CYBERTEC
POSTGRESQL SERVICES & SUPPORT

Things your explain plan is not telling you

Ants Aasma

PGConf.DE 2024

Hello

About me

- Ants Aasma
- Senior Database Consultant
- 12 years of helping people make PostgreSQL run fast

Everybody loves explain

Explain yourself

- `EXPLAIN` tells us how the database planned to execute our query
- `EXPLAIN ANALYZE` collects statistics how well that went

Explain yourself

- `EXPLAIN` tells us how the database planned to execute our query
- `EXPLAIN ANALYZE` collects statistics how well that went
- If you are really curious, then:

```
EXPLAIN (ANALYZE, VERBOSE, SETTINGS, BUFFERS, WAL, SUMMARY, MEMORY, SERIALIZE
```

Explain yourself

- `EXPLAIN` tells us how the database planned to execute our query
- `EXPLAIN ANALYZE` collects statistics how well that went
- If you are really curious, then:

```
EXPLAIN (ANALYZE, VERBOSE, SETTINGS, BUFFERS, WAL, SUMMARY, MEMORY, SERIALIZE
```

  - Maybe it's time for `EXPLAIN EVERYTHING`?

What are we going to talk about

- Explain is great!
- Everybody should be using it.

What are we going to talk about

- Explain is great!
- Everybody should be using it.
- This talk is about the parts that are not (yet) great.

Warning

- This talk will have code.

Warning

- This talk will have code.
- A lot of code.

Warning

- This talk will have code.
- A lot of code.
- Like really a lot of it.

```
SELECT 'If this is too small, you need to try to get closer';
```

Slides are also available on the conference website to follow along.

Crash course on reading EXPLAIN

Parts of an explain plan

- Represents the tree of a volcano execution model.
- Each node pulls from those below it.
- Read from the inside out

```
EXPLAIN SELECT * FROM tasks JOIN jobs USING (job_id) WHERE value > 99.9 LIMIT 10;
```

Parts of an explain plan

- Represents the tree of a volcano execution model.
- Each node pulls from those below it.
- Read from the inside out

```
EXPLAIN SELECT * FROM tasks JOIN jobs USING (job_id) WHERE value > 99.9 LIMIT 10;
```

```
Limit  (cost=0.42..149.83 rows=100 width=44)
  ->  Nested Loop  (cost=0.42..716.10 rows=479 width=44)
        ->  Seq Scan on jobs  (cost=0.00..188.00 rows=8 width=16)
              Filter: (value > 99.9)
              Rows Removed by Filter: 1180
        ->  Index Scan using tasks_job_id_id_done_idx on tasks
                                   (cost=0.42..65.41 rows=60 width=32)
              Index Cond: (job_id = jobs.job_id)
```

Running it

```sql
EXPLAIN ANALYZE
SELECT * FROM tasks JOIN jobs USING (job_id) WHERE value > 99.9 LIMIT 10;
```

Running it

```sql
EXPLAIN ANALYZE
SELECT * FROM tasks JOIN jobs USING (job_id) WHERE value > 99.9 LIMIT 10;
```

```
Limit  (cost=0.42..149.83 rows=100 width=44) (actual time=0.153..0.279 rows=100 loops=1)
  -> Nested Loop  (cost=0.42..716.10 rows=479 width=44) (actual time=0.152..0.272 rows=1
      -> Seq Scan on jobs  (cost=0.00..188.00 rows=8 width=16) (actual time=0.144..0.167
            Filter: (value > 99.9)
            Rows Removed by Filter: 1180
      -> Index Scan using tasks_job_id_id_done_idx on tasks  (cost=0.42..65.41 rows=60 w
            Index Cond: (job_id = jobs.job_id)
Planning Time: 0.188 ms
Execution Time: 0.299 ms
```

