Lifetime of a SELECT

A blick into the depth of PostgreSQL internals

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Zalando SE

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Who am I ?

A Senior Database Engineer in Zalando

Earlier more infra, now more consultancy

Volunteer in the PostgreSQL community

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Zalando SE

- In-house PostgreSQL as a Service
- > 3000 PostgreSQL clusters
- **Popular open source projects:**
  - Postgres-operator
  - Spilo

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Who are you ?

Developers with some PostgreSQL experience who want to understand what happens under the hood

Why this talk ?

PostgreSQL internals are fun

Repetitive questions are not

Money saved on avoidable incidents is nice

Philosophy

KISS

More why than how

A problem is more important than a solution

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All models are wrong, but some are useful.

George E. P. Box, a British statistician

The plan

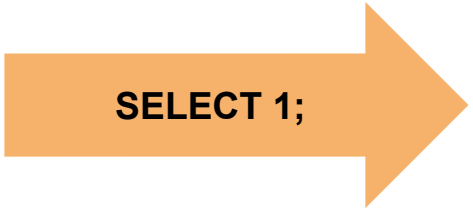
How PostgreSQL runs

How PostgreSQL runs SELECTs

How PostgreSQL runs SELECTs fast

SELECT 1 as hello_pg_meetup;

How PostgreSQL runs



No DB is 100% available

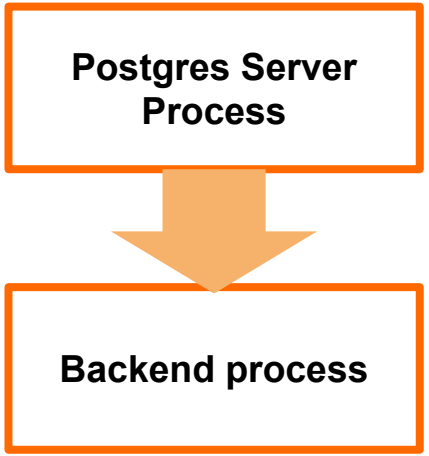
Why you will forget

PostgreSQL is very reliable

Infrastructure is rapidly maturing

“Hay in a haystack”

Process model



Connections
come with a cost

Typical issues

Opening and closing many short-lived connections. Fine if load is low.

Hitting max_connections

Connection not terminated

TODOs

Monitor!

Connection pooler is your ❤️ ❤️ ❤️

Teach yourself to cancel backends gracefully. Hint: pg_(cancel|terminate)_backend()

Have a way to nicely restart an application and a connection pool

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The Lifetime

How PostgreSQL runs

```
EXPLAIN ANALYZE SELECT 1 AS hello_pg_meetup;
                                QUERY PLAN
═══════════════════════════════════════════════════════
 Result  (cost=0.00..0.01 rows=1 width=4) (actual
time=0.002..0.003 rows=1.00 loops=1)
 Planning Time: 0.027 ms
 Execution Time: 0.018 ms
(3 rows)
```

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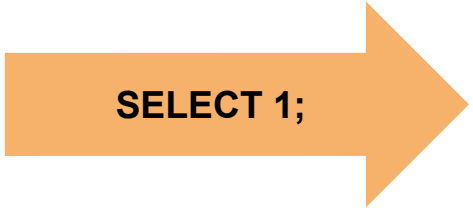
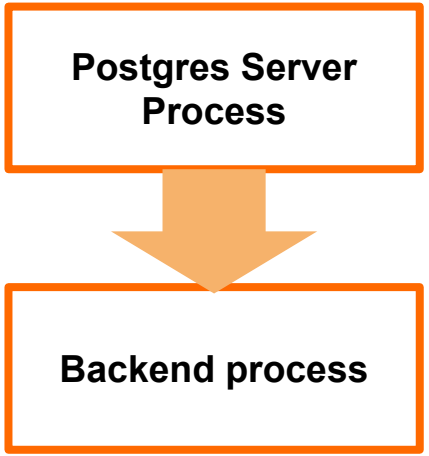
Mental model v1.0





The plan

How PostgreSQL runs

How PostgreSQL runs SELECTs

How PostgreSQL runs SELECTs fast

```
SELECT * FROM t;
```

… If you've chosen the right data structures and organized things well, the algorithms will almost always be self-evident …

Rob Pike’s
5 Rules of Programming

User’s table

```
CREATE TABLE t (
        id SERIAL PRIMARY KEY,
        payload TEXT
);

INSERT INTO t (payload)
SELECT gen_random_uuid()::TEXT
FROM generate_series(1, 10000000);
```

* You need pgcrypto for gen_random_uuid()
** Do you see the problem here ?

