Вся правда об индексах в PostgreSQL

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Конференция
разработчиков
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систем

Индекс как «серебряная пуля»

the only weapon that is effective against a werewolf, witch, or other monsters.

Индекс как «серебряная пуля»

- Индекс — это дополнительная структура данных (не SQL) для **ускорения** работы запросов.
- Результат запроса с индексом и без должны быть одинаковы !
- Индексы важны для
  - Поиска - обычное использование
  - Ограничений целостности
  - Сортировки,группировки, соединения таблиц
- Индексы не всегда полезны
  - Малая селективность, затраты на поддержание

Индекс как «серебряная пуля»

- Разработчики приложения
  - SQL как язык — таблицы, представления, транзакции, ограничения, запросы, работа с данными
- Администраторы СУБД
  - Хранилище, бэкапы и восстановление, индексы, настройки, высокая доступность
  - Не знают запросов, а если узнают, то не могут их поменять.
- **Индексы должны быть заботой разрабочиков приложений !**
- **Мониторинг индексов остается администраторам**

Индекс в PostgreSQL

- Все индексы — вторичные, они отделены от таблицы. Вся информация о них содержится в системном каталоге
- Индексы связывают ключи и TID (tuple id - #page: offset)
- Индексы могут быть многоколончатые, только GIN-индекс порядок колонок не важен.
- MVCC: записи таблицы имеют версии (туплы), из которых только одна видна конкретной транзакции.
- Индексы не содержат информации о видимости
- Любое обновление записи в таблице приводит к появлению новой записи в индексе, index bloat.

Использование индекса при поиске

Индекс может использоваться для:

- WHERE col opr value
- ORDER BY col [ASC|DESC]
- ORDER BY col opr value [ASC]

Использование индекса при поиске

Индекс может использоваться для:

- WHERE expr opr value
- ORDER BY expr [ASC|DESC]
- ORDER BY expr opr value [ASC]

Условия для использования индекса

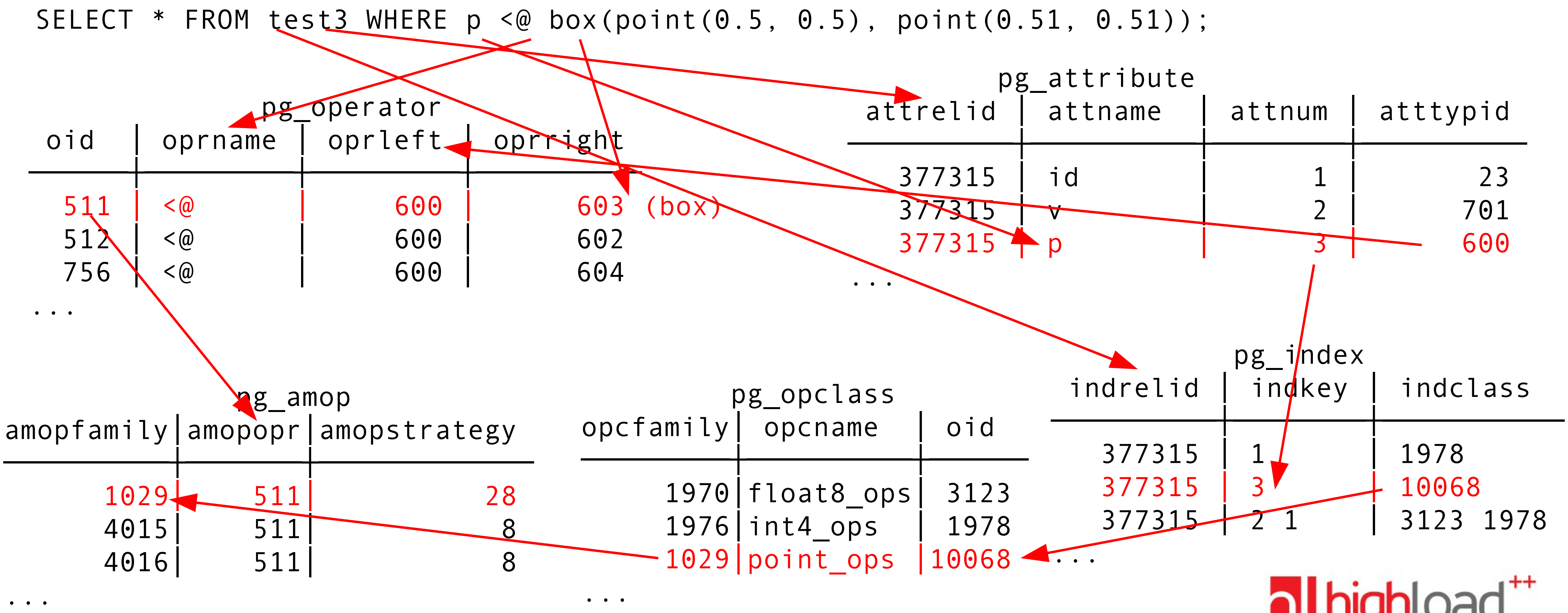
- Совпадают оператор и типы аргументов (порядок важен)
- Индекс валиден (например, concurrent index может быть не валиден)
- В многоколончатом индексе важен порядок (для GIN не важен)
- План с его использованием — оптимален (минимальная стоимость)
- Всю информацию постгрес берет из системного каталога

Выбор нужного индекса: пример

```
CREATE TABLE test3 AS (SELECT id, random() AS v, point(random(), random()) AS p
FROM generate_series(1,1000000) id);
ALTER TABLE test3 ADD PRIMARY KEY (id);
CREATE INDEX test3_p_idx ON test3 USING gist (p);
CREATE INDEX test3_v_id_idx ON test3 (v, id);

SELECT * FROM test3 WHERE p <@ box(point(0.5, 0.5), point(0.51, 0.51));
 Bitmap Heap Scan on test3  (cost=48.36..2805.41 rows=1000 width=28) (actual time=0.069..0.15
   Recheck Cond: (p <@ '(0.51,0.51),(0.5,0.5)'::box)
   ->  Bitmap Index Scan on test3_p_idx  (cost=0.00..48.11 rows=1000 width=0) (actual time=0.
         Index Cond: (p <@ '(0.51,0.51),(0.5,0.5)'::box)
 Total runtime: 0.172 ms
```

Выбор нужного индекса: схема



```
SELECT * FROM test3 WHERE p <@ box(point(0.5, 0.5), point(0.51, 0.51));
```

pg_operator

oid	oprname	oprleft	oprright
511	<@	600	603 (box)
512	<@	600	602
756	<@	600	604

...

pg_attribute

attrelid	attname	attnum	atttypid
377315	id	1	23
377315	v	2	701
377315	p	3	600

...

pg_amop

amopfamily	amopopr	amopstrategy
1029	511	28
4015	511	8
4016	511	8

...

pg_opclass

opcfamily	opcname	oid
1970	float8_ops	3123
1976	int4_ops	1978
1029	point_ops	10068

...

pg_index

indrelid	indkey	indclass
377315	1	1978
377315	3	10068
377315	2 1	3123 1978

...

Выбор нужного индекса: алгоритм

1. Поиск номера и типа данных столбца в pg_attribute по имени столбца и таблицы
2. Поиск oid оператора в pg_operator по имени оператора и типам операндов
3. Поиск подходящих индексов по таблице и номеру столбца
4. Поиск oid семейства операторов в pg_opclass по классам операторов подходящих индексов
5. Поиск поддерживаемых индексами операторов в pg_amop по oid семейства операторов и oid оператора
6. Индексы, которые поддерживают нужные операторы (найдены в pg_amop) могут быть использованы.

