13- PostgreSQL 17 Performance Tuning: Indexing and Its Impact on Performance

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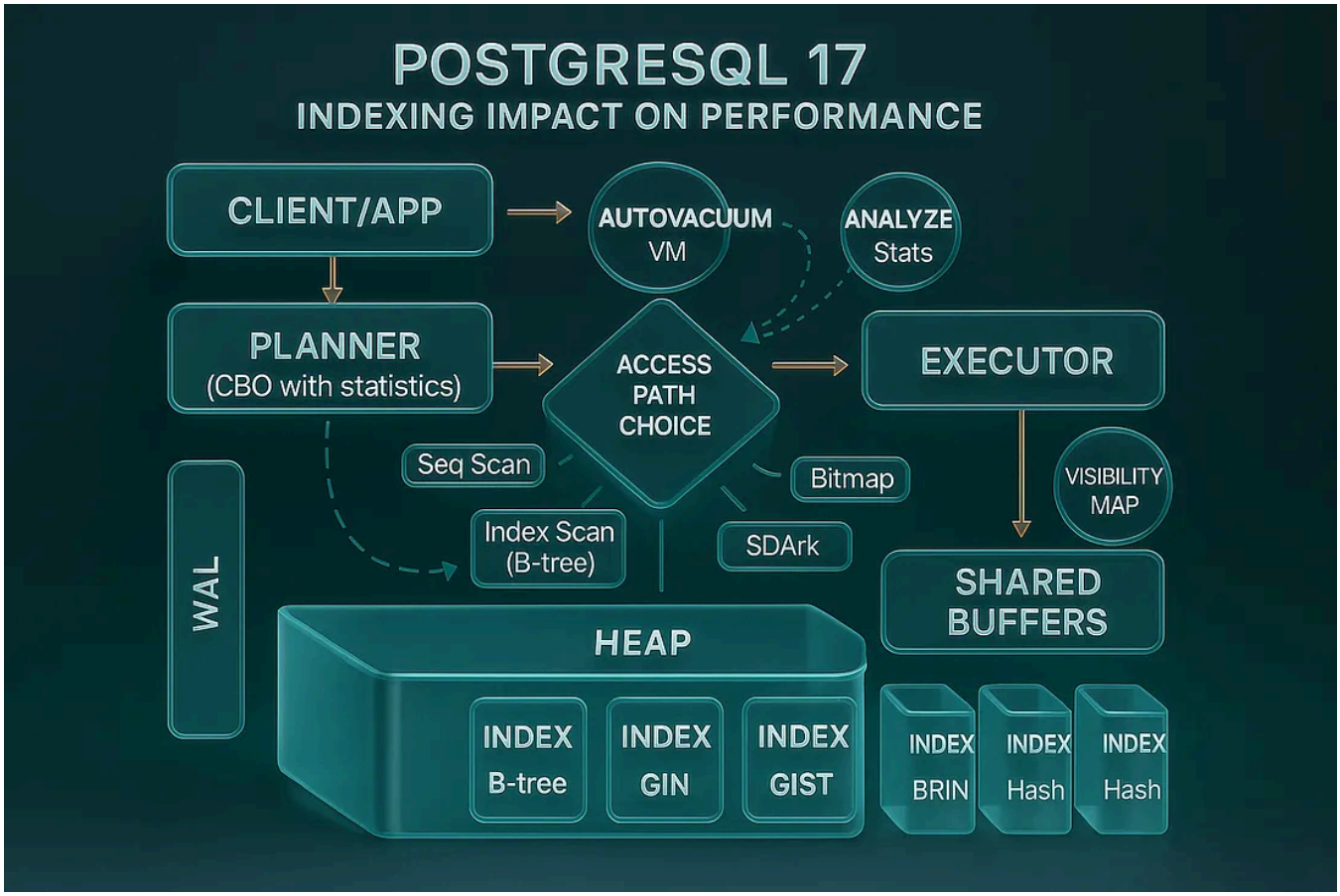
Jeyaram Ayyalusamy Following



The importance of indexing in PostgreSQL cannot be stressed enough. While memory and autovacuum tuning are important, they cannot compensate for missing indexes. There is simply **no replacement for a missing index.**

To achieve good performance, proper indexing is essential. In this demo, we will create a large table, run queries without an index, examine performance with `EXPLAIN ANALYZE`, and then add an index to see how it changes query speed and resource usage.