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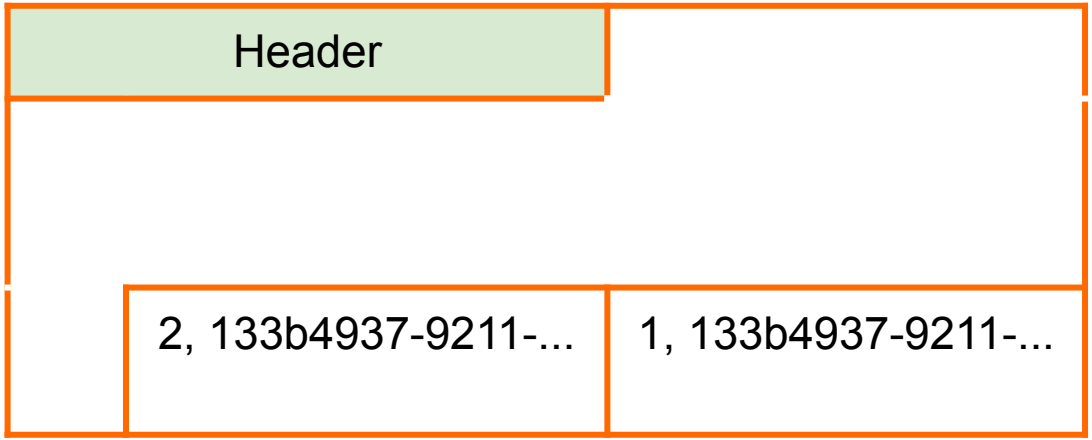
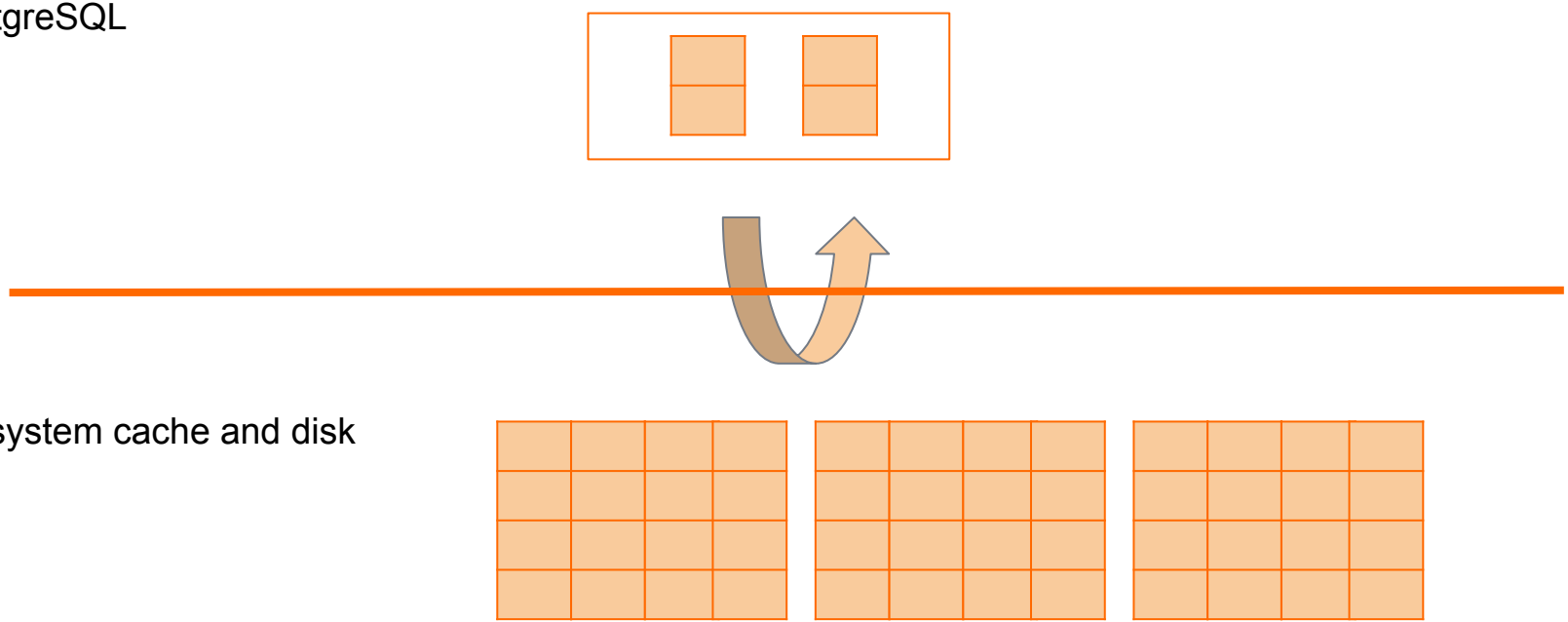
System’s page



The buffer pool

PostgreSQL



Filesystem cache and disk

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Typical issues

Buffer manager is PostgreSQL.

Filesystem cache is important.

Be careful with load tests.