Что все эти «сканы» означают ?

```
Seq Scan on tbl  (cost=0.00..17.50 rows=700 width=8)
  Filter: (a > 30)
  Rows Removed by Filter: 300

Index Only Scan using ab_idx on tbl  (cost=0.28..6.03 rows=100 width=8)
  Index Cond: (a > 90)
  Heap Fetches: 0
update tbl set a=18;

Bitmap Heap Scan on tbl  (cost=9.67..20.92 rows=180 width=8)
  Recheck Cond: (a > 90)
  ->  Bitmap Index Scan on ab_idx  (cost=0.00..9.63 rows=180 width=0)
        Index Cond: (a > 90)
set enable_indexonlyscan to off; set enable_bitmapscan to off;

Index Scan using ab_idx on tbl  (cost=0.28..6.04 rows=1 width=8)
  Index Cond: (a > 90)
```

Sequential Scan

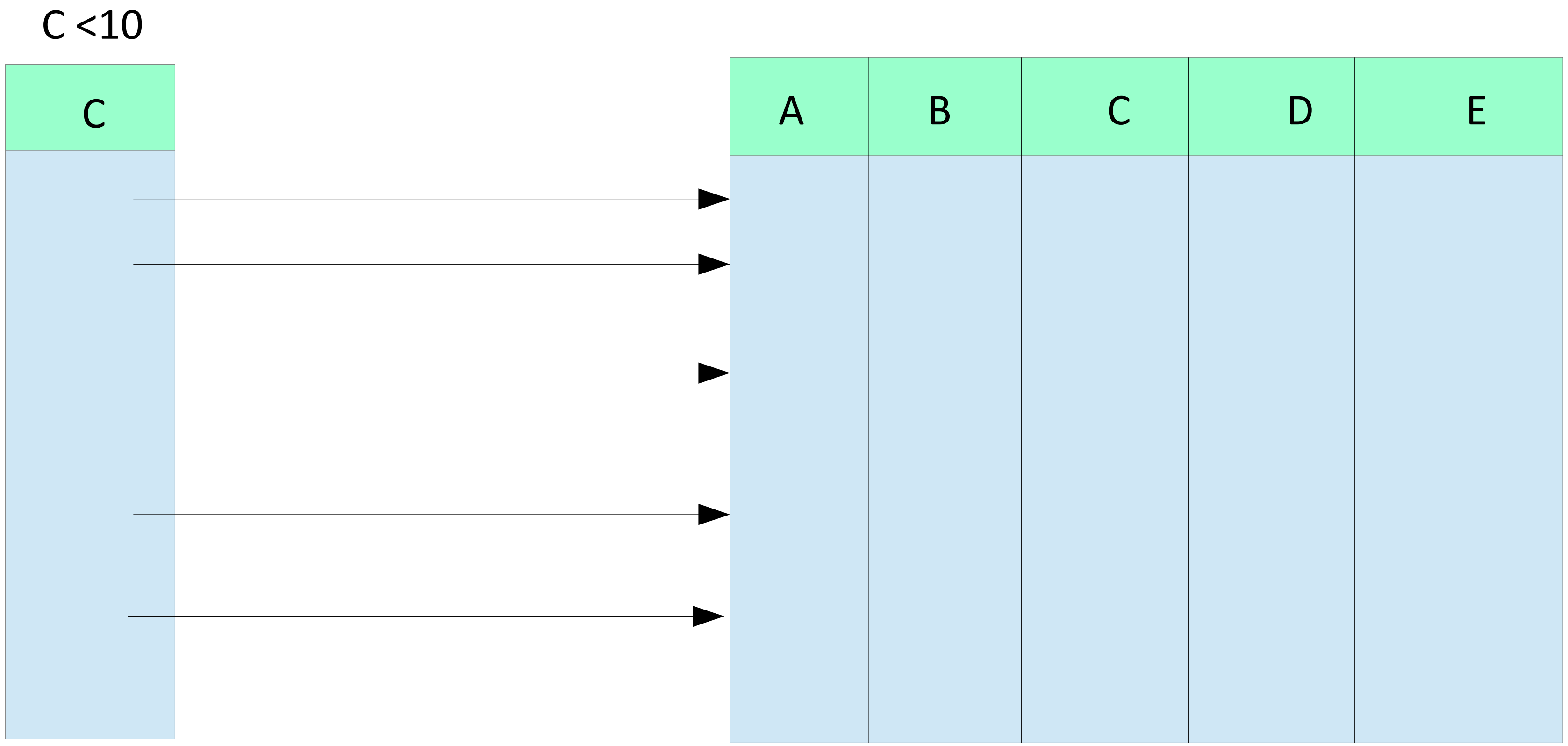
- Читаем последовательно таблицу и фильтруем записи по предикату

C <10

A	B	C	D	E

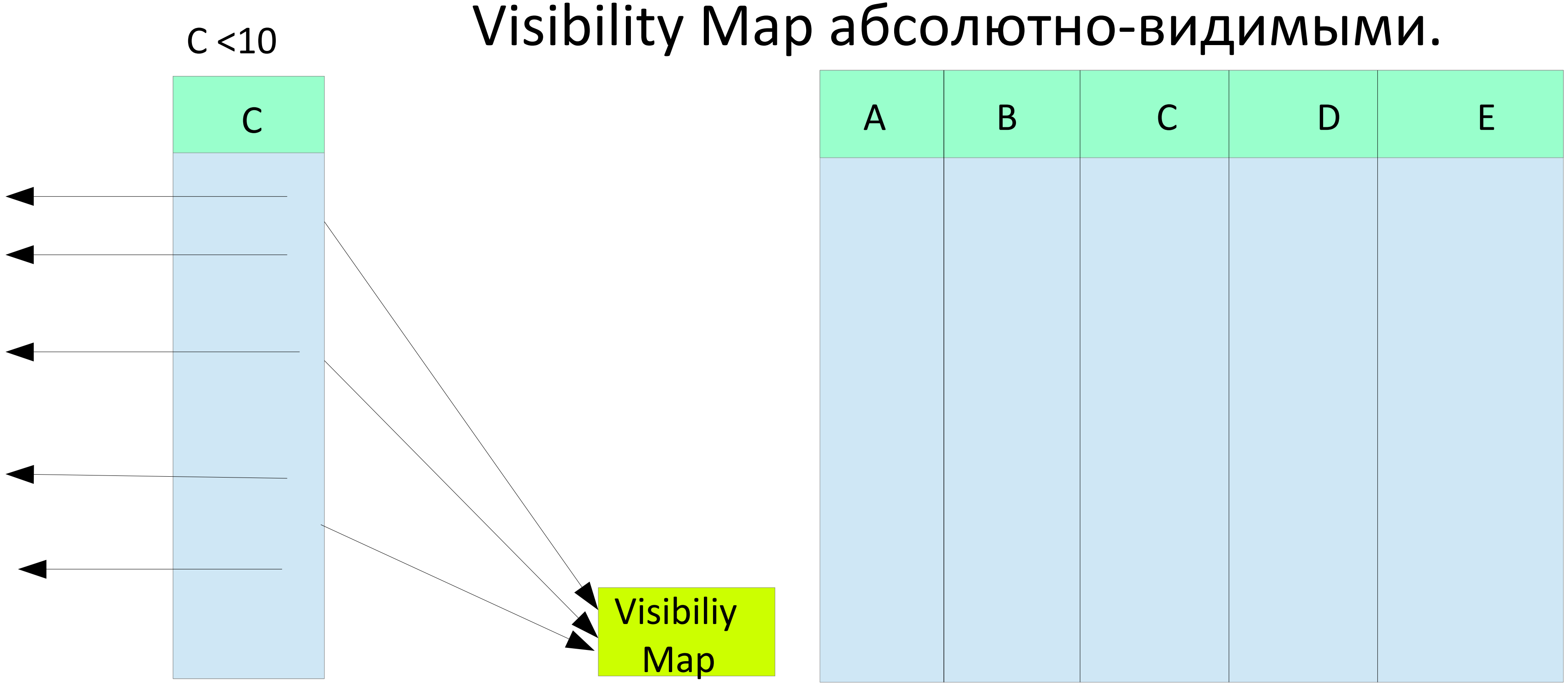
Простейший индекс (Index Scan)