Running it

```sql
EXPLAIN (ANALYZE, COSTS OFF)
SELECT * FROM tasks JOIN jobs USING (job_id) WHERE value > 99.9 LIMIT 10;
```

```
Limit  (actual time=0.153..0.279 rows=100 loops=1)
  ->  Nested Loop  (actual time=0.152..0.272 rows=100 loops=1)
        ->  Seq Scan on jobs  (actual time=0.144..0.167 rows=2 loops=1)
              Filter: (value > 99.9)
              Rows Removed by Filter: 1180
      -> Index Scan using tasks_job_id_id_done_idx on tasks  (actual time=0.006..0.045 r
              Index Cond: (job_id = jobs.job_id)
Planning Time: 0.188 ms
Execution Time: 0.299 ms
```

Buffers

```
EXPLAIN (ANALYZE, BUFFERS, COSTS OFF) SELECT COUNT(*) FROM tasks;
```

```
Aggregate (actual time=56.689..56.690 rows=1 loops=1)
   Buffers: shared hit=2519 read=2153
   I/O Timings: shared read=2.774
   ->  Seq Scan on tasks (actual time=0.008..35.051 rows=599524 loops=1)
         Buffers: shared hit=2519 read=2153
         I/O Timings: shared read=2.774
 Planning Time: 0.059 ms
 Execution Time: 56.711 ms
```

Buffers

```
EXPLAIN (ANALYZE, BUFFERS, COSTS OFF) SELECT COUNT(*) FROM tasks;
```

```
Aggregate (actual time=56.689..56.690 rows=1 loops=1)
   Buffers: shared hit=2519 read=2153
   I/O Timings: shared read=2.774
   ->  Seq Scan on tasks (actual time=0.008..35.051 rows=599524 loops=1)
         Buffers: shared hit=2519 read=2153
         I/O Timings: shared read=2.774
 Planning Time: 0.059 ms
 Execution Time: 56.711 ms
```

- `read` means from OS, can't tell if it came from disk or not.
  - I/O Timings help, always set track_io_timing = on

Chapter 1: Why am I smelling TOAST

We need a schema

```
CREATE TABLE reports (
    report_id int primary key,
    ruleset_id int not null,
    data jsonb not null -- {"metric1": 0.42, ..., "metric1000": 0.123}
);
CREATE TABLE rules (
    rule_id int primary key,
    ruleset_id int not null,
    rule_nr int not null,
    metric_field text not null,
    max_value real not null -- reports.data->metric_field <= max_value
);
CREATE INDEX ON reports (ruleset_id);
CREATE INDEX ON rules (ruleset_id);
```

And some data

```
-- 10000 reports with 1000 metrics each
INSERT INTO reports
SELECT id,
       floor(random()*100)+1 ruleset_id,
       (SELECT jsonb_object_agg('metric' || metric::text, random())
        FROM generate_series(1,1000) metric)
FROM generate_series(1, 10000) id;
-- 100 rulesets with 10 rules each
INSERT INTO rules
SELECT row_number() over (),
       ruleset_id,
       rule_nr,
       'metric' || floor(random()*1000 + 1)::text metric_field,
       0.95 + 0.1*random() max_value
FROM generate_series(1, 100) ruleset_id, generate_series(1,10) rule_nr;
```

The data

```sql
SELECT pg_size_pretty(avg(length(data::text))) avg_size,
    pg_size_pretty(sum(length(data::text))) total_data_size,
    pg_size_pretty(pg_total_relation_size('reports')) total_table_size
FROM reports;
```

```
 avg_size | total_data_size | total_table_size
----------+-----------------+------------------
 32 kB    | 316 MB          | 159 MB
```

Lets read the data

```
EXPLAIN (ANALYZE, COSTS OFF)
SELECT * FROM reports;
```

```
1   Seq Scan on reports (actual time=0.008..0.591 rows=10000 loops=1)
2   Planning Time: 0.053 ms
3   Execution Time: 0.868 ms
```