Typical issues

Use EXPLAIN (ANALYZE, BUFFERS)

Nikolay Samokhvalov, EXPLAIN (ANALYZE) needs BUFFERS
https://tinyurl.com/ywyhpz73

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Typical issues

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM t;
                                   QUERY PLAN
═══════════════════════════════════════════════════════════════════
 Seq Scan on t  (cost=0.00..193460.13 rows=10000113 width=41)
(actual time=0.076..1384.638 rows=10000010.00 loops=1)
 Buffers: shared hit=12659 read=80800
 Planning Time: 3.210 ms
 Execution Time: 1711.777 ms
(4 rows)
```

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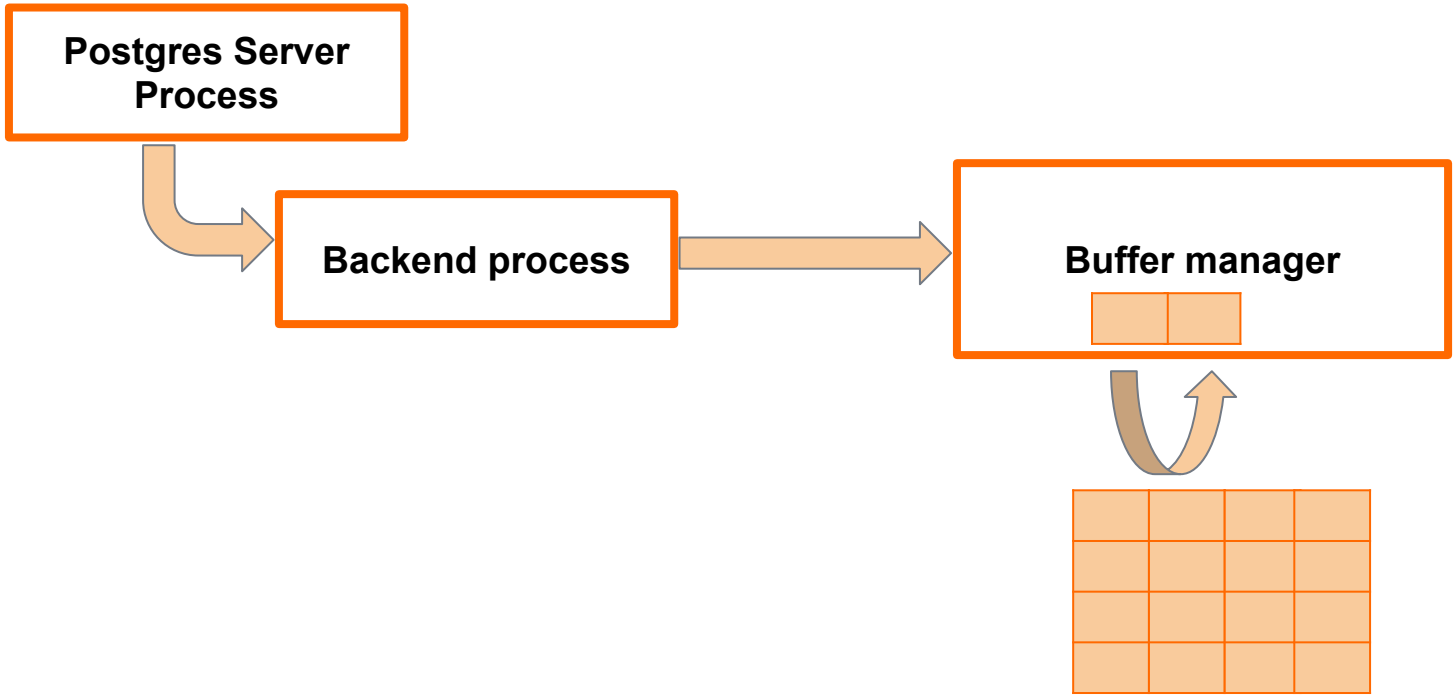
Mental model v1.5



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```
SELECT * FROM t ORDER BY payload;
```

Sort and Seq Scan ?

```
EXPLAIN  SELECT * FROM t ORDER BY payload;
                        QUERY PLAN
=================================================================
=================================================
 Sort  (cost=1971392.92..1996393.20 rows=10000113
width=41)
   Sort Key: payload
   ->  Seq Scan on t  (cost=0.00..193460.13 rows=10000113
width=41)
```

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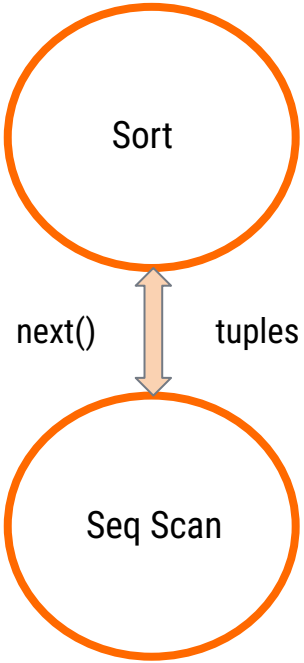
Iterator model

