming buffers

Hash becomes output table name

- Cache is per-user



Aggregation

Optimization: Late aggregation

Original code

```
select
  t1.dim1,
  sum(t1.m1),
  sum(t2.m2)
from (select
    dim1,
    sum(metric1) m1
  from `dataset.table1` group by 1) t1
join (select
    dim1,
    sum(metric2) m2
  from `dataset.table2` group by 1) t2
on t1.dim1 = t2.dim1
group by 1;
```

Optimized

```
select
  t1.dim1,
  sum(t1.m1),
  sum(t2.m2)
from (select
    dim1,
    metric1 m1
  from `dataset.table1`) t1
join (select
    dim1,
    metric2 m2
  from `dataset.table2`) t2
on t1.dim1 = t2.dim1
group by 1;
```

Reasoning

Aggregate as late and as seldom as possible because **aggregation is very costly**.

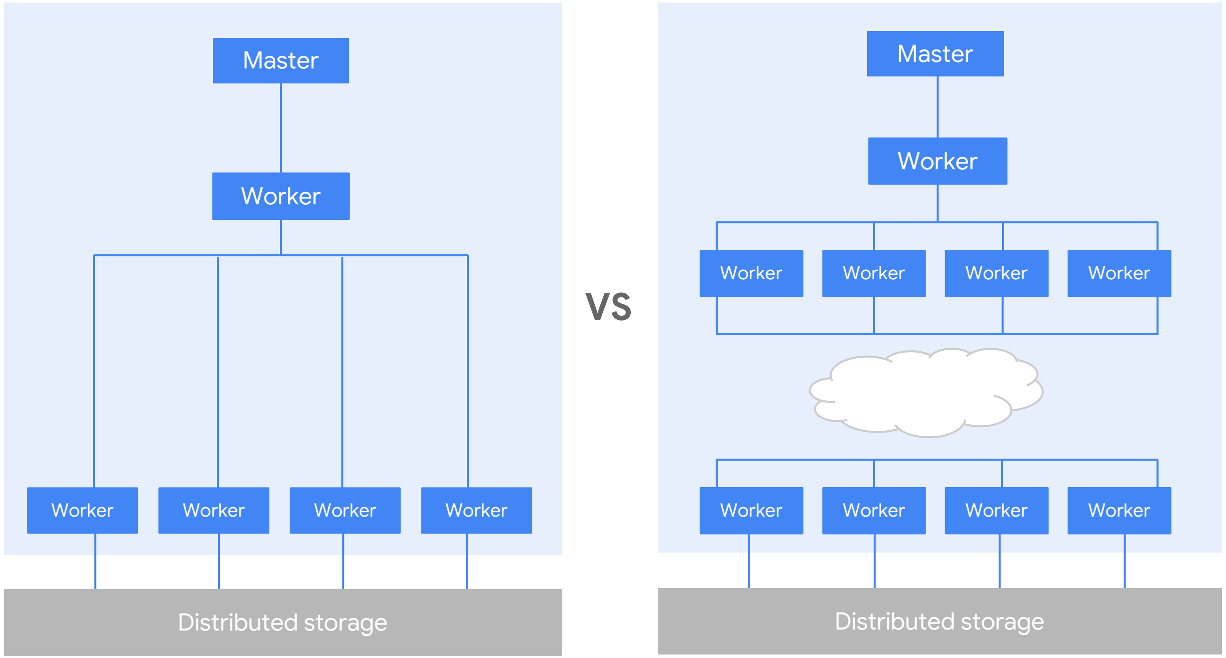
BUT *if a table can be reduced drastically by aggregation in preparation for being joined, then aggregate it early.*

Caution: With JOINS, this only works if the two tables are already aggregated to the same level (i.e., if there is only one row for every join key value).

Shuffle aggregation execution

```
SELECT language, MAX(views)
as views
FROM
`wikipedia_benchmark.Wiki1B`
WHERE title LIKE "G%o%"
GROUP BY 1 ORDER BY 2 DESC
LIMIT 100
```

Simple select query VS Aggregation query



Stage 3: SORT, LIMIT (1 worker)

Stage 2: GROUP BY, SORT, LIMIT (289 workers)

Shuffle

Stage 1: Partial GROUP BY (40,859 sinks)