Lets read the data

```
EXPLAIN (ANALYZE, COSTS OFF)
SELECT * FROM reports;
```

```
Seq Scan on reports (actual time=0.008..0.591 rows=10000 loops=1)
Planning Time: 0.053 ms
Execution Time: 0.868 ms
```

- 316MB in 0.9ms –> 339 GB/s . . .
  - That's suspiciously fast. . .
  - Lets double check

Actually read the data

```
\timing on
\copy ( SELECT * FROM reports ) TO '/dev/null'
COPY 10000
Time: 1687.562 ms (00:01.688)
```

What's going on

- Large values are split up and stored in a secondary table (toasting)
- Main table contains only the identifier
- Value is transparently read in as needed. (detoasting)
- EXPLAIN ANALYZE doesn't need it.
  - The data is not serialized so detoasting is not triggered.

Fixed in PostgreSQL 17

```
EXPLAIN (ANALYZE, COSTS OFF, SERIALIZE TEXT)
SELECT * FROM reports;
```

```
Seq Scan on reports (actual time=0.009..0.728 rows=10000 loops=1)
Planning Time: 0.040 ms
Serialization: time=1169.736 ms output=323787kB format=text
Execution Time: 1171.082 ms
```

Detoasting can be anywhere

```sql
SELECT report_id, rule_id
FROM reports JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value AND rule_nr = 1;
```

Detoasting can be anywhere

```sql
SELECT report_id, rule_id
FROM reports JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value AND rule_nr = 1;
```

```
Merge Join (actual time=82.500..299.761 rows=108 loops=1)
  Merge Cond: (rules.ruleset_id = reports.ruleset_id)
  Join Filter: (((reports.data -> rules.metric_field))::real > rules.max_value)
  Rows Removed by Join Filter: 9892
  Buffers: shared hit=28351 read=17915 written=1
  -> Index Scan using rules_ruleset_id_idx on rules (actual time=0.030..0.326 rows=100 loops=
        Filter: (rule_nr = 1)
        Rows Removed by Filter: 900
        Buffers: shared hit=748 read=3
  -> Index Scan using reports_ruleset_id_idx on reports (actual time=0.010..3.275 rows=10000 l
        Buffers: shared hit=5515
Execution Time: 299.787 ms
```

Detoasting can be anywhere

```
SELECT report_id, rule_id
FROM reports JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value AND rule_nr = 1;
```

```
Merge Join (actual time=82.500..299.761 rows=108 loops=1)
  Merge Cond: (rules.ruleset_id = reports.ruleset_id)
  Join Filter: (((reports.data -> rules.metric_field))::real > rules.max_value)
  Rows Removed by Join Filter: 9892
  Buffers: shared hit=28351 read=17915 written=1
  -> Index Scan using rules_ruleset_id_idx on rules (actual time=0.030..0.326 rows=100 loops=
        Filter: (rule_nr = 1)
        Rows Removed by Filter: 900
        Buffers: shared hit=748 read=3
  -> Index Scan using reports_ruleset_id_idx on reports (actual time=0.010..3.275 rows=10000
        Buffers: shared hit=5515
Execution Time: 299.787 ms
```

Detoasting is not cached

```
/*+ MergeJoin(reports rules) Leading(reports rules) */
SELECT report_id, rule_id
FROM reports JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value
```

Detoasting is not cached

```sql
/*+ MergeJoin(reports rules) Leading(reports rules) */
SELECT report_id, rule_id
FROM reports JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value
```

```
Merge Join (actual time=45.499..2579.457 rows=1593 loops=1)
  Merge Cond: (rules.ruleset_id = reports.ruleset_id)
  Join Filter: (((reports.data -> rules.metric_field))::real > rules.max_value)
  Rows Removed by Join Filter: 98407
  Buffers: shared hit=436246 read=20105
  -> Index Scan using rules_ruleset_id_idx on rules (actual time=0.042..0.411 rows=1000 loops=
        Buffers: shared hit=740 read=11
  -> Index Scan using reports_ruleset_id_idx on reports (actual time=0.012..22.575 rows=99991
        Buffers: shared hit=55590 read=10
Execution Time: 2579.533 ms
```