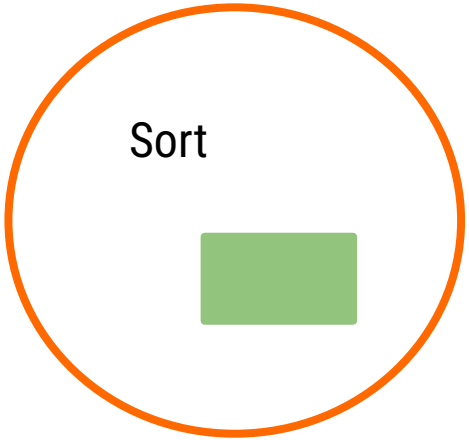


As in Java Iterator<E>:

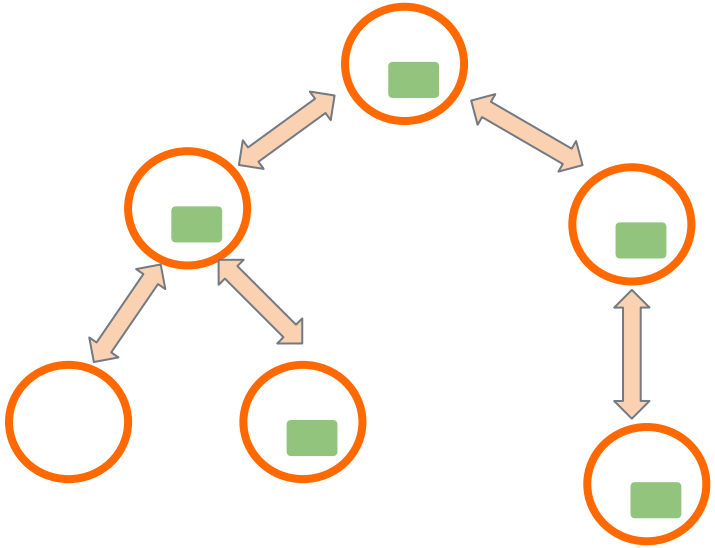
1. next()
2. hasNext()

Goetz Graefe,
Volcano - an Extensible and Parallel Query Evaluation System
https://tinyurl.com/4zaxyjzy

work_mem



Mind the memory !



Reads generate writes

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM t ORDER BY payload;
QUERY PLAN
═══════════════════════════════════════════════════════════
 Sort  (cost=1971392.92..1996393.20 rows=10000113 width=41) (actual
time=34302.764..44241.243 rows=10000010.00 loops=1)
   Sort Key: payload
   Sort Method: external merge  Disk: 499152kB
   Buffers: shared hit=12691 read=80768, temp read=124778 written=124996
   ->  Seq Scan on t  (cost=0.00..193460.13 rows=10000113 width=41) (actual
time=0.145..3214.634 rows=10000010.00 loop>
         Buffers: shared hit=12691 read=80768
 Planning Time: 2.388 ms
 Execution Time: 44699.701 ms
```

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Reads generate writes