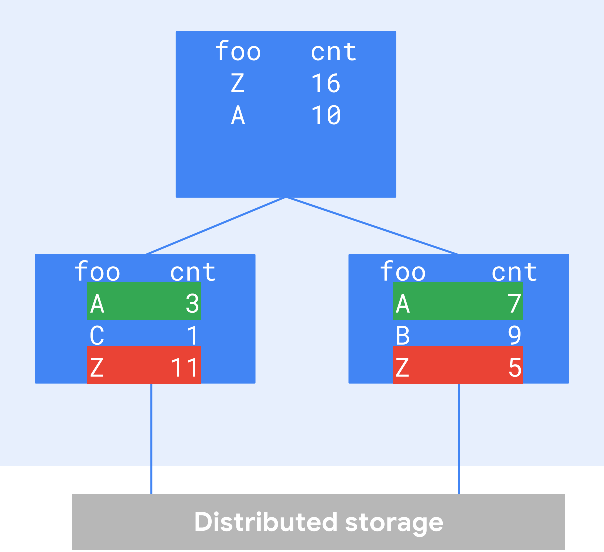
Demo

Aggregation with shuffle query plan

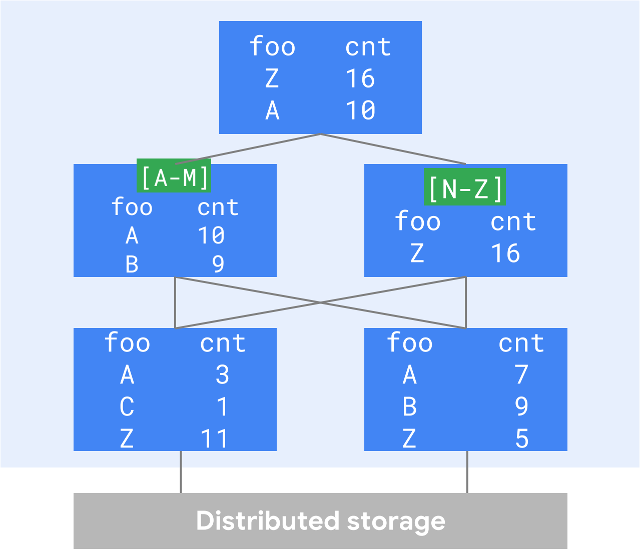
Query plan, stages, and metrics

Aggregation with high cardinality

Without shuffle (non-BQ)



With Shuffle (BQ)

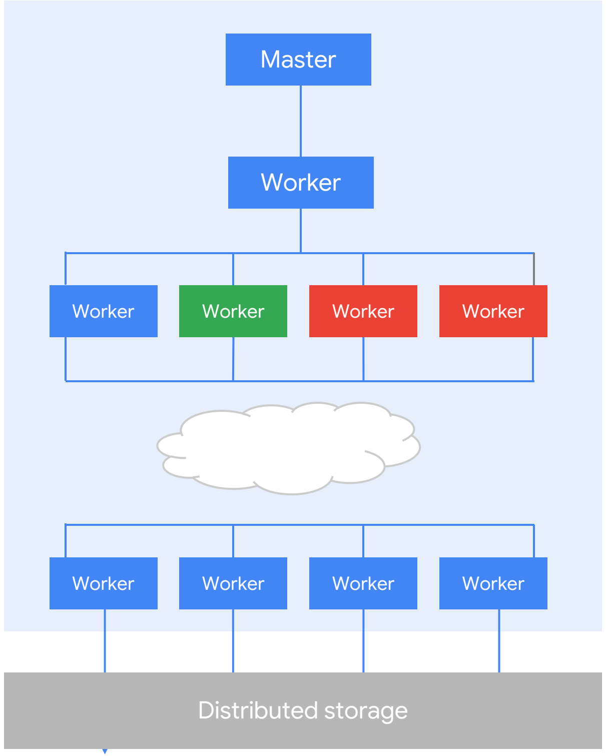



```
SELECT foo,
COUNT(*) as cnt
FROM `...`
GROUP BY 1
ORDER BY 2 DESC
LIMIT 2
```

- Can’t discard “B” or “C” until after all previous stages are complete.

- Shuffle puts like values in the same node.
- Scalable because you never have to return more than *N* from each node in middle tier.

Repartitioning



SELECT title FROM Wiki10B
GROUP BY title ORDER BY title
LIMIT 1000

Stage 2 (X workers)
Stage 2.1 (Y workers)
Stage 2.2 (Z workers)

Shuffle

Stage 1: Read

Demo

Repartitioning

Query plan, stages, and metrics

03

JOINs and Skewed JOINs

JOINs

Optimization: JOIN pattern

Original code

```
select
  t1.dim1,
  sum(t1.metric1),
  sum(t2.metric2)
from
  small_table t1
join
  large_table t2
on
  t1.dim1 = t2.dim1
where t1.dim1 = 'abc'
group by 1;
```

Optimized

```
select
  t1.dim1,
  sum(t1.metric1),
  sum(t2.metric2)
from
  large_table t2
join
  small_table t1
on
  t1.dim1 = t2.dim1
where t1.dim1 = 'abc'
group by 1;
```

Reasoning

When you create a query by using a JOIN, consider the **order** in which you are merging the data. The standard SQL query optimizer can determine which table should be on which side of the join, but we still recommend that you order your joined tables appropriately.

The best practice is to manually **place the largest table first**, followed by the smallest, and then by decreasing size. Only under specific table conditions does BigQuery automatically reorder/optimize based on table size.

Optimization: Filter before JOINs

Original code

```
select
  t1.dim1,
  sum(t1.metric1),
  sum(t2.metric3)
from
  `dataset.table1` t1
left join
  `dataset.table2` t2
on
  t1.dim1 = t2.dim1
where t2.dim2 = 'abc'
group by 1;
```

Optimized

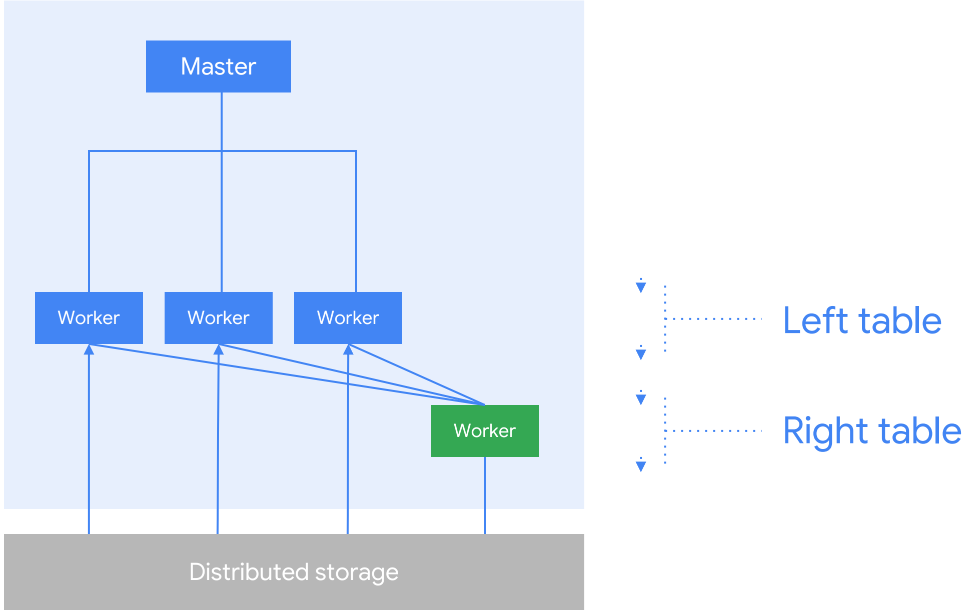
```
select
  t1.dim1,
  sum(t1.metric1),
  sum(t2.metric3)
from
  `dataset.table1` t1
left join
  `dataset.table2` t2
on
  t1.dim1 = t2.dim1
where t1.dim2 = 'abc' AND t2.dim2 = 'abc'
group by 1;
```