How to spot detoasting

- Look for unreasonably high buffer accesses.
- Look for large columns used in predicates and function calls (`VERBOSE` helps)

Example of early detoasting

```
EXPLAIN (BUFFERS, VERBOSE, ANALYZE, COSTS OFF)
SELECT LENGTH(data::text) FROM reports ORDER BY random() LIMIT 100;
```

```
Limit (actual time=1291.706..1291.725 rows=100 loops=1)
  Output: ((data)::text), (random())
  Buffers: shared hit=20342 read=19732
  -> Sort (actual time=1291.704..1291.717 rows=100 loops=1)
        Output: ((data)::text), (random())
        Sort Key: (random())
        Sort Method: top-N heapsort Memory: 3945kB
        -> Seq Scan on public.reports (actual time=0.210..1279.087 rows=10000 loops=1)
              Output: (data)::text, random()
              Buffers: shared hit=20342 read=19732
Execution Time: 1291.764 ms
```

How to fix detoasting

Case 1: value is detoasted too early.

- Use subqueries with `OFFSET/LIMIT` as a boundary to limit evaluation push down.

Subquery boundary

```
SELECT data::text FROM (SELECT data FROM reports ORDER BY random() LIMIT 100);
```

Subquery boundary

```
SELECT data::text FROM (SELECT data FROM reports ORDER BY random() LIMIT 100);
```

```
Subquery Scan on unnamed_subquery (actual time=2.232..14.562 rows=100 loops=1)
  Output: (unnamed_subquery.data)::text
  Buffers: shared hit=442 read=32
  -> Limit (actual time=2.076..2.089 rows=100 loops=1)
        Output: reports.data, (random())
        -> Sort (actual time=2.076..2.081 rows=100 loops=1)
              Output: reports.data, (random())
              Sort Key: (random())
              Sort Method: top-N heapsort Memory: 37kB
              -> Seq Scan on public.reports (actual time=0.008..0.990 rows=10000 loops=1)
                    Output: reports.data, random()
                    Buffers: shared hit=74
Execution Time: 14.582 ms
```

How to fix detoasting 2

Case 2: value is detoasted multiple times

- Force early detoasting by a dummy operation.

Add dummy operation

```
SELECT report_id, rule_id
FROM reports
  JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value
```

to

```
SELECT report_id, rule_id
FROM (SELECT report_id, ruleset_id, data || '{}' data FROM reports OFFSET 0)
    JOIN rules USING (ruleset_id)
WHERE (data->metric_field)::real > max_value;
```

Dummy operation explain

```
Hash Join (actual time=0.749..333.923 rows=1248 loops=1)
  Hash Cond: (reports.ruleset_id = rules.ruleset_id)
  Join Filter: (((((reports.data || '{}'::jsonb)) -> rules.metric_field))::real > rules.max_va
  Rows Removed by Join Filter: 98752
  Buffers: shared hit=30216 read=9866
  -> Seq Scan on reports (actual time=0.045..273.442 rows=10000 loops=1)
        Buffers: shared hit=30214 read=9860
  -> Hash (actual time=0.213..0.214 rows=1000 loops=1)
        Buckets: 1024 Batches: 1 Memory Usage: 63kB
        Buffers: shared hit=2 read=6
        -> Seq Scan on rules (actual time=0.004..0.099 rows=1000 loops=1)
              Buffers: shared hit=2 read=6
Execution Time: 334.006 ms
```

Handling TOAST in queries

- Be concious of whether large values are involved in a query plan.
- The planner is completely oblivious about detoasting.
- Think if you need to be eager or lazy.
- Use tricks to force the planners hand.