```
SET work_mem = '1000MB';
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM t ORDER BY payload;
QUERY PLAN
═══════════════════════════════════════════════════════════
 Sort  (cost=1356148.92..1381149.20 rows=10000113 width=41) (actual
time=46419.621..49033.799 rows=10000010.00 loops=1)
   Sort Key: payload
   Sort Method: quicksort  Memory: 904274kB
   Buffers: shared hit=12755 read=80704
   ->  Seq Scan on t  (cost=0.00..193460.13 rows=10000113 width=41) (actual
time=0.033..1302.849 rows=10000010.00 loop>
         Buffers: shared hit=12755 read=80704
 Planning Time: 4.058 ms
 Execution Time: 49732.897 ms
```

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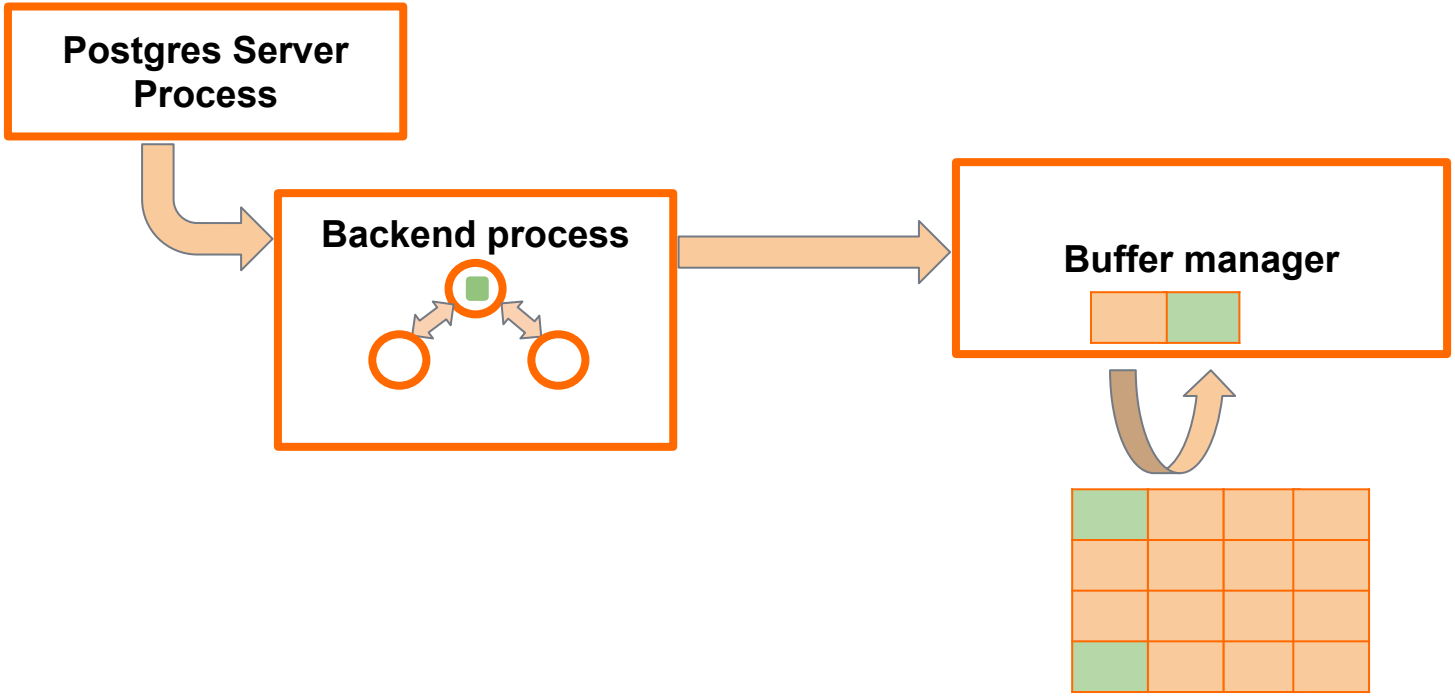
Mental model v2.0



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The plan

How PostgreSQL runs

How PostgreSQL runs SELECTs

How PostgreSQL runs SELECTs fast

```
SELECT * FROM t
WHERE payload = '...' ;
```

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM t WHERE payload =
'db5c138e-5f56-402b-88d3-fae4d42a7c43';
QUERY PLAN
═══════════════════════════════════════════════════════════════════════
 Gather  (cost=1000.00..146543.02 rows=1 width=41) (actual time=0.496..350.039
rows=1.00 loops=1)
   Workers Planned: 2
   Workers Launched: 2
   Buffers: shared hit=13011 read=80448
   ->  Parallel Seq Scan on t  (cost=0.00..145542.92 rows=1 width=41) (actual
time=226.272..341.485 rows=0.33 loops=3)
         Filter: (payload = 'db5c138e-5f56-402b-88d3-fae4d42a7c43'::text)
         Rows Removed by Filter: 3333336
         Buffers: shared hit=13011 read=80448
 Planning Time: 0.089 ms
 Execution Time: 350.074 ms
```

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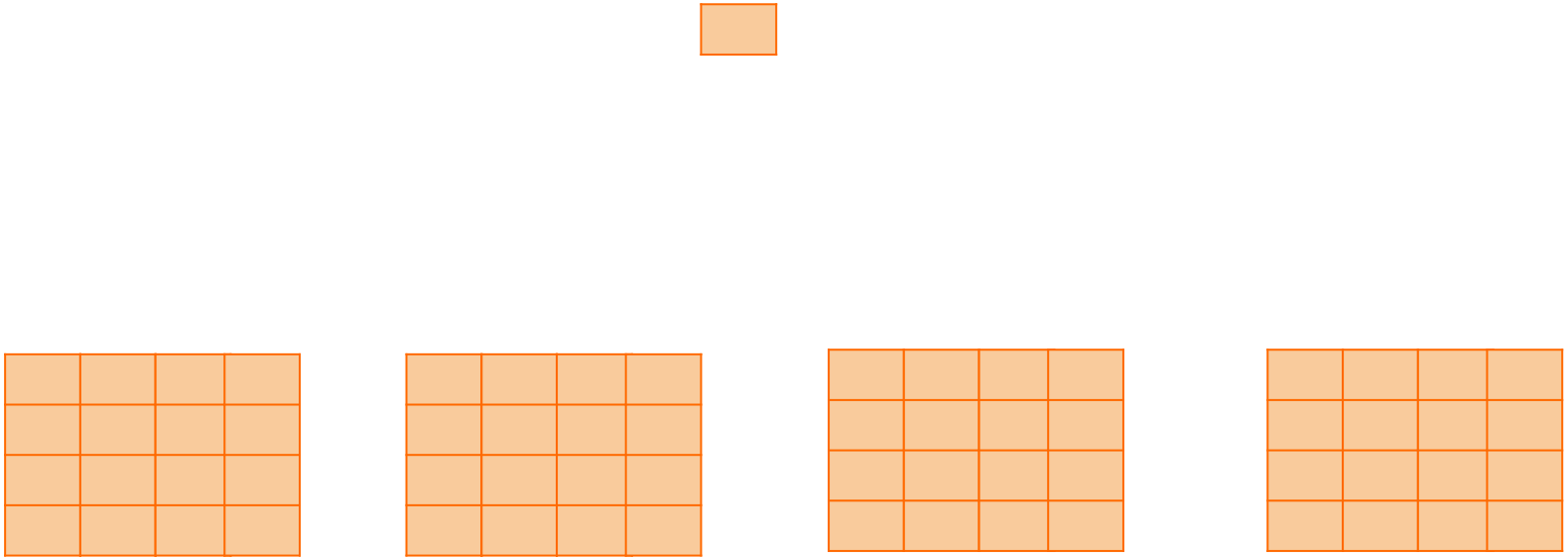
What a waste …