- Читаем последовательно колонку, читаем таблицу (только нужные записи), выигрыш за счет меньшего размера колонки



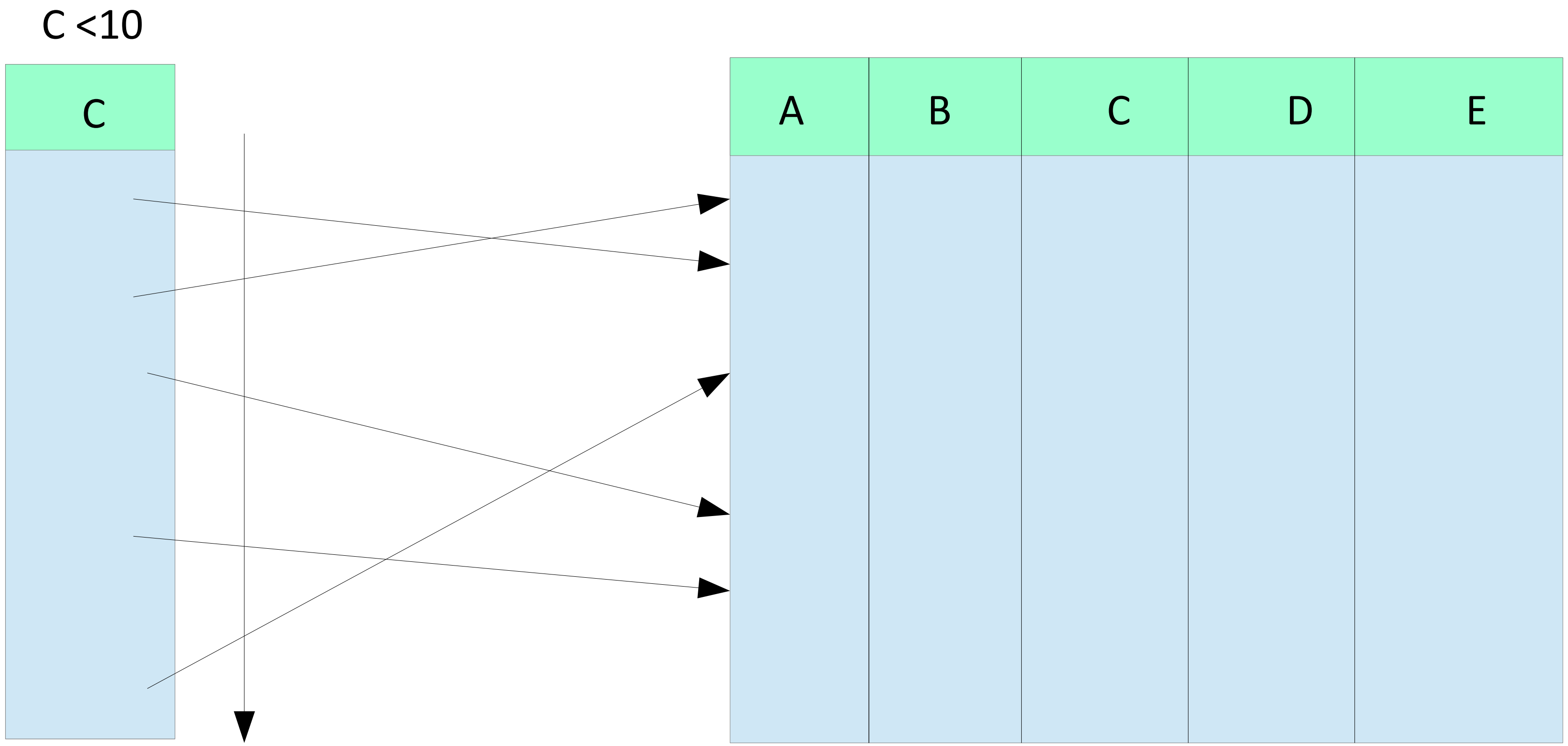
Простейший индекс (Index-only Scan)

- Читаем последовательно колонку, находим нужные значения и напрямик выдаем наружу, если страницы таблицы помечены в Visibility Map абсолютно-видимыми.



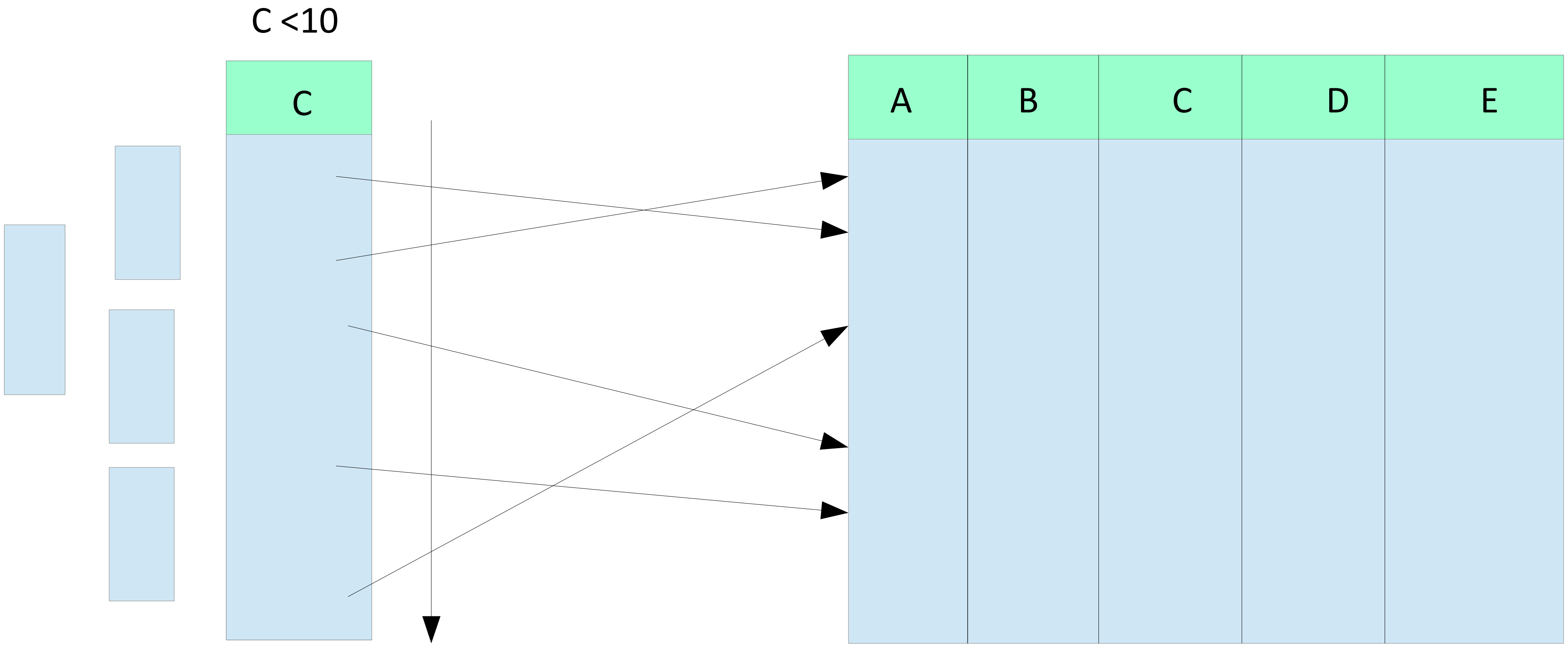
Простейший индекс++

- Упорядочиваем — получаем быстрый поиск, ускоряем ORDER BY, но случайное чтение таблицы.