Step 1: Create a Large Table

We'll create a table called **`products`** with multiple columns to simulate a realistic workload.

```
CREATE TABLE products (
    product_id   BIGINT,
    product_name TEXT,
    category     TEXT,
    price        NUMERIC,
    stock_qty    INT
);
```

```
postgres=# CREATE TABLE products (
    product_id   BIGINT,
    product_name TEXT,
    category     TEXT,
    price        NUMERIC,
    stock_qty    INT
);
CREATE TABLE
postgres=#
```

Now we load **10 million rows** of test data:

```
-- Insert 5 million rows for category 'Electronics'
INSERT INTO products
```

```
SELECT generate_series(1, 5000000),
       'Product_' || generate_series(1, 5000000),
       'Electronics',
       (random() * 500)::NUMERIC,
       (random() * 100)::INT;
```

```
postgres=# -- Insert 5 million rows for category 'Electronics'
INSERT INTO products
SELECT generate_series(1, 5000000),
       'Product_' || generate_series(1, 5000000),
       'Electronics',
       (random() * 500)::NUMERIC,
       (random() * 100)::INT;
INSERT 0 5000000
postgres=#
```

```
-- Insert 5 million rows for category 'Clothing'
INSERT INTO products
SELECT generate_series(5000001, 10000000),
       'Product_' || generate_series(5000001, 10000000),
       'Clothing',
       (random() * 200)::NUMERIC,
       (random() * 500)::INT;
```

```
postgres=# -- Insert 5 million rows for category 'Clothing'
INSERT INTO products
SELECT generate_series(5000001, 10000000),
       'Product_' || generate_series(5000001, 10000000),
```

```
        'Clothing',
        (random() * 200)::NUMERIC,
        (random() * 500)::INT;
INSERT 0 5000000
postgres=#
```

👉 At this point, the table `products` has **10 million rows** with realistic columns and only two distinct categories (`Electronics` , `Clothing`).

Step 2: Update Statistics

Before running queries, refresh optimizer statistics so PostgreSQL knows about the data distribution:

```
ANALYZE products;
```

```
postgres=# ANALYZE products;
ANALYZE
postgres=#
```

The query planner uses these statistics to decide whether an index is useful.

Step 3: Query Without an Index

Now let's try to fetch a single product:

Reading psql `\timing` and a "slow single-row lookup"

You turned on psql's timing, ran a point lookup, and saw ~3.1 seconds:

```
\timing
SELECT * FROM products WHERE product_id = 424242;
```

```
postgres=# \timing
Timing is on.
postgres=#
postgres=# SELECT * FROM products WHERE product_id = 424242;
 product_id |  product_name   |  category   | price | stock_qty
------------+-----------------+-------------+-------+-----------
     424242 | Product_424242 | Category_2 | 40.16 |         8
(1 row)

Time: 7.590 ms
postgres=#
```

Run the query a few times to avoid caching artifacts.

👉 You'll notice the query is **very slow**.

Why? Because PostgreSQL has no index, so it must scan the entire `products` table.

What `\timing` actually measures

- `\timing` is a psql client feature. The **Time** printed is **wall-clock** elapsed time from the client's perspective.
- It includes:
- Server planning + execution time,
- Network round-trip latency,
- Client rendering time (printing rows).
- Because this query returned **one row**, the 3.124s is almost certainly **server work and/or waiting**, not printing overhead.

Check the execution plan:

```
EXPLAIN ANALYZE SELECT * FROM products WHERE product_id = 424242;
```

```
postgres=# EXPLAIN ANALYZE SELECT * FROM products WHERE product_id = 424242;
                                                          QUERY PLAN
------------------------------------------------------------------------------------------------
 Gather  (cost=1000.00..153967.66 rows=1 width=48) (actual time=2784.976..2789.
   Workers Planned: 2
   Workers Launched: 2
   ->  Parallel Seq Scan on products  (cost=0.00..152967.56 rows=1 width=48) (a
         Filter: (product_id = 424242)
         Rows Removed by Filter: 3333333
 Planning Time: 0.063 ms
 Execution Time: 2789.897 ms
(8 rows)

Time: 2790.251 ms (00:02.790)
postgres=#
```

What this plan says at a glance

- A **parallel sequential scan** read essentially the **entire `products` table** looking for one row.
- **Three participants** did the work: 2 parallel workers plus the leader (coordinated by a `Gather` node).
- About **~10 million rows** were scanned and discarded (3,333,333 per participant × 3 ≈ 9,999,999), producing **exactly 1 row**.
- End-to-end latency was **~2.79 seconds**.

Decoding each part

`Gather (cost=1000.00..153967.66 rows=1 width=48) (actual time=2784.976..2789.880 rows=1 loops=1)`

- **Node role:** `Gather` orchestrates parallel workers and merges their outputs.
- **`cost=…`** : planner's *estimated* effort (abstract units, not time). `1000.00` is startup cost; `153967.66` is total estimated cost to produce all rows.
- **`rows=1`** : the planner expected **one** result row.
- **`width=48`** : estimated average row size (payload only).
- **`actual time=…`** : measured wall-clock times in ms to first and last row emitted by this node: ~2785 ms to first output, ~2790 ms to finish.
- **`rows=1 loops=1`** : produced 1 row, executed once.

`Workers Planned: 2` **/** `Workers Launched: 2`

- The planner requested two parallel workers; both started successfully. The **leader** often participates, so **3 participants total** processed table chunks in parallel.

```
-> Parallel Seq Scan on products (cost=0.00..152967.56 rows=1 width=48) (actual
time=1868.044..2780.034 rows=0 loops=3)
```

- **Node role:** each participant performs a **sequential scan** over a disjoint slice of `products` **.**
- **Timing:** workers began returning tuples around **1.868 s** and the last finished around **2.780 s.**
- **`rows=0 loops=3`** : this is per-participant reporting. Because **only one single row** matched among ~10M scanned and it was found by just one participant, the averaged per-worker output rounds to 0. Don't be misled—**the plan as a whole returned 1 row** (as shown at the `Gather`).