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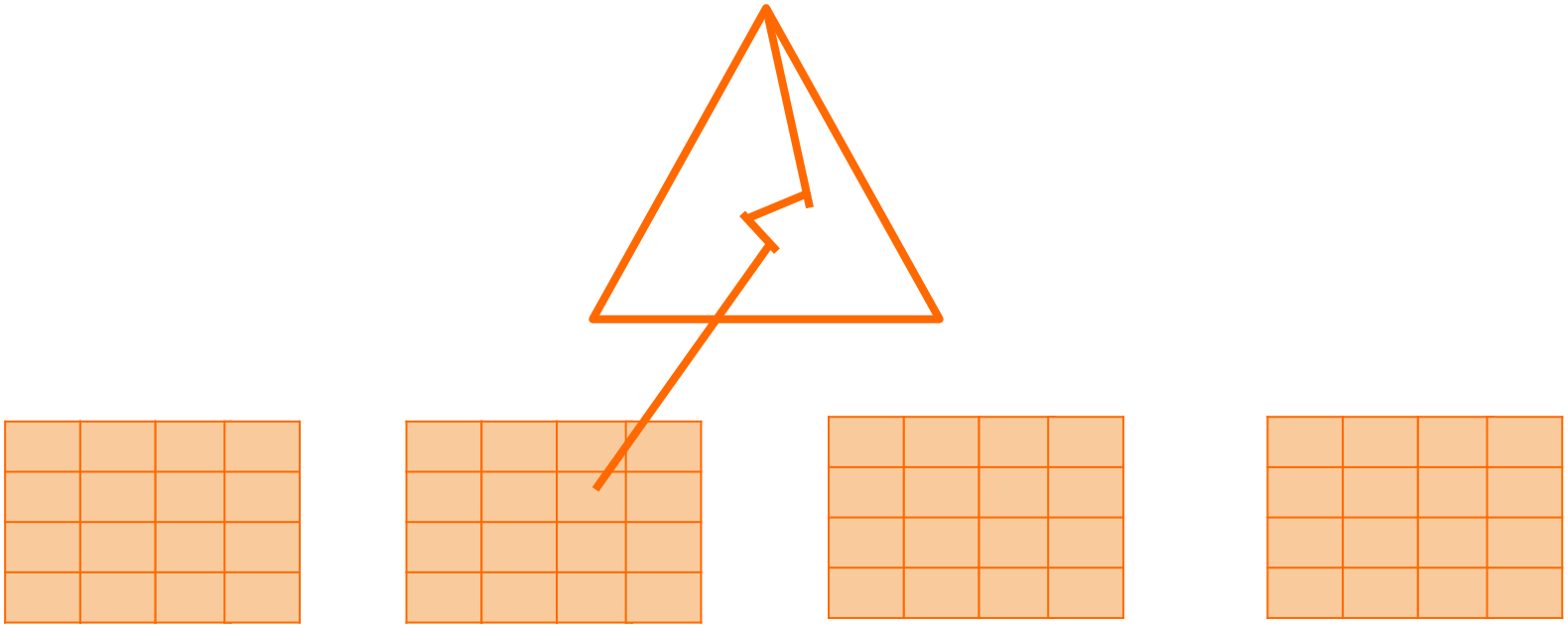
How to locate



Aside: B-trees

Fundamental: 99% of all indexes

PostgresPro, Indexes in PostgreSQL, part 4 (B-Tree)
https://tinyurl.com/y9bbjwxm

```
CREATE INDEX CONCURRENTLY ON t(payload);
CREATE INDEX
Time: 66830.423 ms (01:06.830)
```