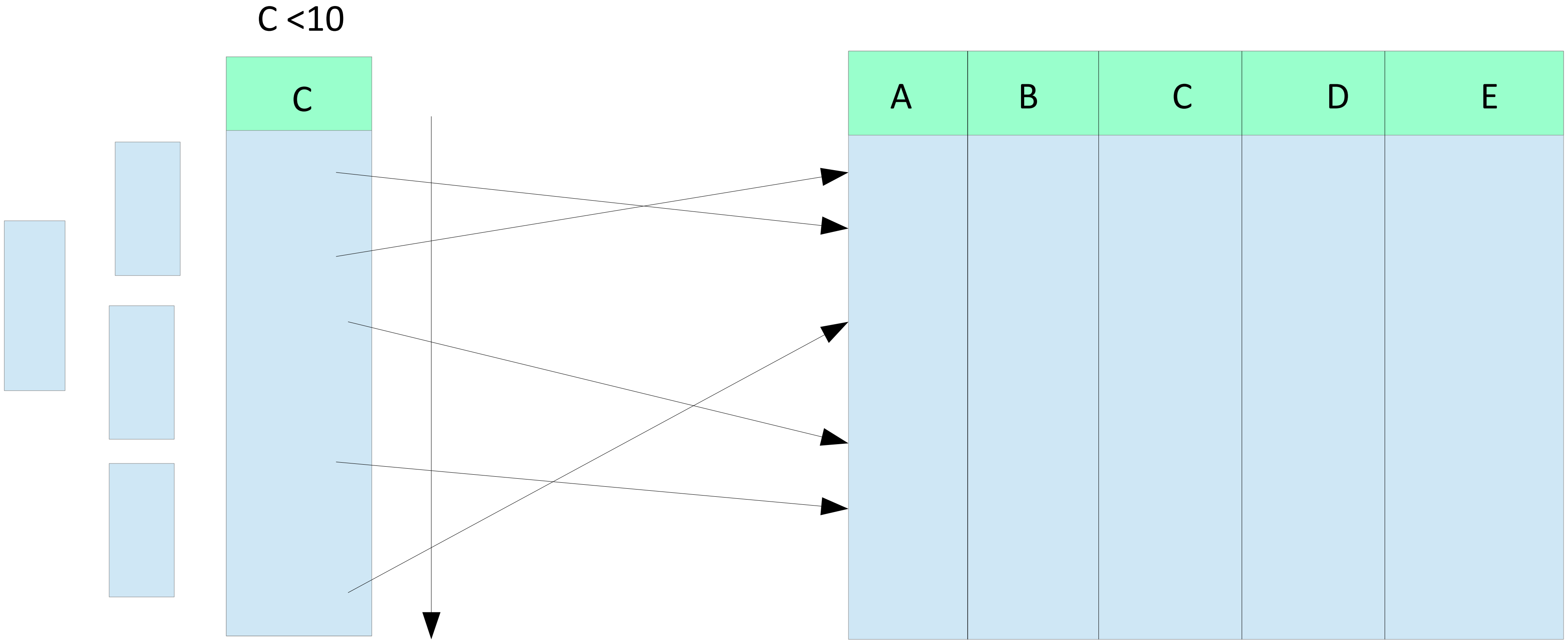
B-tree индекс

- Строим дерево — уменьшаем чтение индекса при быстром поиске



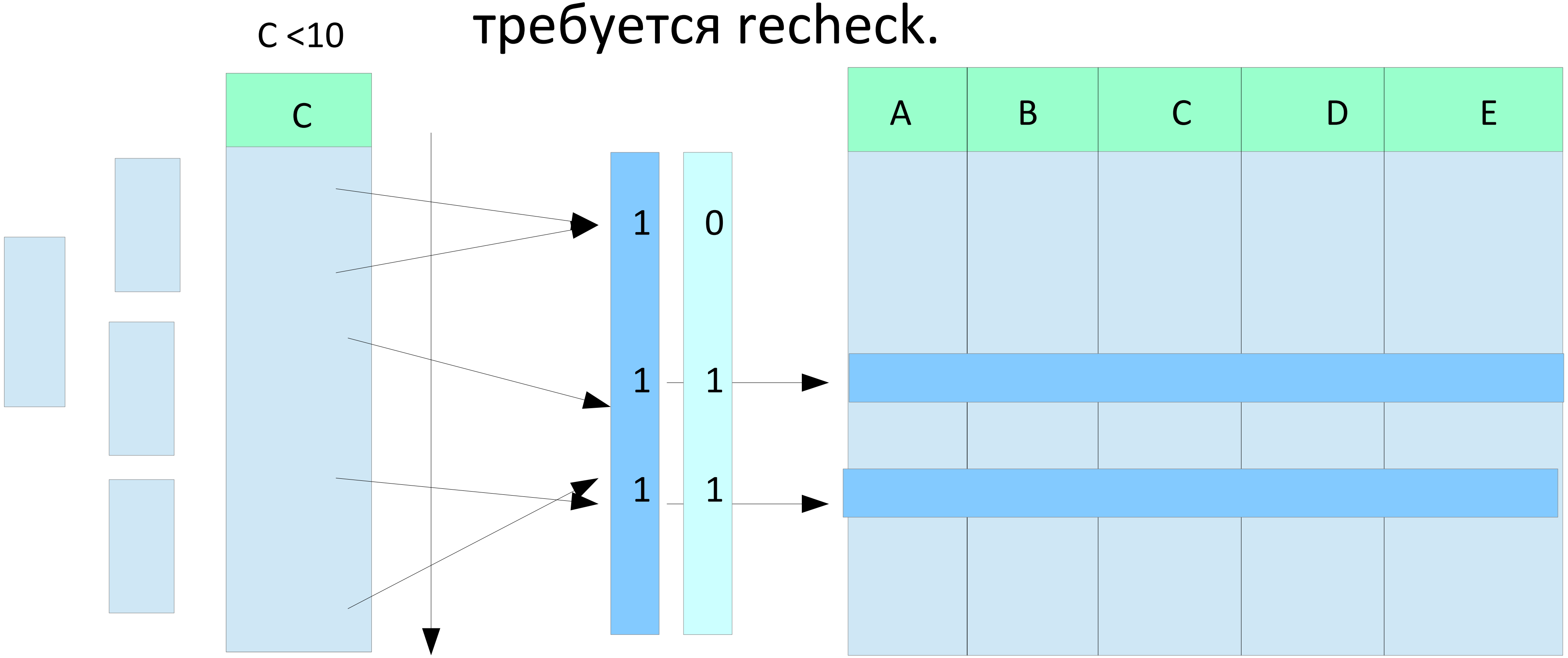
GiST,GIN,SP-GiST индексы

- Дерево — шаблон с API, поддержка произвольных типов данных



Bitmap index scan

- Результат Index scan сортируем, строим в памяти bitmap index и читаем таблицу. Можно комбинировать индексы. Иногда требуется recheck.