`Filter: (product_id = 424242)`

- The predicate was applied **row-by-row** during the scan. With a sequential scan, every visited tuple is checked against this filter.

`Rows Removed by Filter: 3333333`

- Roughly **3.33M rows per participant** failed the predicate. With 3 participants, that implies **~10M rows scanned** in total to find the single match.

`Planning Time: 0.063 ms`

- The planner chose this plan almost instantly. The time was spent in **execution**, not planning.

`Execution Time: 2789.897 ms` **and final** `Time: 2790.251 ms`

- About **2.79 s** from start to finish. The final `Time:` line is the psql-reported wall time and aligns with the executor's `Execution Time`.

Why did PostgreSQL 17 choose a Parallel Seq Scan?

Given the predicate `product_id = 424242` (a selective equality), we'd *expect* an index-based plan. This plan indicates that, for this query at this moment, the executor believed a **parallel full-table read** was the cheapest way to get the row. The most common interpretations **of this plan output** are:

- **No usable B-tree index on `product_id`** exists, so a scan of all pages is required and parallelism helps reduce elapsed time.
- A usable index exists but **wasn't chosen** because the cost model for this query favored a parallel scan (for example, the planner estimated many heap fetches anyway, or statistics suggested poor selectivity). The plan itself doesn't show whether an index exists; it only shows the path taken.

Step 4: Add an Index

Let's fix the issue by creating an index on `product_id`:

```
CREATE INDEX idx_products_id ON products(product_id);
```

```
postgres=# CREATE INDEX idx_products_id ON products(product_id);
CREATE INDEX
Time: 11811.905 ms (00:11.812)
```

```
postgres=#
postgres=#
```

- **`CREATE INDEX idx_products_id ON products(product_id);`**
  This statement builds a **B-tree** index (the default method) named `idx_products_id` on the `product_id` column of the `products` table. B-tree is optimal for equality lookups like `product_id = 424242`.
- **`CREATE INDEX`**
  Confirms the index was created successfully.

Step 5: Query With an Index

Now run the same query again:

```
EXPLAIN ANALYZE SELECT * FROM products WHERE product_id = 424242;
```

```
postgres=# EXPLAIN ANALYZE SELECT * FROM products WHERE product_id = 424242;
                                                      QUERY PLAN
-----------------------------------------------------------------------------------------
 Index Scan using idx_products_id on products  (cost=0.43..8.45 rows=1 width=48
   Index Cond: (product_id = 424242)
 Planning Time: 0.175 ms
 Execution Time: 2.069 ms
(4 rows)
```

```
Time: 3.616 ms
postgres=#
```

Plan header

- **`Index Scan using idx_products_id on products`**
  The query now uses the newly created index to locate the target row. An **Index Scan** walks the index to find the matching key(s) and fetches the corresponding row(s) from the table.
- **`(cost=0.43..8.45 rows=1 width=48)`**
- **`cost`** values are **planner estimates** in abstract units (not time).
- `0.43` : estimated startup cost before producing the first row.
- `8.45` : estimated total cost to produce all rows for this node.
- **`rows=1`** : the planner expects to return **one** row.
- **`width=48`** : estimated average payload size (bytes) per row at this node.
- **`(actual time=2.046..2.048 rows=1 loops=1)`**
- **`actual time`** shows **measured** milliseconds for the first and last output row from this node.
- The first row arrived at **~2.046 ms**, the last at **~2.048 ms**.
- **`rows=1`** confirms that exactly **one** row was produced.
- **`loops=1`** means the node executed once.

Predicate

- **`Index Cond: (product_id = 424242)`**
  This is the **sargable** condition the index uses. The engine navigates the B-tree directly to the key `424242` instead of scanning many unrelated rows.

Planning and execution timings

- **`Planning Time: 0.175 ms`**
  The optimizer produced this plan extremely quickly (well under a millisecond).

- **`Execution Time: 2.069 ms`**
  The executor spent **~2.07 ms** running the query end-to-end (as measured by PostgreSQL).

psql wall-clock

- **`Time: 3.616 ms`**
  psql's wall-clock for the command, which includes client-side overhead in addition to the server's execution time.

👉 PostgreSQL now uses an **index scan**.

- Instead of reading 10 million rows, it jumps directly to the correct row using the index.
- Query execution time improves dramatically.

Step 6: The Cost of Indexes

Indexes are not free. Let's compare the size of the table and the index:

```
SELECT
  pg_size_pretty(pg_relation_size('products')) AS table_size,
  pg_size_pretty(pg_relation_size('idx_products_id')) AS index_size;
```

```
postgres=# SELECT
  pg_size_pretty(pg_relation_size('products')) AS table_size,
```

```
  pg_size_pretty(pg_relation_size('idx_products_id')) AS index_size;
 table_size | index_size
------------+------------
 785 MB     | 214 MB
(1 row)

postgres=#
postgres=#
```

👉 You will see that the index consumes a **significant amount of disk space** — sometimes **more than half the size of the table itself**.