Chapter 2: I (don’t) see dead tuples

Schema time

- We are building a task queue

```
CREATE TYPE task_status AS ENUM ('Todo', 'Done', 'Failed');

CREATE TABLE tasks (
    id bigserial primary key,
    job_id int not null default floor(random()*10 + 1)::int,
    status task_status not null,
    added timestamptz not null default now(),
    done timestamptz
);

CREATE INDEX ON tasks (added) WHERE status = 'Todo';
```

Add some tasks

```
INSERT INTO tasks (status)
    SELECT 'Todo' FROM generate_series(1,100) i;
```

The workload

queue-insert.sql

```sql
INSERT INTO tasks (status) VALUES ('Todo');
```

queue-complete.sql

```sql
UPDATE tasks SET status = 'Done', done = NOW()
WHERE id = (SELECT id FROM tasks
            WHERE status = 'Todo' ORDER BY added
            FOR UPDATE SKIP LOCKED LIMIT 1);
```

Running the workload

```
pgbench -n -f queue-insert.sql -f queue-complete.sql \
    --rate=2000 -j8 -c8 \
    -P 10 -T 600
```

Running the workload

```
pgbench -n -f queue-insert.sql -f queue-complete.sql \
    --rate=2000 -j8 -c8 \
    -P 10 -T 600
```

```
progress: 10.0 s, 1996.6 tps, lat 4.251 ms stddev 2.994, 0 failed, lag 1.945 ms
progress: 20.0 s, 1991.9 tps, lat 3.897 ms stddev 2.686, 0 failed, lag 1.673 ms
progress: 30.0 s, 1969.4 tps, lat 6.368 ms stddev 13.453, 0 failed, lag 4.003 ms
progress: 40.0 s, 2006.0 tps, lat 4.353 ms stddev 3.135, 0 failed, lag 2.026 ms
progress: 50.0 s, 2008.1 tps, lat 4.225 ms stddev 2.830, 0 failed, lag 1.905 ms
```

Meanwhile in another part of town

A business analyst using DBeaver:

```
BEGIN ISOLATION LEVEL REPEATABLE READ;
SELECT COUNT(*) FROM tasks WHERE status = 'Todo';
```

Meanwhile in another part of town

A business analyst using DBeaver:

```
BEGIN ISOLATION LEVEL REPEATABLE READ;
SELECT COUNT(*) FROM tasks WHERE status = 'Todo';
```

“Let’s go get a coffee to think about that number. . . ”

Back at benchmark central

```
progress: 90.0 s, 1985.0 tps, lat 17.509 ms stddev 17.266, 0 failed, lag 14.128 ms
progress: 100.0 s, 1654.7 tps, lat 1188.524 ms stddev 343.977, 0 failed, lag 1183.696 ms
progress: 110.0 s, 1552.0 tps, lat 2753.375 ms stddev 686.912, 0 failed, lag 2748.222 ms
progress: 120.0 s, 1353.5 tps, lat 5476.902 ms stddev 987.954, 0 failed, lag 5470.992 ms
progress: 130.0 s, 1280.2 tps, lat 8885.448 ms stddev 1064.684, 0 failed, lag 8879.201 ms
progress: 140.0 s, 1177.2 tps, lat 12687.523 ms stddev 1277.164, 0 failed, lag 12680.729 ms
progress: 150.0 s, 1103.0 tps, lat 17038.791 ms stddev 1365.447, 0 failed, lag 17031.536 ms
progress: 160.0 s, 1047.2 tps, lat 21655.815 ms stddev 1455.754, 0 failed, lag 21648.179 ms
progress: 170.0 s, 985.5 tps, lat 26621.604 ms stddev 1573.951, 0 failed, lag 26613.488 ms
progress: 180.0 s, 923.9 tps, lat 31668.206 ms stddev 1587.211, 0 failed, lag 31659.547 ms
progress: 190.0 s, 918.5 tps, lat 37157.963 ms stddev 1645.525, 0 failed, lag 37149.256 ms
progress: 200.0 s, 877.3 tps, lat 42607.753 ms stddev 1721.361, 0 failed, lag 42598.632 ms
progress: 210.0 s, 853.5 tps, lat 48289.559 ms stddev 1720.792, 0 failed, lag 48280.190 ms
progress: 220.0 s, 788.5 tps, lat 54187.022 ms stddev 1852.551, 0 failed, lag 54176.878 ms
progress: 230.0 s, 751.6 tps, lat 60477.265 ms stddev 1899.692, 0 failed, lag 60466.617 ms
```

Incident resolution

- “Our CPUs are on fire, what is going on?”
- “pg_stat_statements says that the queue completion query is 100x slower.”
- “I know, let’s get an explain plan!”