CREATE INDEX

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ name ] ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ] [ ASC | DESC ]
    [ NULLS { FIRST | LAST } ] [, ...] )
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

Syntax:

```
ALTER INDEX [ IF EXISTS ] name RENAME TO new_name
ALTER INDEX [ IF EXISTS ] name SET TABLESPACE tablespace_name
ALTER INDEX [ IF EXISTS ] name SET ( storage_parameter = value [, ... ] )
ALTER INDEX [ IF EXISTS ] name RESET ( storage_parameter [, ... ] )
```

```
DROP INDEX [ CONCURRENTLY ] [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

CREATE INDEX

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ name ] ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ] [ ASC | DESC ]
    [ NULLS { FIRST | LAST } ] [, ...] )
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

```
=# \d pg_am
        Table "pg_catalog.pg_am"
     Column      |   Type    | Modifiers
-----------------+----------+-----------
 amname          | name     | not null
 amstrategies    | smallint | not null
 amsupport       | smallint | not null
 amcanorder      | boolean  | not null
 …...................................
 amcanunique     | boolean  | not null
 amoptions       | regproc  | not null
```

```
=# select amname from pg_am;
 amname
--------
 btree
 hash
 gist
 gin
 spgist
(5 rows)
```

ACCESS METHODS

CREATE INDEX

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ name ] ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ] [ ASC | DESC ]
    [ NULLS { FIRST | LAST } ] [, ...] )
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

- storage_parameter
  - BTREE, GiST - FILLFACTOR
  - GIN — FASTUPDATE
- TABLESPACE — размещение индекса на альтернативном хранилище для улучшения ввода/вывода
- opclass — оператор для колонки (если доступны несколько)
- ASC|DESC — матчить ORDER BY для использования индекса

CREATE INDEX

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ name ] ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ] [ ASC | DESC ]
    [ NULLS { FIRST | LAST } ] [, ...] )
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

- CONCURRENTLY — конкурентное создание индекса
  - Не блокирует таблицу на изменения
  - Спасает в «боевых» условиях
  - Требует два прохода и окончания всех текущих транзакций
  - Нельзя создавать в транзакции
  - DROP INDEX CONCURRENTLY

```
postgres=# \d tt
      Table "public.tt"
 Column |  Type   | Modifiers
--------+---------+-----------
 i      | integer |
Indexes:
    "tt_idx" btree (i) INVALID
```

CREATE INDEX

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ name ] ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ] [ ASC | DESC ]
    [ NULLS { FIRST | LAST } ] [, ...] )
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

- Функциональный индекс
  - Функция должна быть IMMUTABLE
  - «Дорогое» изменение индекса
  - Условие при поиске должно «матчить» CREATE INDEX

```
create index sin_idx on foo(sin(id));
=# explain select 1 from foo where sin(id)=0;
                            QUERY PLAN
--------------------------------------------------------------------
 Index Scan using sin_idx on foo  (cost=0.14..8.16 rows=1 width=0)
   Index Cond: (sin((id)::double precision) = 0::double precision)
(2 rows)
```

Мониторинг индексов

- Неиспользуемые индексы
  Индексы-дубликаты
  Пересекающиеся индексы
  - Результат эволюционного развития и/или бардака
  - Занимают место
  - Замедляют обновление
  - Замедляют репликацию
- Дело DBA мониторить индексы
- http://wiki.postgresql.org/wiki/Index_Maintenance

Мониторинг индексов::неиспользуемые индексы

```
SELECT
    schemaname || '.' || relname AS table,
    indexrelname AS index,
    pg_size_pretty(pg_relation_size(i.indexrelid)) AS index_size,
    idx_scan as index_scans
  FROM pg_stat_user_indexes ui
  JOIN pg_index i ON ui.indexrelid = i.indexrelid
  WHERE NOT indisunique AND idx_scan < 50 AND pg_relation_size(relid) > 5 * 819
  ORDER BY pg_relation_size(i.indexrelid) / nullif(idx_scan, 0) DESC NULLS FIRS
  pg_relation_size(i.indexrelid) DESC;
     table      |      index       | index_size | index_scans
----------------+------------------+------------+-------------
 public.apod    | gin_apod_fts_idx | 1616 kB    |           0
 public.tbl     | ab1_idx          | 40 kB      |           0
 public.tbl     | a_idx            | 40 kB      |           0
 public.tbl     | ba_idx           | 40 kB      |           0
 public.reviews | reviews_gin_idx  | 160 MB     |           9
 public.events  | e_date_id        | 3352 kB    |           4
 public.tbl     | ab_idx           | 88 kB      |          28
(7 rows)
```

Мониторинг индексов

- Индексы-дубликаты
  - Учитываем все пересечения

```
=# \d tbl
      Table "public.tbl"
 Column |  Type   | Modifiers
--------+---------+-----------
 a      | integer |
 b      | integer |
Indexes:
    "a_idx" btree (a)
    "ab1_idx" btree (a, b)
    "ab_idx" btree (a, b)
    "ba_idx" btree (a, b)
```

```
SELECT a.indrelid::regclass, a.indexrelid::regclass, b.indexrelid::regclass
FROM (SELECT *,array_to_string(indkey,' ') AS cols FROM pg_index) a JOIN
           (SELECT *,array_to_string(indkey,' ') AS cols FROM pg_index) b  ON
( a.indrelid=b.indrelid AND a.indexrelid > b.indexrelid AND
   (    (a.cols LIKE b.cols||'%' AND coalesce(substr(a.cols,length(b.cols)+1,1),' ')=' ' ) OR
        (b.cols LIKE a.cols||'%' AND coalesce(substr(b.cols,length(a.cols)+1,1),' ')=' ')
   )
) ORDER BY indrelid;
 indrelid | indexrelid | indexrelid
----------+------------+------------
 tbl      | a_idx      | ab1_idx
 tbl      | a_idx      | ba_idx
 tbl      | a_idx      | ab_idx
(3 rows)
```

Мониторинг индексов::дубликаты V2

```
SELECT idstat.relname AS tname,indexrelname AS iname, idstat.idx_scan AS used,
       pg_size_pretty(pg_relation_size(idstat.relid)) AS tsize,
       pg_size_pretty(pg_relation_size(indexrelid)) AS isize,
       n_tup_upd + n_tup_ins + n_tup_del as writes, indexdef AS create
FROM pg_stat_user_indexes AS idstat
   JOIN pg_indexes  ON (indexrelname = indexname AND idstat.schemaname = pg_indexes.schemaname)
   JOIN pg_stat_user_tables AS tabstat ON idstat.relid = tabstat.relid
WHERE idstat.idx_scan  < 200 AND indexdef !~* 'unique'
ORDER BY idstat.relname, indexrelname;
  tname  |      iname       | used |  tsize  |  isize  | writes |                           creat
---------+------------------+------+---------+---------+--------+-----------------------------------
 apod    | gin_apod_fts_idx |    0 | 2712 kB | 1616 kB |   1754 | CREATE INDEX gin_apod_fts_idx O
 events  | e_date_id        |    4 | 14 MB   | 3352 kB | 151643 | CREATE INDEX e_date_id ON even
 reviews | reviews_gin_idx  |    9 | 270 MB  | 160 MB  | 589859 | CREATE INDEX reviews_gin_idx O
 tbl     | a_idx            |    0 | 72 kB   | 40 kB   |   2000 | CREATE INDEX a_idx ON tbl USIN
 tbl     | ab1_idx          |    0 | 72 kB   | 40 kB   |   2000 | CREATE INDEX ab1_idx ON tbl US
 tbl     | ab_idx           |   28 | 72 kB   | 88 kB   |   2000 | CREATE INDEX ab_idx ON tbl USI
 tbl     | ba_idx           |    0 | 72 kB   | 40 kB   |   2000 | CREATE INDEX ba_idx ON tbl USI
(7 rows)
```

maintenance_work_mem

```
SET maintenance_work_mem = '1 MB';
CREATE INDEX test1_v_idx ON test1 (v);
Time: 1194,299 ms

SET maintenance_work_mem = '128 MB';
CREATE INDEX test1_v_idx ON test1 (v);
Time: 708,644 ms
```

Чем больше памяти, тем быстрее создастся индекс
(если она действительно есть)

Выбор способа сканирования таблицы (нет статистики)

```
CREATE TABLE test1 WITH (autovacuum_enabled = off) AS (SELECT id, random() v FROM generate_ser
CREATE INDEX test1_v_idx ON test1 (v);

SELECT * FROM test1 WHERE v BETWEEN 0.1 AND 0.9      Нет статистики!
 Bitmap Heap Scan on test1  (cost=107.61..5701.58 rows=5000 width=12)
 (actual time=63.206..205.054 rows=800235 loops=1)
   Recheck Cond: ((v >= 0.1::double precision) AND (v <= 0.9::double precision))
   Rows Removed by Index Recheck: 152799
   Buffers: shared hit=7596
   ->  Bitmap Index Scan on test1_v_idx  (cost=0.00..106.36 rows=5000 width=0) (actual time=63
         Index Cond: ((v >= 0.1::double precision) AND (v <= 0.9::double precision))
         Buffers: shared hit=2190
 Total runtime: 239.768 ms
```

Выбор способа сканирования таблицы (нет статистики)

Нет статистики!