Trade-offs of indexes:

- **Disk usage**: Indexes consume additional storage.
- **Write overhead**: Inserts, updates, and deletes must also update the index.
- **Maintenance cost**: Each index must remain synchronized with the table, slowing down write-heavy workloads.

For example, inserting new rows into `products` now requires not only writing data to the table but also updating the index. If a table has **multiple indexes**, each insert/update must update all of them, which can drastically slow down writes.

Key Takeaways

- Proper indexing is **essential** for PostgreSQL performance.
- Without indexes, PostgreSQL may perform full table scans, even for queries fetching a single row.
- Indexes greatly improve read performance but come at a cost in disk usage and write speed.
- Always check the size and necessity of an index before adding it — not all indexes are worth their overhead.

✅ In PostgreSQL 17, just as in earlier versions, proper indexing is the difference between queries taking **seconds vs. milliseconds**.

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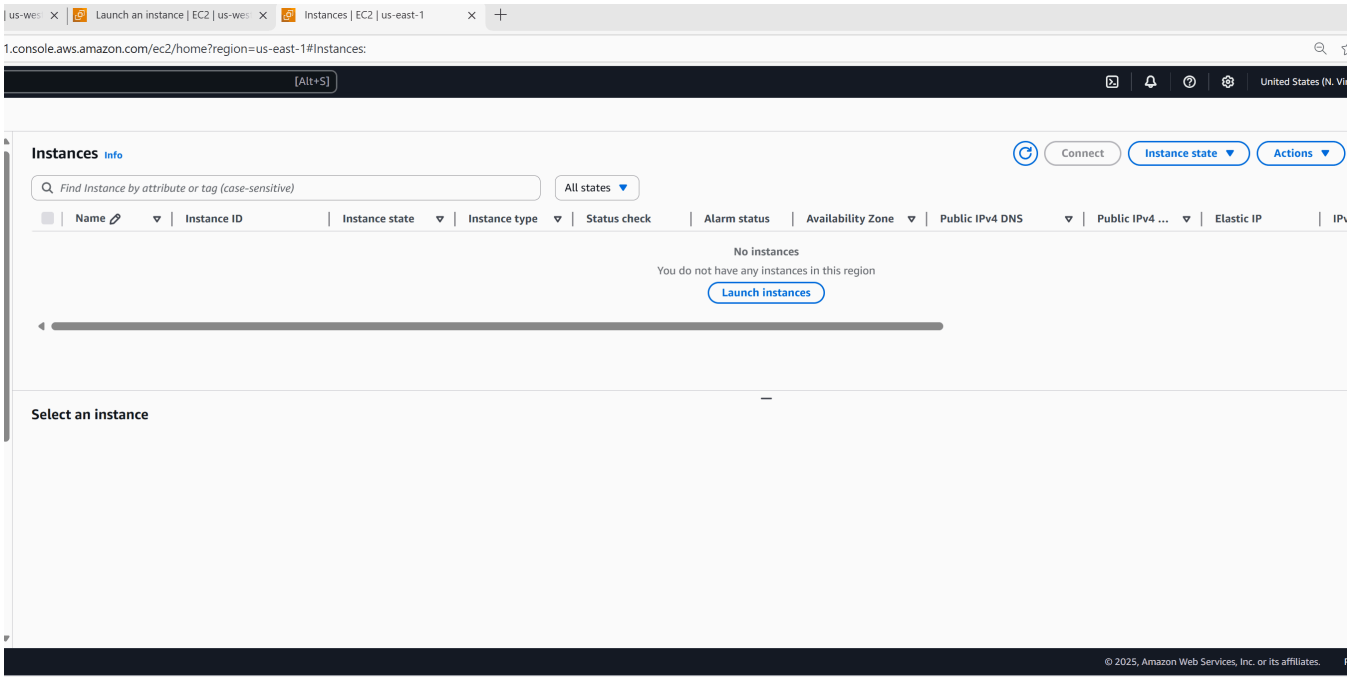