Reasoning

WHERE clauses should be executed **as soon as possible, especially within joins**, so the tables to be joined are as small as possible.

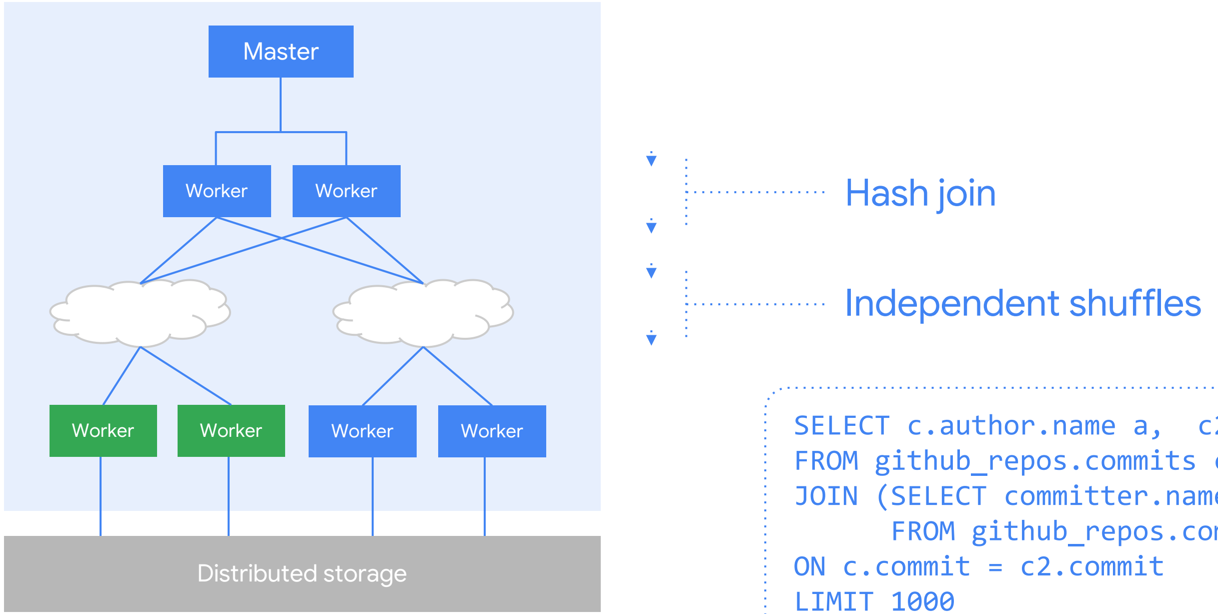
WHERE clauses may not always be necessary, because standard SQL will do its best to push down filters. Review the explanation plan to see whether filtering is happening as early as possible, and either fix the condition or use a subquery to filter in advance.

Small JOIN (broadcast)




```sql
SELECT
  c.author.name a, c2.a m
FROM github_repos.commits c
JOIN (
  SELECT
     committer.name a,
     commit
  FROM github_repos.commits) c2
ON
  c.commit = c2.commit
WHERE c2.a = 'tom'
LIMIT 1000
```

Large JOIN (shuffle)




```
SELECT c.author.name a,  c2.a m
FROM github_repos.commits c
JOIN (SELECT committer.name a, commit
      FROM github_repos.commits) c2
ON c.commit = c2.commit
LIMIT 1000
```

Demo

Broadcast JOIN and Shuffle JOIN

Query plan, stages, and metrics

JOIN optimization with clustered tables

Subquery titles (“Animated_**Google**”, ”A_**Google**_A_Day”, etc.) are used to filter table `pageviews_2017` **BEFORE** joining.

```
SELECT
  tbl2017.*
FROM
`wikipedia_v3.pageviews_2017` tbl2017
JOIN(SELECT * FROM
      `wikipedia_vt.just_latest_rows`
      WHERE
        REGEXP_CONTAINS(title, "Google"))
USING(title)
WHERE
  DATE(tbl2017.datehour)
  BETWEEN '2017-06-01' AND '2017-06-30'
```

Query complete (0.8 sec elapsed, 21.1 MB processed)

Job information | Results | JSON | Execution details

Row	datehour	wiki	title	views
1	2018-10-22 16:00:00 UTC	en	Animated_Google	1
2	2018-10-23 14:00:00 UTC	en	Alphabet_(Google)	1
3	2018-10-24 23:00:00 UTC	en	Actions_on_Google	1
4	2018-10-24 23:00:00 UTC	en	Authors_Guild,_Inc._v._Google,_Inc.	2
5	2018-10-22 15:00:00 UTC	en	Acquisitions_by_Google	1
6	2018-10-23 02:00:00 UTC	en	Adblock_Plus_for_Google_Chrome	1
7	2018-10-23 15:00:00 UTC	en	Accomplished_Googlebombs	1
8	2018-10-24 16:00:00 UTC	en	Are_You_Smart_Enough_to_Work_at_Google?	1
9	2018-10-24 21:00:00 UTC	en	Authors_Guild_v._Google	1
10	2018-10-24 21:00:00 UTC	en	A_Google_A_Day	1