```
SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.500001;
 Bitmap Heap Scan on test1  (cost=107.61..5701.58 rows=5000 width=12)
 (actual time=0.014..0.014 rows=1 loops=1)
   Recheck Cond: ((v >= 0.5::double precision) AND (v <= 0.500001::double precision))
   Buffers: shared hit=4
   ->  Bitmap Index Scan on test1_v_idx  (cost=0.00..106.36 rows=5000 width=0) (actual time=0.011
         Index Cond: ((v >= 0.5::double precision) AND (v <= 0.500001::double precision))
         Buffers: shared hit=3
 Total runtime: 0.035 ms
```

Нет статистики!

```
SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.6;
 Bitmap Heap Scan on test1  (cost=107.61..5701.58 rows=5000 width=12)
 (actual time=12.368..30.688 rows=99951 loops=1)
   Recheck Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
   Buffers: shared hit=5681 read=1
   ->  Bitmap Index Scan on test1_v_idx  (cost=0.00..106.36 rows=5000 width=0) (actual time=11.64
         Index Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
         Buffers: shared hit=275 read=1
```

Выбор способа сканирования таблицы (есть статистика)

```
VACUUM ANALYZE test1;

SELECT * FROM test1 WHERE v BETWEEN 0.1 AND 0.9;
 Seq Scan on test1  (cost=0.00..20406.00 rows=801140 width=12)
 (actual time=0.007..159.966 rows=800235 loops=1)
   Filter: ((v >= 0.1::double precision) AND (v <= 0.9::double precision))
   Rows Removed by Filter: 199765
   Buffers: shared hit=5406
 Total runtime: 196.179 ms

SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.500001;
 Index Scan using test1_v_idx on test1  (cost=0.00..8.38 rows=1 width=12)
 (actual time=0.018..0.019 rows=1 loops=1)
   Index Cond: ((v >= 0.5::double precision) AND (v <= 0.500001::double precision))
   Buffers: shared hit=4
 Total runtime: 0.037 ms
```

CLUSTER

```
SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.6;
 Bitmap Heap Scan on test1  (cost=2187.43..9137.44 rows=102934 width=12) (actual time=9.386..28
   Recheck Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
   Buffers: shared hit=5682
   ->  Bitmap Index Scan on test1_v_idx  (cost=0.00..2161.70 rows=102934 width=0) (actual time=
         Index Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
         Buffers: shared hit=276
 Total runtime: 33.688 ms

CLUSTER test1 USING test1_v_idx;

SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.6;
 Bitmap Heap Scan on test1  (cost=2187.43..9137.44 rows=102934 width=12) (actual time=7.014..15
   Recheck Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
   Buffers: shared hit=816
   ->  Bitmap Index Scan on test1_v_idx  (cost=0.00..2161.70 rows=102934 width=0) (actual time=
         Index Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
         Buffers: shared hit=276
 Total runtime: 20.461 ms
```

Индекс и ORDER BY

```
SELECT * FROM test1 ORDER BY v;
 Index Scan using test1_v_idx on test1  (cost=0.00..47604.02 rows=1000000 width=12) (actual tim
   Buffers: shared hit=8141
 Total runtime: 188.832 ms

SET enable_indexscan = off;

SELECT * FROM test1 ORDER BY v;
 Sort  (cost=132154.34..134654.34 rows=1000000 width=12) (actual time=636.567..752.384 rows=100
   Sort Key: v
   Sort Method: external sort  Disk: 25424kB
   Buffers: shared hit=5406, temp read=3178 written=3178
   ->  Seq Scan on test1  (cost=0.00..15406.00 rows=1000000 width=12) (actual time=0.010..86.15
         Buffers: shared hit=5406
 Total runtime: 819.682 ms
```

Индекс, ORDER BY и LIMIT

```
SELECT * FROM test1 ORDER BY v LIMIT 20;
 Limit  (cost=0.00..0.95 rows=20 width=12) (actual time=0.014..0.021 rows=20 loops=1)
   Buffers: shared hit=4
   ->  Index Scan using test1_v_idx on test1  (cost=0.00..47604.02 rows=1000000 width=12) (actua
         Buffers: shared hit=4
 Total runtime: 0.033 ms
```

А если нужно «листание»?

```
SELECT * FROM test1 ORDER BY v LIMIT 20 OFFSET 900000;
 Limit  (cost=42843.62..42844.57 rows=20 width=12) (actual time=178.863..178.868 rows=20 loops=1
   Buffers: shared hit=7327
   ->  Index Scan using test1_v_idx on test1  (cost=0.00..47604.02 rows=1000000 width=12) (actua
         Buffers: shared hit=7327
 Total runtime: 178.887 ms
```

Лучше постараться сделать вот так

```
SELECT * FROM test1 WHERE v >= 0.9 ORDER BY v LIMIT 20;
 Limit  (cost=0.00..4.85 rows=20 width=12) (actual time=0.050..0.058 rows=20 loops=1)
   Buffers: shared hit=3 read=1
   ->  Index Scan using test1_v_idx on test1  (cost=0.00..24503.79 rows=101021 width=12) (actual
         Index Cond: (v >= 0.9::double precision)
         Buffers: shared hit=3 read=1
 Total runtime: 0.075 ms
```

Составной индекс, ORDER BY и LIMIT

```
CREATE TABLE test4 AS (SELECT id, (random()*20::int) AS v1, random() AS v2 FROM generate_series(1
CREATE INDEX test4_v1_v2_idx ON test4 (v1, v2);

SELECT * FROM test4 ORDER BY v1, v2 LIMIT 20;
 Limit  (cost=0.00..1.12 rows=20 width=20) (actual time=0.012..0.097 rows=20 loops=1)
   ->  Index Scan using test4_v1_v2_idx on test4  (cost=0.00..55892.40 rows=1000000 width=20) (ac
 Total runtime: 0.110 ms

SELECT * FROM test4 WHERE (v1, v2) > (9,0.5) ORDER BY v1, v2 LIMIT 20;
 Limit  (cost=0.00..1.58 rows=20 width=20) (actual time=0.025..0.088 rows=20 loops=1)
   ->  Index Scan using test4_v1_v2_idx on test4  (cost=0.00..43628.52 rows=551512 width=20) (act
         Index Cond: (ROW(v1, v2) > ROW(9::double precision, 0.5::double precision))
 Total runtime: 0.111 ms
```

Index only scan

```
ANALYZE test4;

SELECT v1, v2 FROM test4 WHERE v1 BETWEEN 0.5 AND 0.51;
 Bitmap Heap Scan on test4  (cost=18.15..1709.51 rows=561 width=16) (actual time=0.109..0.455 row
   Recheck Cond: ((v1 >= 0.5::double precision) AND (v1 <= 0.51::double precision))
   ->  Bitmap Index Scan on test4_v1_v2_idx  (cost=0.00..18.01 rows=561 width=0) (actual time=0.0
         Index Cond: ((v1 >= 0.5::double precision) AND (v1 <= 0.51::double precision))
 Total runtime: 0.488 ms

SET enable_bitmapscan = OFF;
SET enable_indexscan = OFF;
SET enable_seqscan = OFF;
SELECT v1, v2 FROM test4 WHERE v1 BETWEEN 0.5 AND 0.51;
 Index Only Scan using test4_v1_v2_idx on test4  (cost=10000000000.00..10000002175.62 rows=561 w
   Index Cond: ((v1 >= 0.5::double precision) AND (v1 <= 0.51::double precision))
   Heap Fetches: 482
 Total runtime: 0.593 ms
```

Index only scan

```
VACUUM test4;