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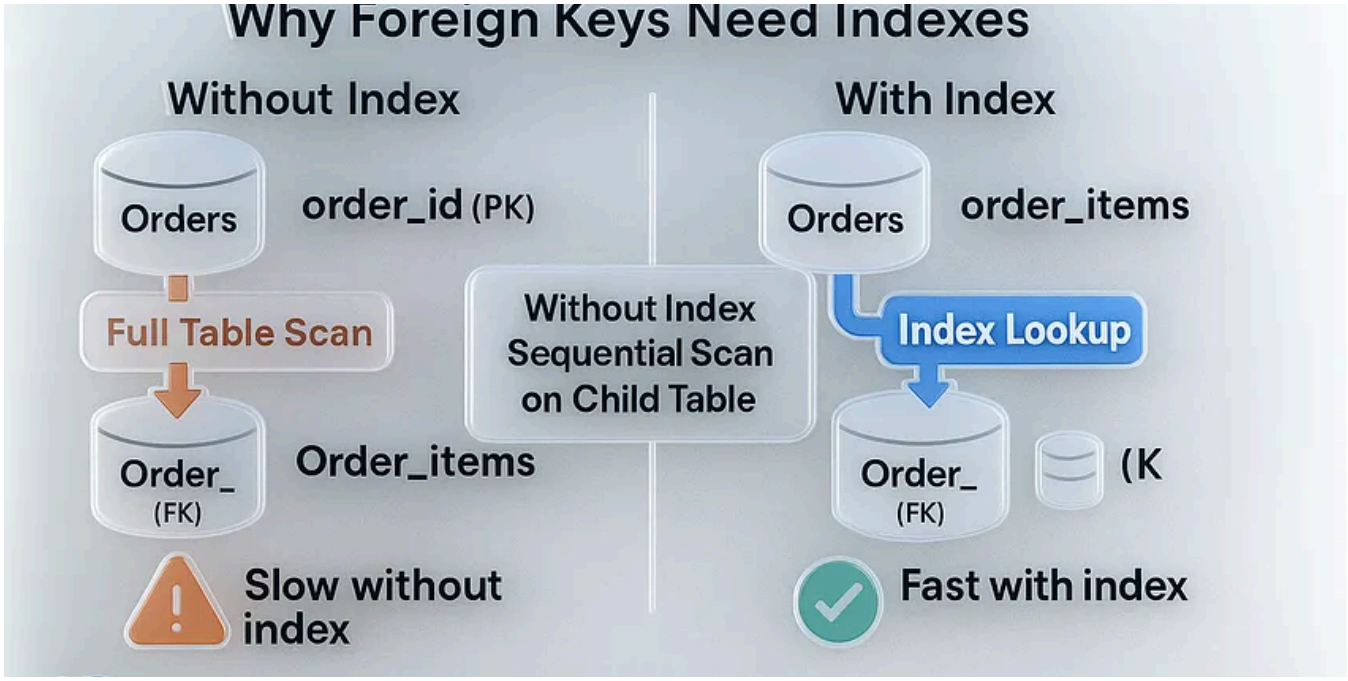

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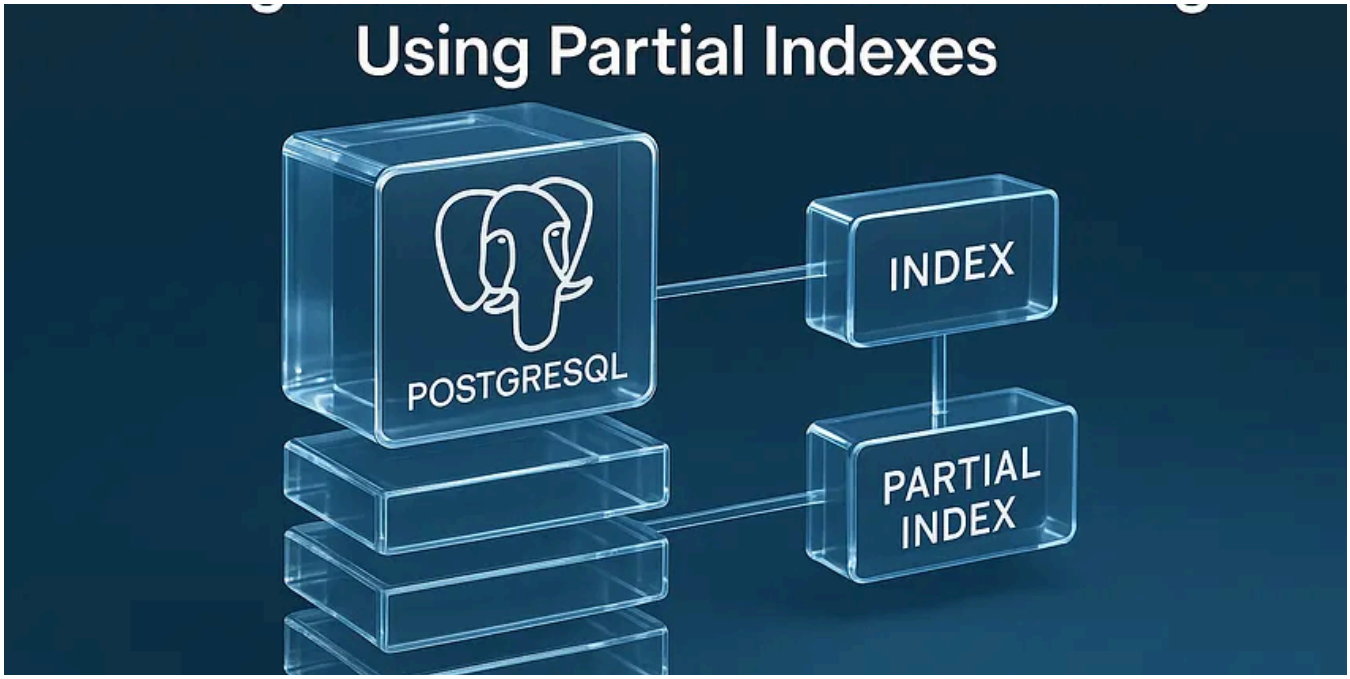