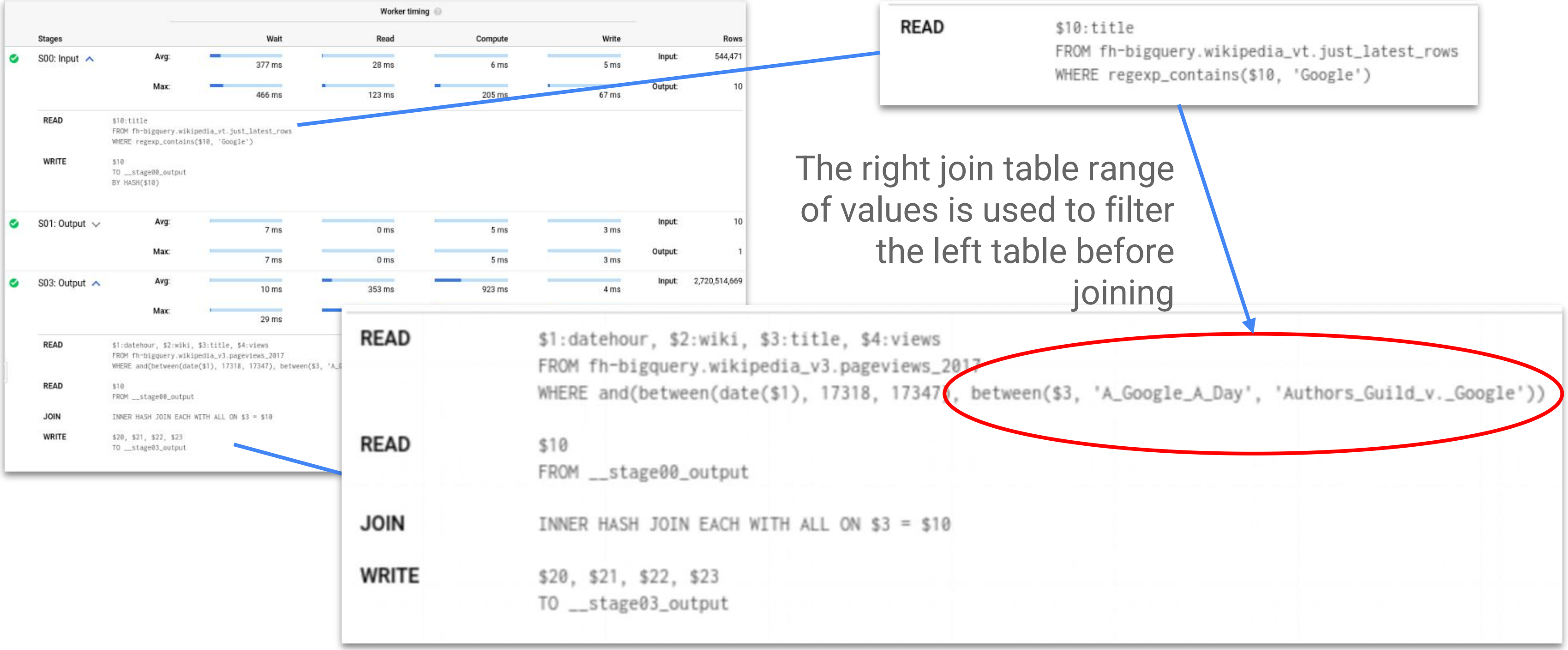
Clustered table JOIN optimization requirements

```
SELECT
  tbl2017.*
FROM
`wikipedia_v3.pageviews_2017` tbl2017
JOIN(SELECT * FROM
     `wikipedia_vt.just_latest_rows`
     WHERE
       REGEXP_CONTAINS(title, "Google"))
USING(title)
WHERE
  DATE(tbl2017.datehour)
  BETWEEN '2017-06-01' AND '2017-06-30'
```

Left table `pageviews_2017` **must be clustered**.

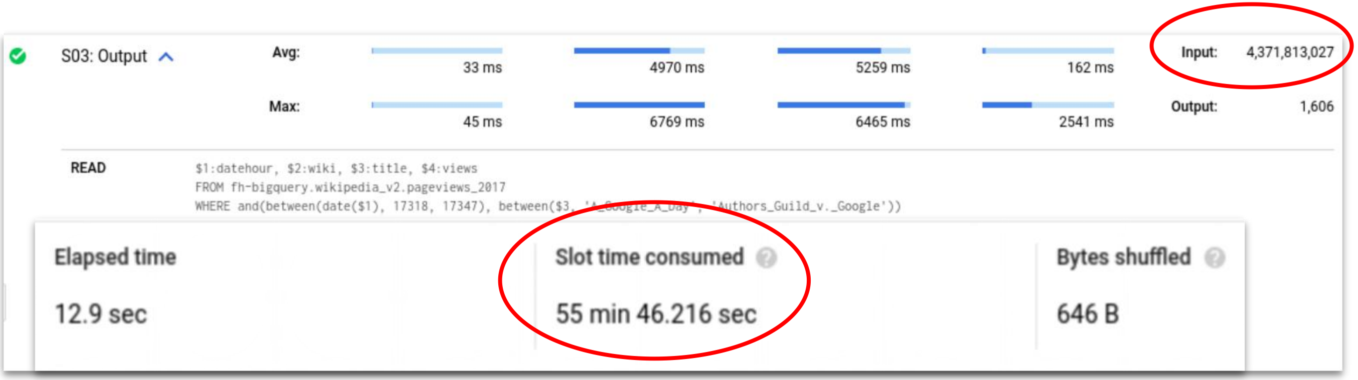
Subquery result size must qualify for **broadcast join** (e.g., JOIN EACH WITH **ALL**).