SELECT v1, v2 FROM test4 WHERE v1 BETWEEN 0.5 AND 0.51;
 Index Only Scan using test4_v1_v2_idx on test4  (cost=10000000000.00..10000000023.62 rows=561 w
   Index Cond: ((v1 >= 0.5::double precision) AND (v1 <= 0.51::double precision))
   Heap Fetches: 0
 Total runtime: 0.173 ms
```

Составной индекс, ORDER BY и LIMIT

```
SELECT * FROM test4 ORDER BY v1 LIMIT 20;
 Limit  (cost=0.00..1.12 rows=20 width=20) (actual time=0.016..0.042 rows=20 loops=1)
   ->  Index Scan using test4_v1_v2_idx on test4  (cost=0.00..55889.49 rows=1000000 width=20) (ac
 Total runtime: 0.060 ms

SELECT * FROM test4 ORDER BY v2 LIMIT 20;
 Limit  (cost=42979.64..42979.69 rows=20 width=20) (actual time=161.618..161.620 rows=20 loops=1)
   ->  Sort  (cost=42979.64..45479.64 rows=1000000 width=20) (actual time=161.616..161.618 rows=2
         Sort Key: v2
         Sort Method: top-N heapsort  Memory: 26kB
         ->  Seq Scan on test4  (cost=0.00..16370.00 rows=1000000 width=20) (actual time=0.036..8
 Total runtime: 161.645 ms
```

Влияние random_page_cost

```
SET random_page_cost = 1;

SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.6;
 Index Scan using test1_v_idx on test1  (cost=0.00..7666.22 rows=99349 width=12)
 (actual time=0.035..63.101 rows=99951 loops=1)
   Index Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
   Buffers: shared hit=100200
 Total runtime: 67.788 ms
```

Влияние work_mem

```
SET work_mem = '128 kB';

SELECT * FROM test1 WHERE v BETWEEN 0.5 AND 0.6;
 Bitmap Heap Scan on test1  (cost=2110.69..9006.92 rows=99349 width=12) (actual time=11.010..1
   Recheck Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
   Rows Removed by Index Recheck: 688322
   Buffers: shared hit=5682
   ->  Bitmap Index Scan on test1_v_idx  (cost=0.00..2085.85 rows=99349 width=0) (actual time=
         Index Cond: ((v >= 0.5::double precision) AND (v <= 0.6::double precision))
         Buffers: shared hit=276
 Total runtime: 114.684 ms
```

Когда индекс используется неправильно

```
CREATE TABLE test2 AS (SELECT id, polygon(20,circle(point(random(), random()),0.01)) AS p
FROM generate_series(1,1000000) id);
ALTER TABLE test2 ADD PRIMARY KEY (id);
CREATE INDEX test2_box_idx ON test2 USING gist (p);

SELECT * FROM test2 t1 JOIN test2 t2 ON t2.id > t1.id AND t1.p && t2.p;
 Nested Loop  (cost=196.89..15740565.92 rows=4166667 width=72) (actual time=9.464..93463.065 rows
   ->  Seq Scan on test2 t1  (cost=0.00..13000.00 rows=50000 width=36) (actual time=0.027..54.015
   ->  Bitmap Heap Scan on test2 t2  (cost=196.89..313.72 rows=83 width=36) (actual time=1.845..1
         Recheck Cond: ((t1.p && p) AND (id > t1.id))
         Rows Removed by Index Recheck: 0
         ->  BitmapAnd  (cost=196.89..196.89 rows=83 width=0) (actual time=1.751..1.751 rows=0 lo
               ->  Bitmap Index Scan on test2_box_idx  (cost=0.00..6.41 rows=250 width=0)
                 (actual time=0.015..0.015 rows=2 loops=50000)
                 Index Cond: (t1.p && p)
               ->  Bitmap Index Scan on test2_pkey  (cost=0.00..190.18 rows=16667 width=0)
                 (actual time=1.733..1.733 rows=25000 loops=50000)
                 Index Cond: (id > t1.id)
 Total runtime: 93465.872 ms
```

Почему так?

```
                         pg_operator
 oprname | oprrest  |   oprjoin   | oprleft | oprright
---------+----------+-------------+---------+----------
 &&      | areasel  | areajoinsel |     604 |      604 (polygon)
```

```
src/backend/utils/adt/geo_selfuncs.c

Datum
areasel(PG_FUNCTION_ARGS)
{
        PG_RETURN_FLOAT8(0.005);
}

Datum
areajoinsel(PG_FUNCTION_ARGS)
{
        PG_RETURN_FLOAT8(0.005);
}
```

Переменные планировщика

```
SET enable_bitmapscan = OFF;

SELECT * FROM test2 t1 JOIN test2 t2 ON t2.id > t1.id AND t1.p && t2.p;
 Nested Loop  (cost=0.00..18358598.00 rows=4166667 width=72) (actual time=2.458..11824.565 rows=1
   ->  Seq Scan on test2 t1  (cost=0.00..13000.00 rows=50000 width=36) (actual time=0.005..20.801
   ->  Index Scan using test2_box_idx on test2 t2  (cost=0.00..366.08 rows=83 width=36) (actual t
         Index Cond: (t1.p && p)
         Rows Removed by Index Recheck: 0
         Filter: (id > t1.id)
         Rows Removed by Filter: 1
 Total runtime: 11826.029 ms
```

Использование plantuner

```
LOAD 'plantuner';
SET plantuner.forbid_index='test2_pkey';

SELECT * FROM test2 t1 JOIN test2 t2 ON t2.id > t1.id AND t1.p && t2.p;
 Nested Loop  (cost=6.43..17418092.51 rows=4166667 width=72) (actual time=1.547..12355.722 rows=1
   ->  Seq Scan on test2 t1  (cost=0.00..13000.00 rows=50000 width=36) (actual time=0.004..22.919
   ->  Bitmap Heap Scan on test2 t2  (cost=6.43..347.27 rows=83 width=36) (actual time=0.224..0.2
         Recheck Cond: (t1.p && p)
         Rows Removed by Index Recheck: 0
         Filter: (id > t1.id)
         Rows Removed by Filter: 1
         ->  Bitmap Index Scan on test2_box_idx  (cost=0.00..6.41 rows=250 width=0)
             (actual time=0.014..0.014 rows=2 loops=50000)
               Index Cond: (t1.p && p)
 Total runtime: 12357.238 ms
```

Больше про pg_hint_plan: http://www.sai.msu.su/~megera/wiki/plantuner

Использование pg_hint_plan

```
LOAD 'pg_hint_plan';

SELECT * FROM test2 t1 JOIN test2 t2 ON t2.id > t1.id AND t1.p && t2.p;
 Nested Loop  (cost=0.00..18358598.00 rows=4166667 width=72) (actual time=2.457..11912.368 rows=1
   ->  Seq Scan on test2 t1  (cost=0.00..13000.00 rows=50000 width=36) (actual time=0.005..21.094
   ->  Index Scan using test2_box_idx on test2 t2  (cost=0.00..366.08 rows=83 width=36) (actual t
         Index Cond: (t1.p && p)
         Rows Removed by Index Recheck: 0
         Filter: (id > t1.id)
         Rows Removed by Filter: 1
 Total runtime: 11913.821 ms
```

Больше про pg_hint_plan: http://habrahabr.ru/post/169751/

Не всё ли равно когда сделать индекс?