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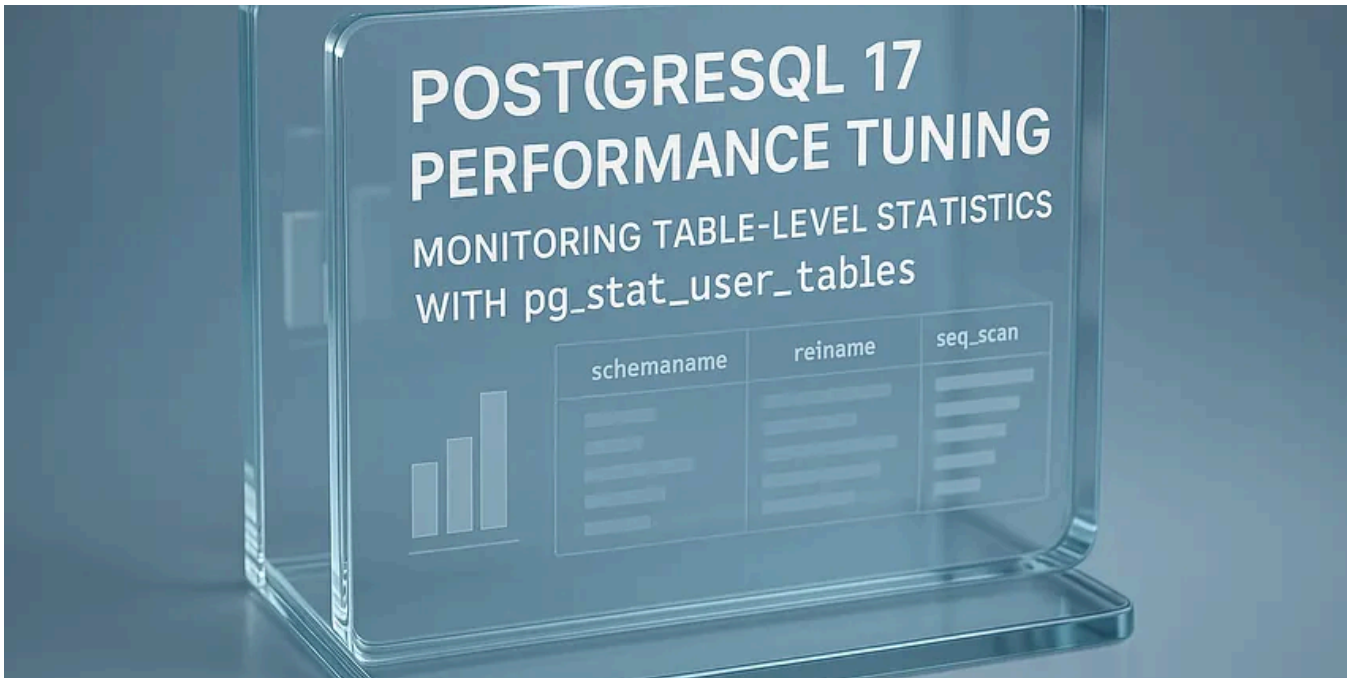