Clustered table JOIN optimization in query plan

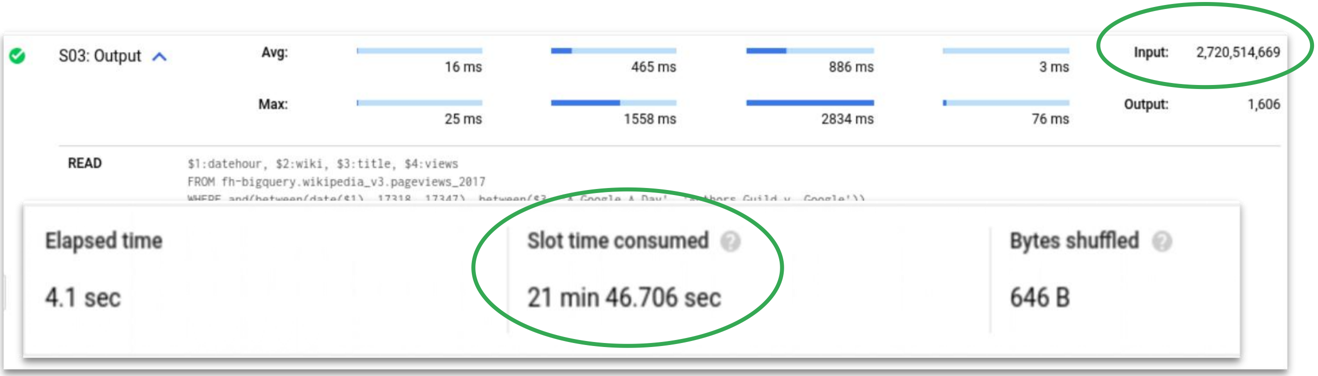


The right join table range of values is used to filter the left table before joining

Clustered table JOIN optimization in query plan



Partitioned but **not clustered** table results in joining **more data** and consuming **more slots**.



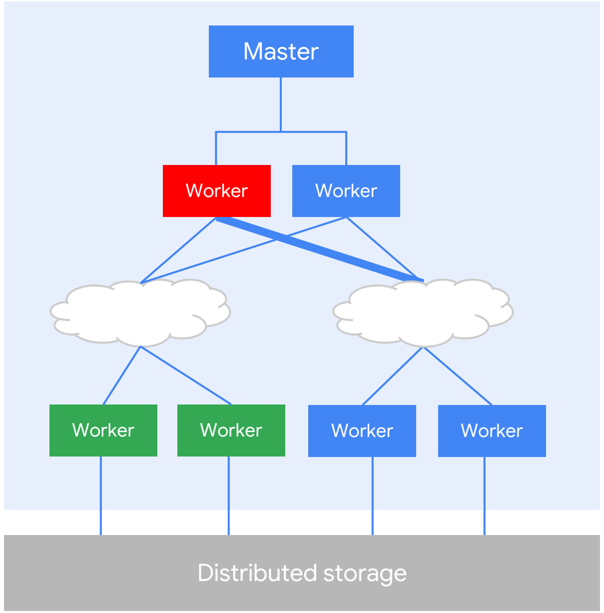
Partitioned **and clustered** table results in joining **less data** and consuming **fewer slots**.

Join explosions

- Are caused by JOIN with non-unique key on both sides.
- SQL relational algebra gives cartesian product of rows that have the same join key.
  - Worst case: The number of output rows is the number of rows in the left table multiplied by the number of rows in the right table.
  - In extreme cases, the query will not finish.
- If the job finishes, the query explanation will show output rows versus input rows.
- Confirm the diagnosis by modifying the query to print the number of rows on each side of the JOIN grouped by the JOIN key.
- A workaround is to use GROUP BY to pre-aggregate.

Skewed JOINs

Skewed JOIN



One worker gets too much data

Independent shuffles

Demo

Skewed JOIN

Query plan, stages, and metrics

Skewed JOIN query plan

S11: Join+

Wait: 4 ms | Read: 0 ms | Compute: 906 ms | Write: 1 ms

Records read: 225753340
Records written: 144

S11: Join+

Wait: 11 ms | Read: 0 ms | Compute: 2 sec | Write: 56 ms

Records read: 225753340
Records written: 144

```
$1, $40
FROM __stage06_output
$60
FROM __stage05_output
$30 := COUNT($71)
$31 := COUNT($70)
$70 := $1, $71 := $40
INNER HASH JOIN EACH WITH EACH ON $40 = $60
$30, $31
TO __stage11_output
```

Max compute time is much larger than average due to skewed JOIN.

Skewed JOINs

- **BigQuery shuffles data on each side of the join:**
  - All data with the same join key goes to the same worker.
  - Data can overload the worker.
- **Typically result from data skew**
- **Workarounds:**
  - Pre-filter rows from query with the unbalanced key.
  - Potentially split into two queries.

04

Filtering and Ordering

WHERE clause: Expression order matters!

Original code

```
SELECT text
FROM
  `stackoverflow.comments`
WHERE
  text LIKE '%java%'
  AND user_display_name = 'anon'
```

Optimized

```
SELECT text
FROM
  `stackoverflow.comments`
WHERE
  user_display_name = 'anon'
  AND text LIKE '%java%'
```

The expression:
`user_display_name = 'anon'`
filters out much more data
than the expression:
`text LIKE '%java%'`

Reasoning

BigQuery assumes that the user has provided the best order of expressions in the WHERE clause and does not attempt to reorder expressions. Expressions in your WHERE clauses should be ordered with the most selective expression first.

The optimized example is faster because it doesn't execute the expensive LIKE expression on the entire column content, but instead only on the content from user 'anon'.