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How to locate

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM t WHERE payload =
'db5c138e-5f56-402b-88d3-fae4d42a7c43';
QUERY PLAN
═══════════════════════════════════════════════════════════
 Index Scan using t_payload_idx on t  (cost=0.56..8.58 rows=1 width=41)
(actual time=0.617..0.619 rows=1.00 loops=1)
   Index Cond: (payload = 'db5c138e-5f56-402b-88d3-fae4d42a7c43'::text)
   Buffers: shared hit=3 read=2
 Planning:
   Buffers: shared hit=10 read=3 dirtied=1
 Planning Time: 4.571 ms
 Execution Time: 1.386 ms
```

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How to choose

One access method costs more than the other

Index Scan: 5 ms, Seq Scan: 350 ms

Observation: it’s relative

The cost

Cost = IO cost + CPU cost

IO = f(number of pages)

CPU = f(number of tuples)

The statistics

of pages, # of tuples, most common values etc.

Normally collected automatically

Typical issues

Outdated, absent or otherwise wrong statistics

Query optimization on a different dataset

Query plan flips (tip: learn auto_explain)

Almighty ANALYZE

The very first step in query optimization

Before v18: the very first step after major version upgrade

```
ANALYZE t;
ANALYZE
Time: 699.738 ms
```

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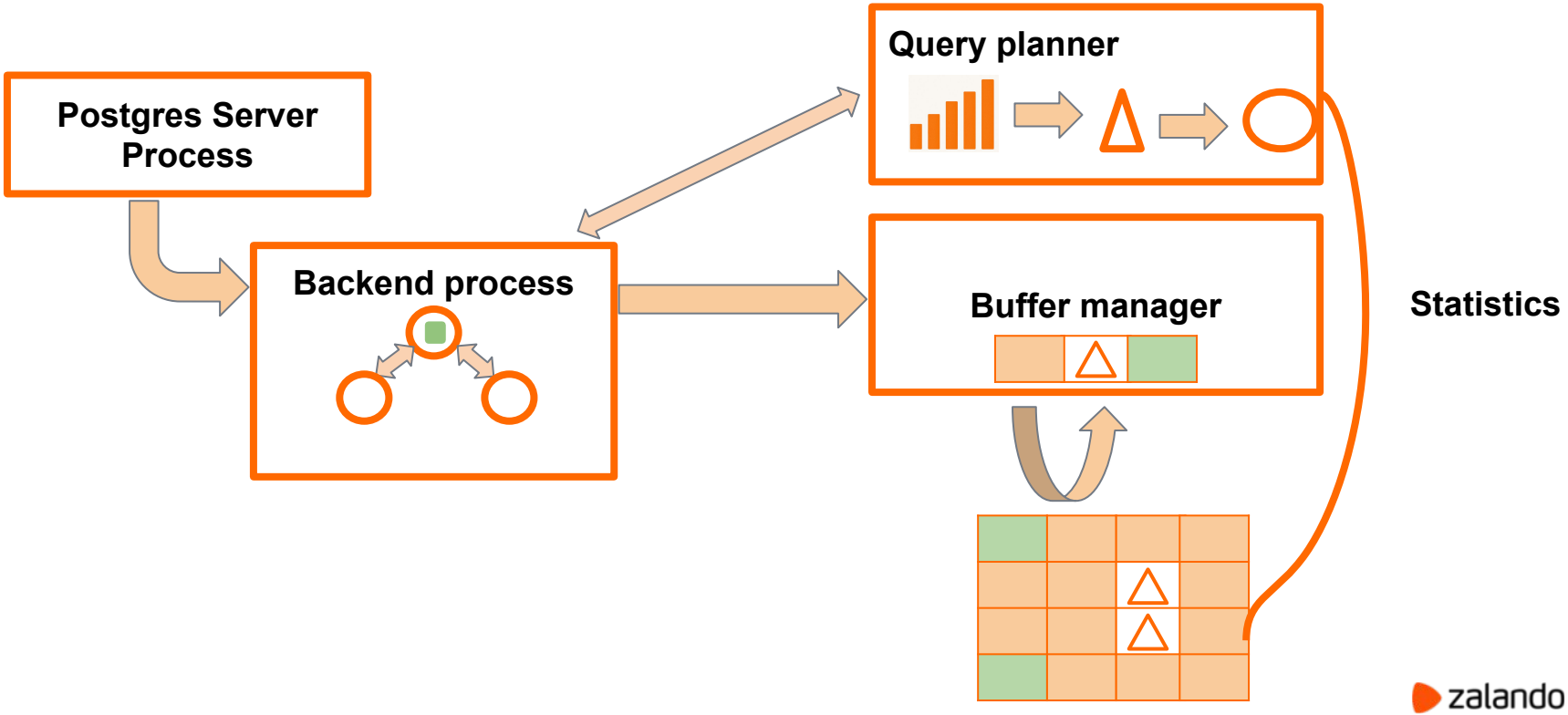
The planner

Statistics

Access methods / joins

Plan / iterator tree

Mental model v3.0



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What’s next ?

Carnegie Mellon Database Group