The explain plan

```
Update on tasks (actual time=25.273..25.274 rows=0 loops=1)
  Buffers: shared hit=95467 dirtied=1 written=1
  I/O Timings: shared write=0.028
  InitPlan 1 (returns $1)
    -> Limit (actual time=25.204..25.205 rows=1 loops=1)
          Buffers: shared hit=95454
          -> LockRows (actual time=25.204..25.204 rows=1 loops=1)
                Buffers: shared hit=95454
                -> Index Scan using tasks_added_idx on tasks tasks_1 (actual time
                      =25.143..25.148 rows=10 loops=1)
                      Filter: (status = 'Todo'::task_status)
                      Buffers: shared hit=95428
  -> Index Scan using tasks_pkey on tasks (actual time=25.214..25.215 rows=1 loops=1)
        Index Cond: (id = $1)
        Buffers: shared hit=95458
Execution Time: 25.292 ms
```

What’s going on

- The open transaction is preventing autovacuum from cleaning up completed jobs.
- Index fills up with old row versions that have actually already been updated.
- Due to the open transaction we can’t cache the dead status in the index.
  - See “Killed Index Tuples” blogpost by Laurenz
- Every time we look for a task, we have to scan over the index entries for already completed tasks.
  - For each one go and look at the row in the table to see that it has been updated.

What’s going on

- The open transaction is preventing autovacuum from cleaning up completed jobs.
- Index fills up with old row versions that have actually already been updated.
- Due to the open transaction we can’t cache the dead status in the index.
  - See “Killed Index Tuples” blogpost by Laurenz
- Every time we look for a task, we have to scan over the index entries for already completed tasks.
  - For each one go and look at the row in the table to see that it has been updated.
- None of this is visible in the explain numbers.

Fixing it

- Avoid mixing long queries/transactions and update heavy workloads.
- Use `statement_timeout`, `idle_in_transaction_session_timeout` to have a backstop against accidents.
- PostgreSQL 17 will also have `transaction_timeout`.

After terminating the naughty connection

```
Update on tasks (actual time=0.308..0.308 rows=0 loops=1)
  Buffers: shared hit=516
  InitPlan 1 (returns $1)
    -> Limit (actual time=0.290..0.291 rows=1 loops=1)
          Buffers: shared hit=506
          -> LockRows (actual time=0.290..0.290 rows=1 loops=1)
                Buffers: shared hit=506
                -> Index Scan using tasks_added_idx on tasks tasks_1 (actual time
                     =0.284..0.285 rows=2 loops=1)
                      Filter: (status = 'Todo'::task_status)
                      Buffers: shared hit=504
  -> Index Scan using tasks_pkey on tasks (actual time=0.294..0.295 rows=1 loops=1)
        Index Cond: (id = $1)
        Buffers: shared hit=510
Execution Time: 0.328 ms
```

The missing information

- How many rows were scanned but found not visible
- How many killed index tuples were skipped over
- This also affects sequential scans, it’s just not as easy to see

The invisible visibility map

We need a larger table for this:

```
CREATE TABLE bigger AS SELECT i, repeat(' ', 100)
  FROM generate_series(1,2) j, generate_series(1,3000000) i;

CREATE INDEX ON bigger(i);

VACUUM ANALYZE bigger;
```