WHERE clause reordering: Proof in the query plan

Elapsed time	Slot time consumed	Bytes shuffled	Bytes spilled to disk
2.9 sec	2 min 48.212 sec	0 B	0 B

Worker timing

Stages		Wait	Read	Compute	Write	Rows	
S00: Output	Avg:	200 ms	1314 ms	812 ms	4 ms	Input:	75,437,848
	Max:	439 ms	1707 ms	1022 ms	28 ms	Output:	24

```
WHERE
  text LIKE '%java%'
  AND
  user_display_name = 'anon'
```

Elapsed time	Slot time consumed	Bytes shuffled	Bytes spilled to disk
1.0 sec	21.537 sec	0 B	0 B

Worker timing

Stages		Wait	Read	Compute	Write	Rows	
S00: Output	Avg:	212 ms	170 ms	21 ms	4 ms	Input:	75,437,848
	Max:	431 ms	359 ms	54 ms	27 ms	Output:	24

```
WHERE
  user_display_name = 'anon'
  AND
  text LIKE '%java%'
```

Optimization: ORDER BY with LIMIT

Original code

```
select
  t.dim1,
  t.dim2,
  t.metric1
from
`dataset.table` t
order by t.metric1 desc
```

Optimized

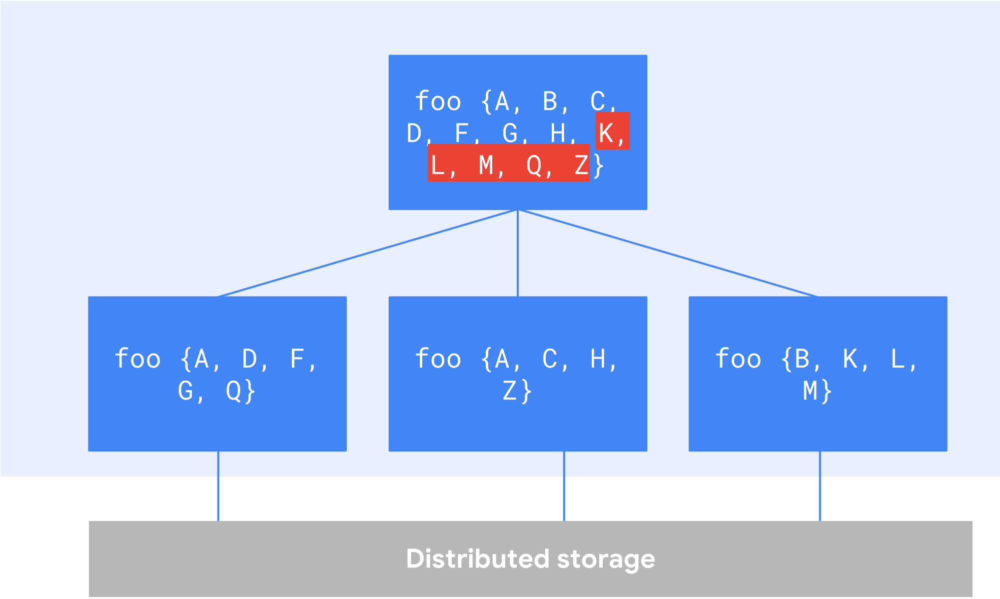
```
select
  t.dim1,
  t.dim2,
  t.metric1
from
  `dataset.table` t
order by t.metric1 desc
limit 1000
```

Reasoning

Writing results for a query with an **ORDER BY** clause can result in Resources Exceeded errors. Because the final sorting must be done on a single slot, if you are attempting to order a very large result set, the final sorting can overwhelm the slot that is processing the data.

If you are sorting a very large number of values, use a **LIMIT** clause.

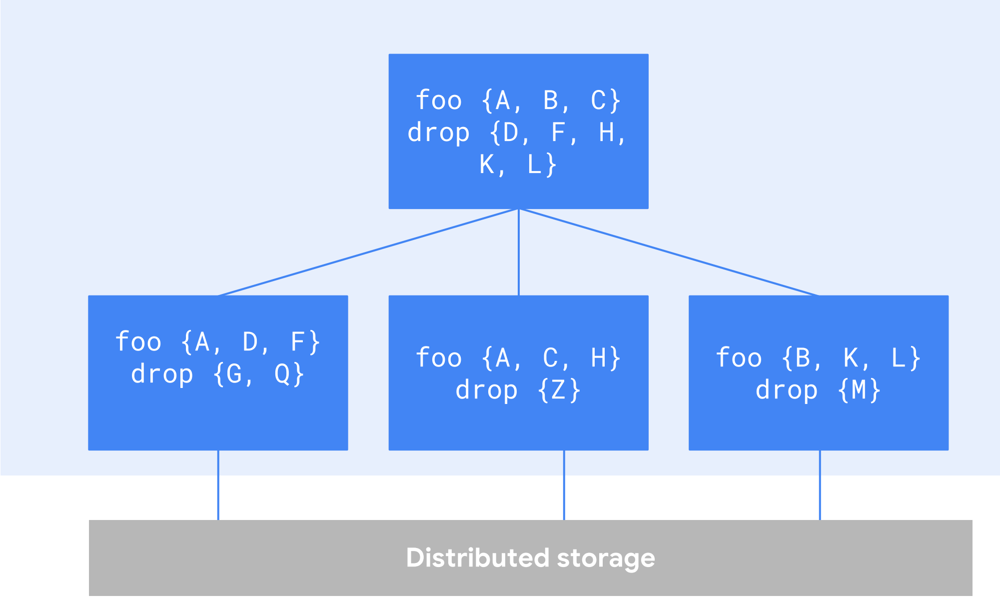
Large ORDER BYs



SELECT foo
FROM table
ORDER BY foo

Master node needs to sort and store all values

ORDER BY and LIMIT



SELECT foo
FROM table
ORDER BY foo
LIMIT 3

Can drop values over the limit at each node

Overloaded ORDER BY query plan

Worker timing

Stages		Wait	Read	Compute	Write	Rows	
S00: Input	Avg:	485 ms	36 ms	60 ms	118 ms	Input:	340,311,544
	Max:	534 ms	525 ms	82 ms	402 ms	Output:	340,311,544