PEOPLE PROJECTS PUBLICATIONS COURSES NEWS

15-445/645 — Intro to Database Systems

This project-oriented course provides an introduction to the internal architecture of database systems.

6.5830/6.5831: Database Systems

Fall 2024

Home | Schedule | Notes & Assignments | Syllabus | FAQ

+ Implement == understand
- Minimum 150 hours

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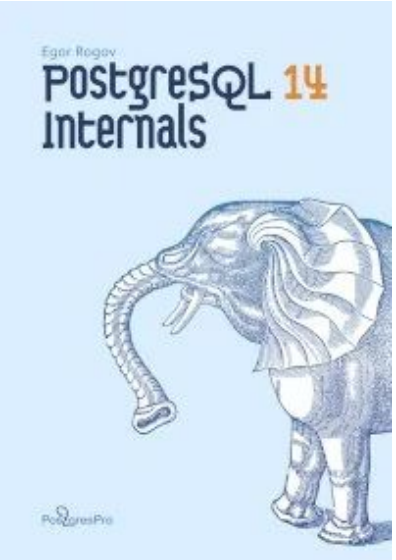
But I want my elephants …



https://www.interdb.jp/pg/index.html

https://postgrespro.com/community/books/internals

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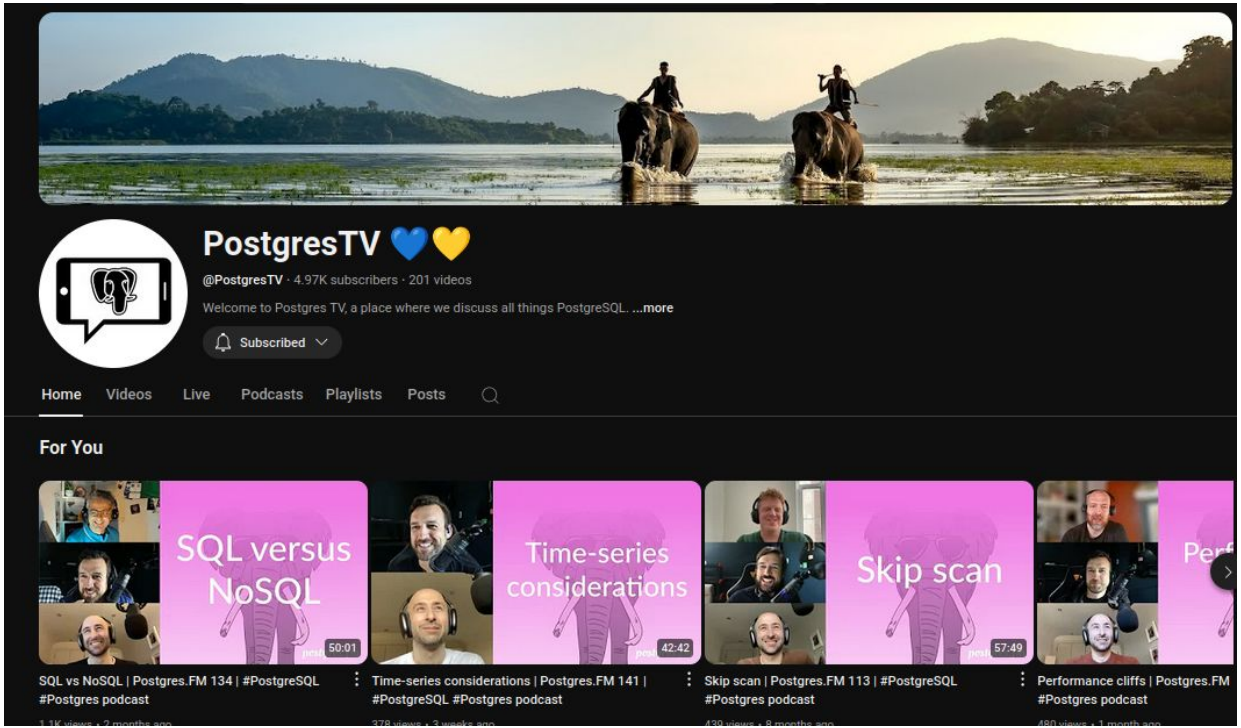
… and fun



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Next talk

The almighty B-trees

Bonus

```
SELECT payload FROM t WHERE id = 1;
              payload
-----------------------------------------
 133b4937-9211-4add-9839-749955xfa2da
(1 row)
```

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Bonus

```
SELECT payload::uuid FROM t WHERE id = 1;

ERROR:  22P02: invalid input syntax for type uuid:
"133b4937-9211-4add-9839-749955xfa2da"
LOCATION:  string_to_uuid, uuid.c:170
Time: 0.559 ms
```

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Bonus

```
CREATE TABLE t (
        id SERIAL PRIMARY KEY,
        payload TEXT
);

INSERT INTO t (payload)
SELECT gen_random_uuid()::TEXT
FROM generate_series(1, 10000000);
```

Not everything is TEXT

UTFT

Use
The
F*bulous
Typesystem

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Thank You!

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