Holy buffer hit count Batman

```
SELECT i FROM bigger;
```

Holy buffer hit count Batman

```
SELECT i FROM bigger;
```

```
Index Only Scan using bigger_i_idx on bigger (actual time=0.016..799.596 rows=6000000
    loops=1)
  Heap Fetches: 0
  Buffers: shared hit=6014781
Planning Time: 0.044 ms
Execution Time: 958.258 ms
```

What's going on

- Index only scan looks at visibility map to check if we can skip the heap fetch
- This happens for each row
- It caches the location of the last looked at VM page and skips buffer lookup if next one is the same.
- Example was constructed so this never works out.
- Happens in the real world too with random access to tables >256MB
  - See "Unexpected downsides of UUID keys in PostgreSQL" blogpost

Fixing it

- Data locality matters.
- Use `CLUSTER`, fillfactor and other tricks to keep data sorted by access patterns.

Fixing it

- Data locality matters.
- Use CLUSTER, fillfactor and other tricks to keep data sorted by access patterns.

```
CLUSTER bigger USING bigger_i_idx;
```

Results

```
Index Only Scan using bigger_i_idx on bigger (actual time=0.017..342.865 rows=6000000
    loops=1)
  Heap Fetches: 0
  Buffers: shared hit=14785
Planning Time: 0.042 ms
Execution Time: 500.547 ms
```

~2x performance difference just from avoiding visibility map buffer lookups.

Chapter 3: Hello? Is this thing on?!

Trip down memory lane

Taking our tasks table from before:

```
CREATE TABLE tasks (
    id bigserial primary key,
    job_id int not null default floor(random()*10 + 1)::int,
    status task_status not null,
    added timestamptz not null default now(),
    done timestamptz
);
```

New goal

We have a query:

```
SELECT id FROM tasks
WHERE job_id = 3 AND added < '1969-07-20 15:17:40-05'
ORDER BY id;
```

Lets try a couple of indexes to make it fast

Tale of two indexes

```
CREATE INDEX j_i_a ON tasks (job_id, id, added);
```

```
Index Only Scan using j_i_a on tasks (actual time=1.207..1.207 rows=0 loops=1)
  Index Cond: ((job_id = 3) AND (added < '1969-07-20 23:17:40+03'::timestamp with time
        zone))
  Heap Fetches: 0
  Buffers: shared hit=300
```

```
CREATE INDEX job_added_id ON tasks (job_id, added, id);
```

```
Sort (actual time=0.020..0.021 rows=0 loops=1)
 -> Index Only Scan using j_a_i on tasks (actual time=0.013..0.013 rows=0 loops=1)
      Index Cond: ((job_id = 3) AND (added < '1969-07-20 23:17:40+03'::timestamp with
           time zone))
      Heap Fetches: 0
      Buffers: shared hit=3
```

The answer

- Index range scans (`col < const`) can only be used if **all** preceding index columns have equality on them.
- With `(job_id, id, added)` we cannot use `added` for scanning as it's unordered:

```
job_id [3      [3      [3      [3      [3
    id  1       2       3       4       7
 added  13:35]  17:49]  11:05]  19:12]  09:12]
```

- But we can scan all for a single job_id and use the added for filtering.
- The fact that Index Cond is only used for filtering is not visible anywhere in the explain plan.
  - Neither is the amount of index tuples scanned and discarded.
- `Rows Removed by Filter:` only includes filters done on table values.

Fin

What did we learn today

- Explain still doesn’t explain everything
- In particular, hidden detoasting and bloat scanning might make things slow.
- EXPLAIN is always improving, hopefully we will soon have more visibility.

Thank you

Q & A

Bonus content

More things to improve

- How many of updates were HOT.
- How many pages were pruned while scanning
- How many index probes were done during planning
- Hint bit updates log WAL, but this doesn't show up with `EXPLAIN (WAL)`
- SLRU accesses are completely hidden.
- Getting explain plans from within functions is quite tricky.
- When are extended statistics consulted.
- How much time was spent waiting on locks.