READ $1:version
FROM bigquery-public-data.bitcoin_blockchain.transactions

WRITE $1
TO __stage00_output

Stages		Wait	Read	Compute	Write	Rows	
S01: Output	Avg:	533 ms	0 ms	15854 ms	0 ms	Input:	134,217,729
	Max:	533 ms	0 ms	15854 ms	0 ms	Output:	0

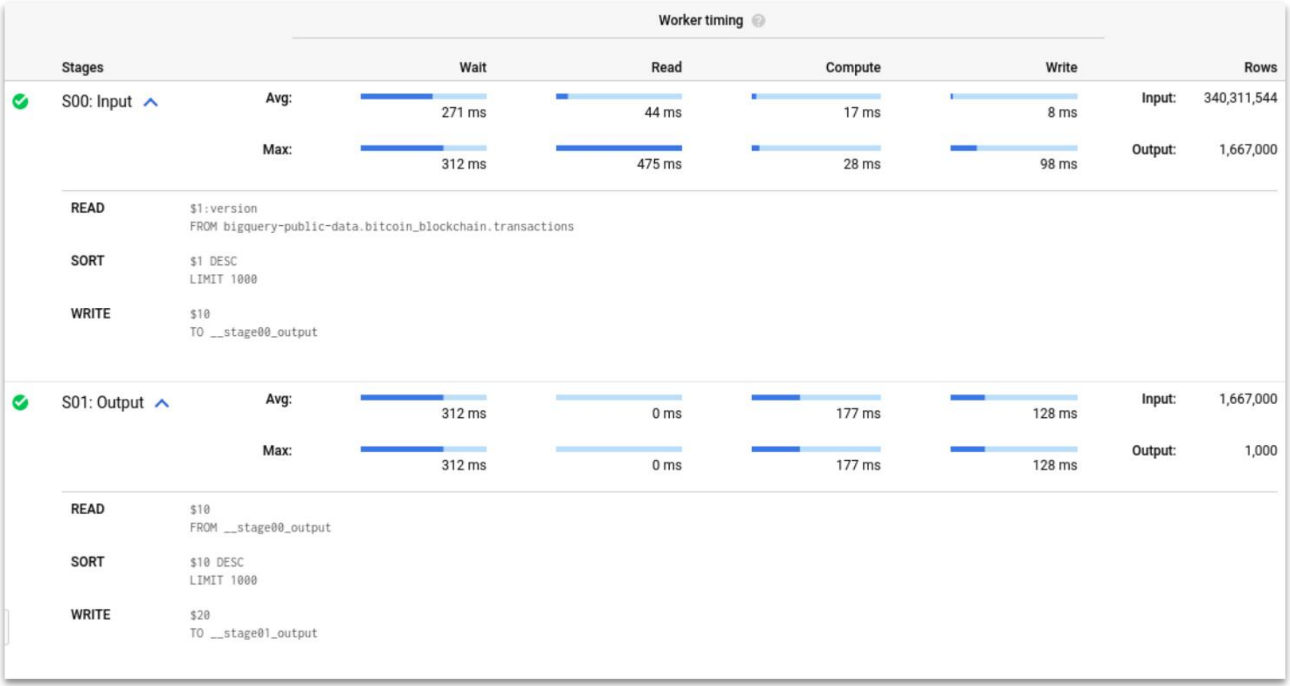
READ $1
FROM __stage00_output

SORT $1 DESC

WRITE $10
TO __stage01_output

```
SELECT
  version
FROM
bitcoin_blockchain.
transactions
ORDER BY
  version DESC
```

ORDER BY with LIMIT query plan



Stages		Wait	Read	Compute	Write	Rows	
		Worker timing					
S00: Input	Avg:	271 ms	44 ms	17 ms	8 ms	Input:	340,311,544
	Max:	312 ms	475 ms	28 ms	98 ms	Output:	1,667,000
S01: Output	Avg:	312 ms	0 ms	177 ms	128 ms	Input:	1,667,000
	Max:	312 ms	0 ms	177 ms	128 ms	Output:	1,000

S00: Input

READ	$1:version FROM bigquery-public-data.bitcoin_blockchain.transactions
SORT	$1 DESC LIMIT 1000
WRITE	$10 TO __stage00_output

S01: Output

READ	$10 FROM __stage00_output
SORT	$10 DESC LIMIT 1000
WRITE	$20 TO __stage01_output

```
SELECT
  version
FROM
bitcoin_blockchain.
transactions
ORDER BY
  version DESC
LIMIT 1000
```

05

Best Practices for Functions

Optimization: String comparison

Original Code

```
select
  dim1
from
  `dataset.table`
where
  regexp_contains(dim1, '.*test.*')
```

Optimized

```
select
  dim1
from
  `dataset.table`
where
  dim1 like '%test%'
```

Reasoning

REGEXP_CONTAINS > LIKE where > means more functionality, but also slower execution time. Prefer LIKE when the full power of regex is not needed (e.g., wildcard matching).

Optimization: Approximate functions

Original code

```
select
  dim1,
  count(distinct dim2)
from
  `dataset.table`
group by 1;
```

Optimized

```
select
  dim1,
  approx_count_distinct(dim2)
from
  `dataset.table`
group by 1;
```

Reasoning

If the SQL aggregation function you're using has an equivalent approximation function, the approximation function will yield faster query performance.