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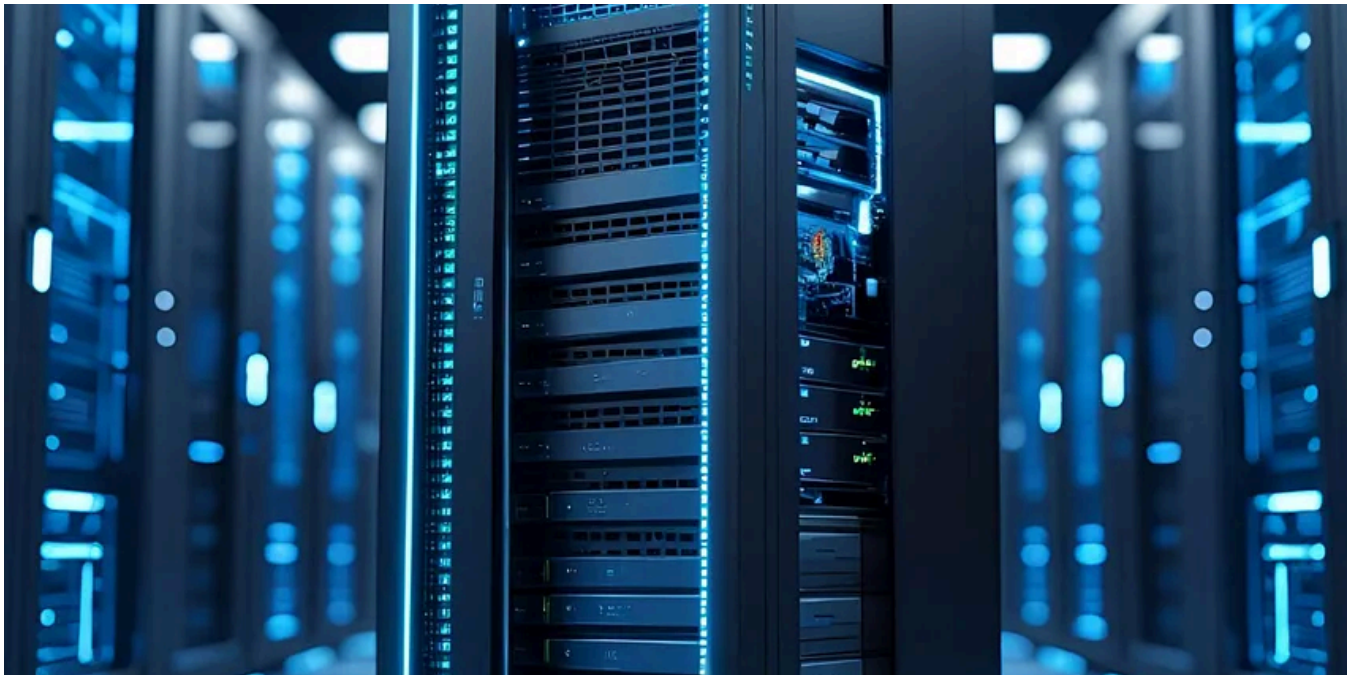

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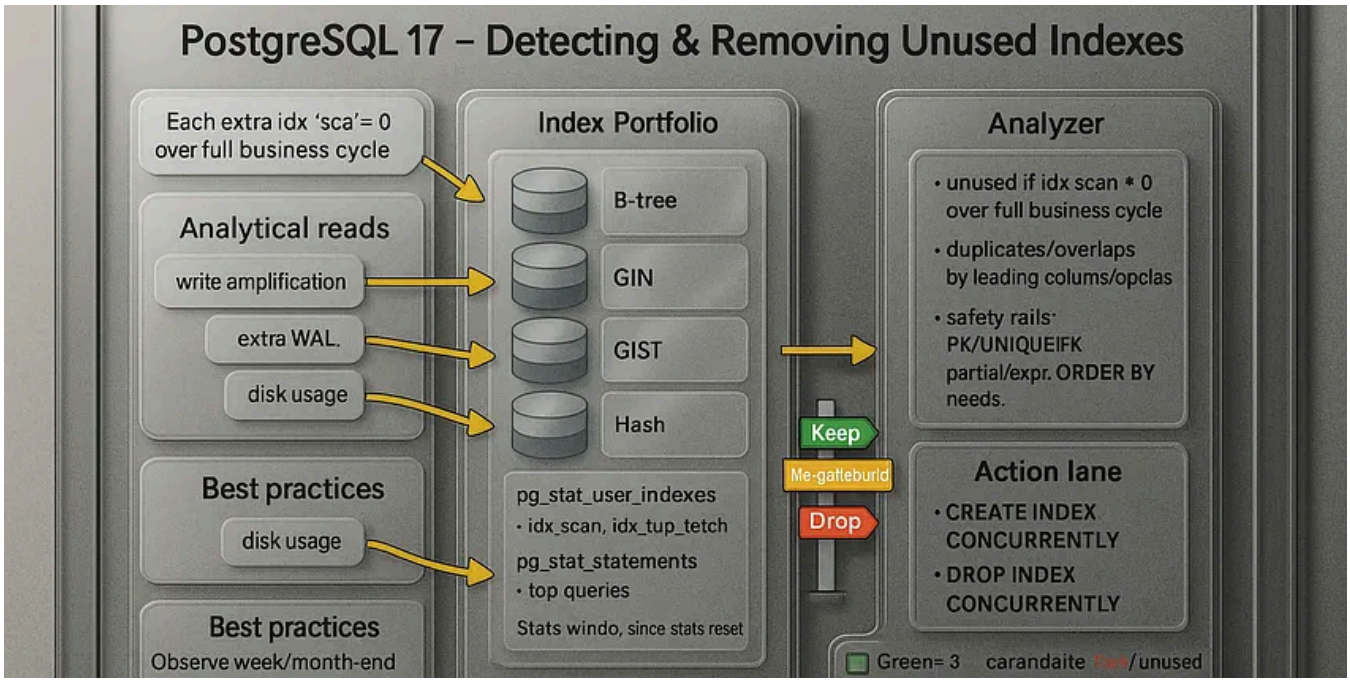