Approximate functions produce a result which is generally **within 1%** of the exact number.

Optimization: SQL UDFs → JavaScript UDFs

Original code

```
create temporary function
  multiply(x INT64, y INT64)
returns INT64
language js
as “””
  return x * y;
“””;

select multiply(2, 2) as result;
```

Optimized

```
create temporary function
  multiply(x INT64, y INT64)
as
  (x * y);

select multiply(2, 2) as result;
```

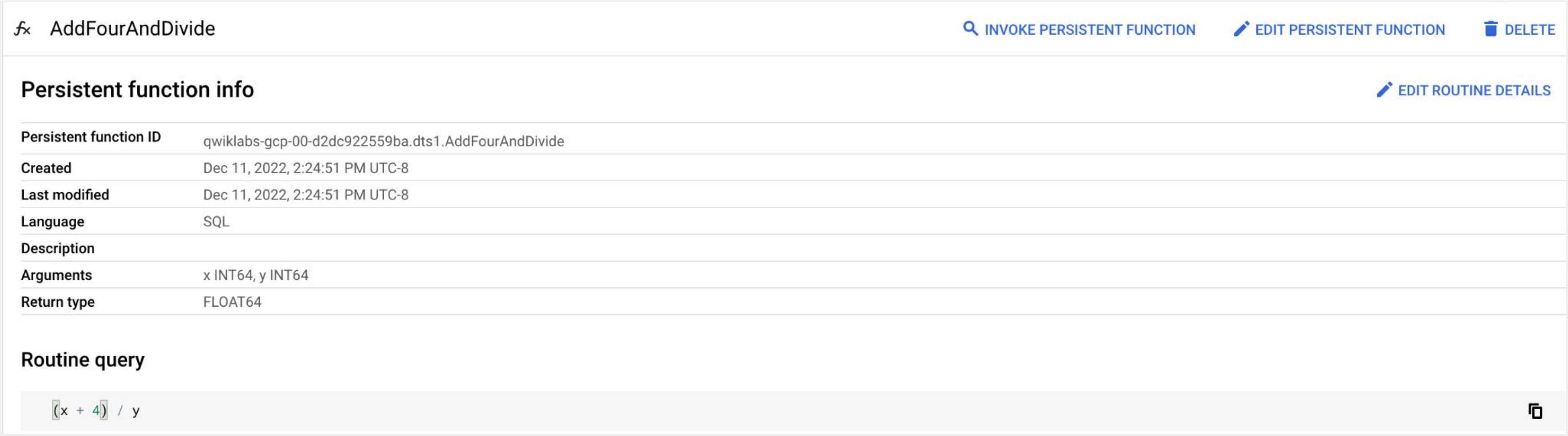
Reasoning

JavaScript UDFs substantially reduce performance because they have to spin up a V8 subprocess evaluate.

Prefer SQL UDFs where possible.

Optimization: Persistent UDFs

```
CREATE OR REPLACE FUNCTION
your_dataset.addFourAndDivide(x INT64, y INT64) AS (
        (x + 4) / y
);
```



Optimization: Persistent UDFs

Original code

```
CREATE TEMP FUNCTION addFourAndDivide(x
INT64, y INT64) AS ((x + 4) / y);

WITH numbers AS
  (SELECT 1 as val
  UNION ALL
  SELECT 3 as val
  UNION ALL
  SELECT 4 as val
  UNION ALL
  SELECT 5 as val)
SELECT val, addFourAndDivide(val, 2) AS
result
FROM numbers;
```

Optimized

```
# Replaced with persistent function
# and invoked below

WITH numbers AS
  (SELECT 1 as val
  UNION ALL
  SELECT 3 as val
  UNION ALL
  SELECT 4 as val
  UNION ALL
  SELECT 5 as val)
SELECT val,
`your_project.your_dataset.addFourAndDivide`
(val, 2) AS result
FROM numbers;
```

Reasoning

Create persistent user-defined SQL and JavaScript functions in a centralized BigQuery dataset that can be invoked across queries and in logical views.

Create org-wide libraries of business logic within shared datasets.

Scripting and stored procedures

- Execute multiple statements in one request.
- Declare, assign, and use variables.
- Control execution with conditions and loops.
- **Caveat:** Statements are committed independently of each other.

```
DECLARE primes ARRAY<INT64> DEFAULT [2];
DECLARE n INT64 DEFAULT 3;
DECLARE max INT64 DEFAULT 30;
WHILE n <= max DO
  BEGIN
    DECLARE n_is_prime BOOL DEFAULT TRUE;

    -- Test all prime numbers from 2 to SQRT(n), inclusive.
    DECLARE i INT64 DEFAULT 0;
    WHILE i < ARRAY_LENGTH(primes) DO
      BEGIN
        DECLARE prime INT64 DEFAULT primes[OFFSET(i)];
        IF MOD(n, prime) = 0 THEN
          -- Found a prime < n, which divides evenly into n, so n is not prime.
          SET n_is_prime = FALSE;
          BREAK;
        END IF;
        IF prime * prime >= n THEN
          -- <primes> is kept sorted in increasing order, so once we find a
          -- single value >= SQRT(n), we can stop.
          BREAK;
        END IF;
      END;
      SET i = i + 1;
    END WHILE;

    -- If n is prime, then add it to the list of known primes.
    IF n_is_prime THEN
      SET primes = ARRAY_CONCAT(primes, [n]);
    END IF;
  END;
  SET n = n + 1;
END WHILE;

-- Display all the primes.
SELECT prime FROM UNNEST(primes) AS prime ORDER BY prime;
```

Questions?

Google Cloud

Lab (75 min)

Optimizing Your BigQuery Queries for Performance

(choose your level)

1:15:00

Google Cloud