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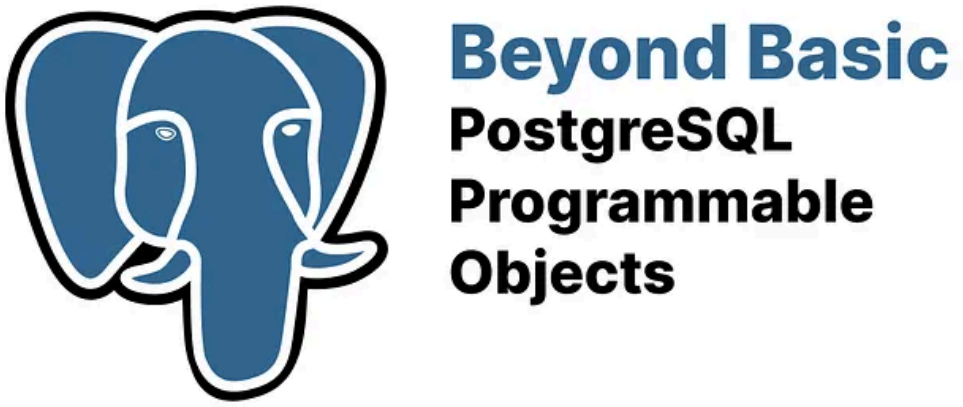

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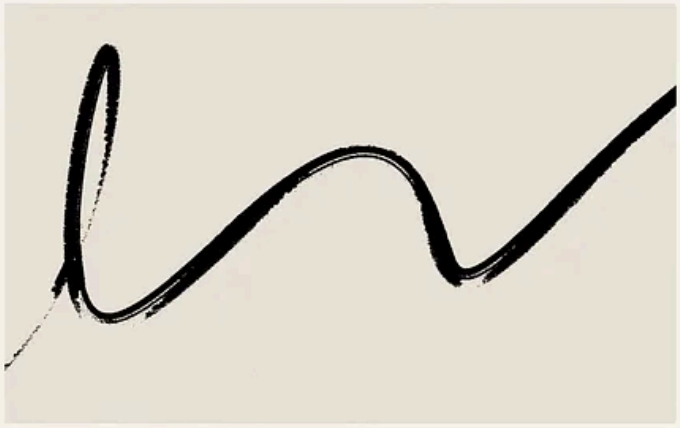

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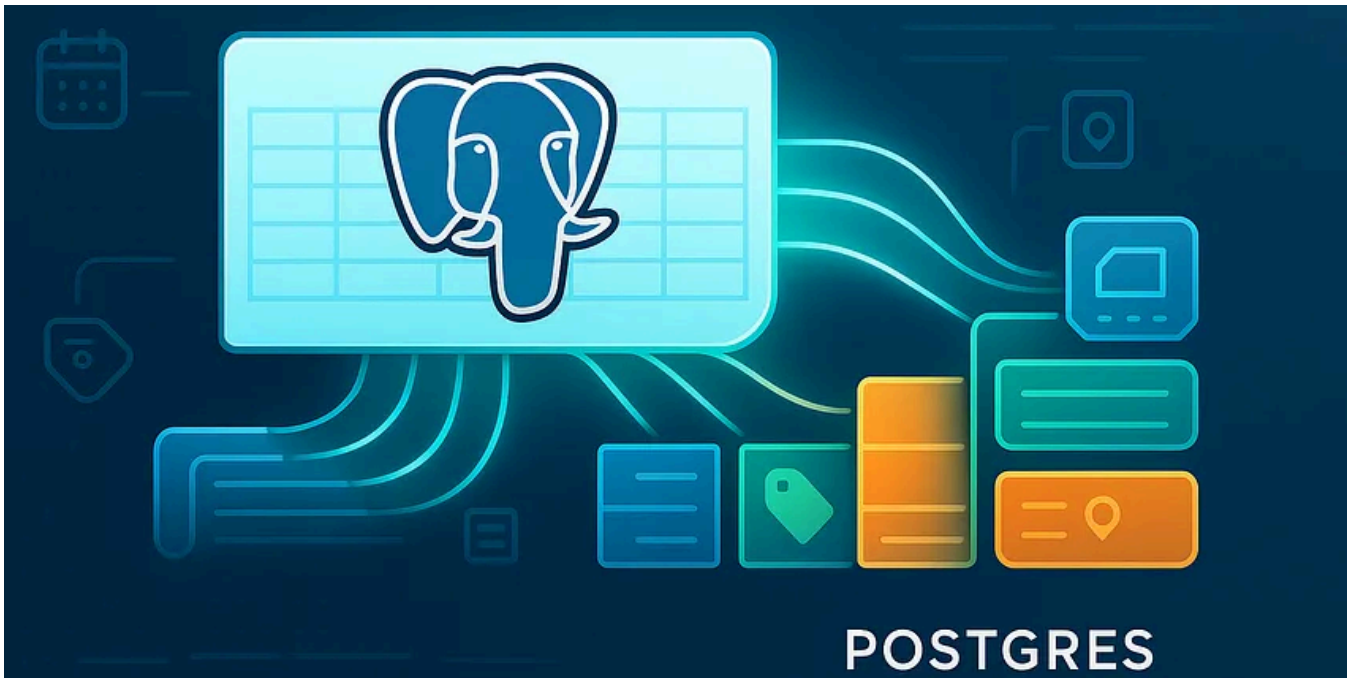

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