```
CREATE TABLE test5 (id integer PRIMARY KEY, v float8);
Time: 1,991 ms
CREATE INDEX test5_v_idx ON test5(v);
Time: 0,506 ms
INSERT INTO test5 (SELECT id, random() FROM generate_series(1,1000000) id);
Time: 4909,127 ms
Total: 4911 ms

CREATE TABLE test5 (id integer, v float8);
Time: 0,763 ms
INSERT INTO test5 (SELECT id, random() FROM generate_series(1,1000000) id);
Time: 938,852 ms
ALTER TABLE test5 ADD PRIMARY KEY (id);
Time: 779,618 ms
CREATE INDEX test5_v_idx ON test5(v);
Time: 1195,492 ms
Total: 2915 ms
```

Частичный индекс

```
CREATE TABLE test6 AS (
SELECT id, (random()*20::int) AS v1, random() AS v2 FROM generate_series(1,1000000) id);

SELECT * FROM test6 WHERE v1 = 0 AND v2 BETWEEN 0.1 AND 0.4;
 Index Scan using test6_v1_0_v2_idx on test6  (cost=0.00..8.27 rows=1 width=20) (actual time=0.00
   Index Cond: ((v2 >= 0.1::double precision) AND (v2 <= 0.4::double precision))
 Total runtime: 0.037 ms

SELECT * FROM test6 WHERE v1 = 0;
 Index Scan using test6_v1_0_v2_idx on test6  (cost=0.00..8.27 rows=1 width=20) (actual time=0.00
 Total runtime: 0.021 ms

SELECT * FROM test6 WHERE v2 BETWEEN 0.1 AND 0.2;
 Seq Scan on test6  (cost=0.00..21370.00 rows=99962 width=20) (actual time=0.044..157.861 rows=10
   Filter: ((v2 >= 0.1::double precision) AND (v2 <= 0.2::double precision))
   Rows Removed by Filter: 899919
 Total runtime: 162.312 ms
```

Функциональный индекс

```
CREATE TABLE test7 AS (
SELECT id, random() AS v1, random() AS v2 FROM generate_series(1,1000000) id);

CREATE INDEX test7_v1_plus_v2_idx ON test7((v1 + v2));

SELECT * FROM test7 WHERE v1 + v2 > 1.9;
 Bitmap Heap Scan on test7  (cost=135.70..6911.42 rows=7140 width=20) (actual time=1.707..21.039
   Recheck Cond: ((v1 + v2) > 1.9::double precision)
   ->  Bitmap Index Scan on test7_v1_plus_v2_idx  (cost=0.00..133.91 rows=7140 width=0) (actual t
         Index Cond: ((v1 + v2) > 1.9::double precision)
 Total runtime: 21.410 ms
```

Head Only Tuple (HOT)

```
CREATE TABLE test8 AS (SELECT id, random() AS v1, random() AS v2, random() AS v3 FROM generate_se
CREATE INDEX test8_v2_idx ON test8(v2);

test8_v2_idx - 21 MB
test8_v3_idx - 21 MB

UPDATE test8 SET v1 = v1 + 1 WHERE id % 20 = 0;

test8_v2_idx - 21 MB
test8_v3_idx - 21 MB

VACUUM test8;
UPDATE test8 SET v2 = v2 + 1 WHERE id % 20 = 0;

test8_v2_idx - 23 MB
test8_v3_idx - 21 MB
```

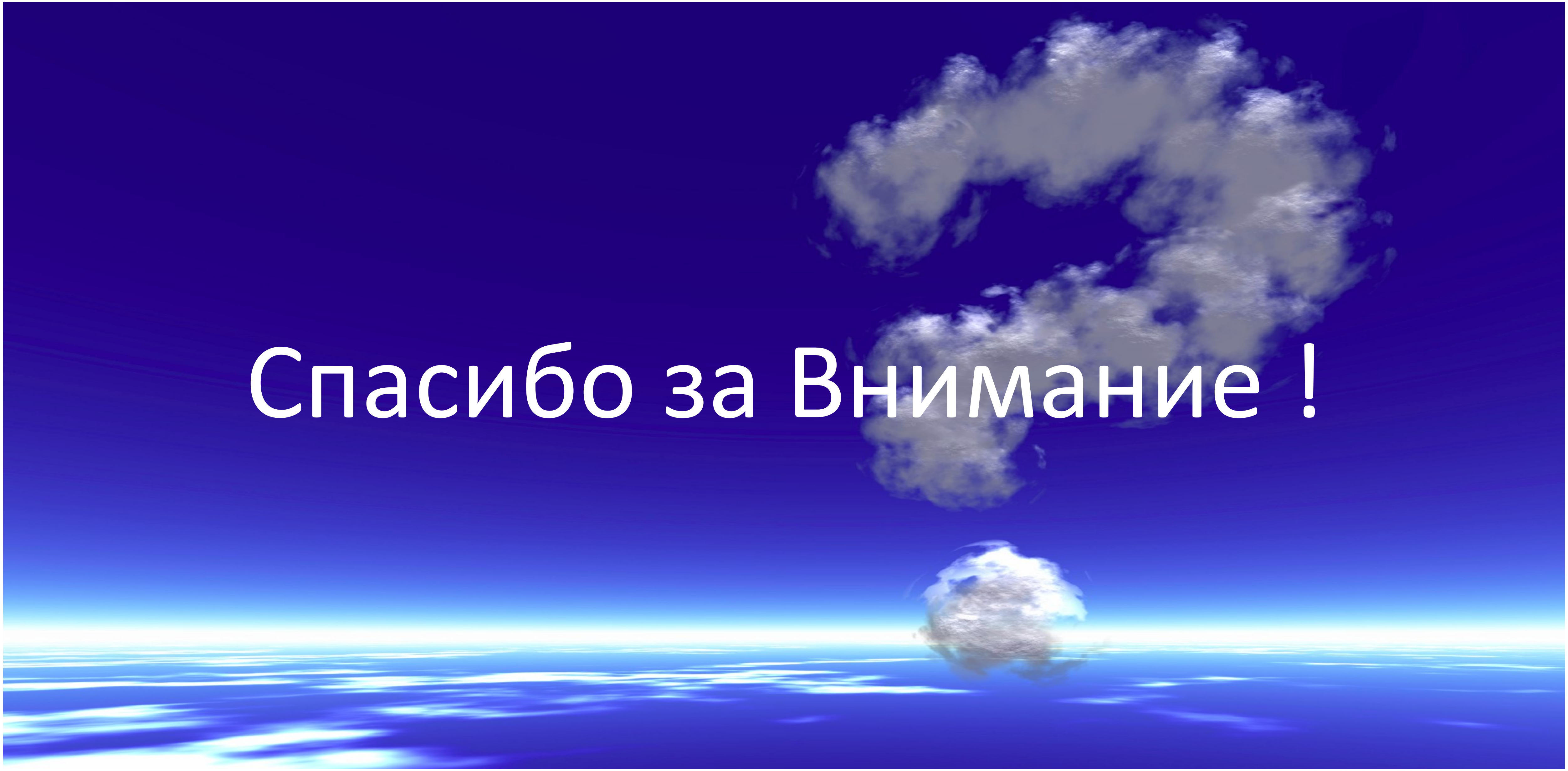
KNN-GiST

```
CREATE TABLE test9 AS (
SELECT id, point(random(), random()) AS p FROM generate_series(1,1000000) id);

SELECT * FROM test9 ORDER BY p <-> point(0.5, 0.5) LIMIT 10;
 Limit  (cost=41786.38..41786.41 rows=10 width=20) (actual time=331.506..331.509 rows=10 loops=1)
   ->  Sort  (cost=41786.38..44382.16 rows=1038310 width=20) (actual time=331.500..331.501 rows=1
         Sort Key: ((p <-> '(0.5,0.5)'::point))
         Sort Method: top-N heapsort  Memory: 25kB
         ->  Seq Scan on test9  (cost=0.00..19348.88 rows=1038310 width=20) (actual time=0.019..2
 Total runtime: 331.528 ms

CREATE INDEX test9_p_idx ON test9 USING gist (p);

SELECT * FROM test9 ORDER BY p <-> point(0.5, 0.5) LIMIT 10;
 Limit  (cost=0.00..0.82 rows=10 width=20) (actual time=0.089..19.541 rows=10 loops=1)
   ->  Index Scan using test9_p_idx on test9  (cost=0.00..81892.61 rows=1000000 width=20) (actual
         Order By: (p <-> '(0.5,0.5)'::point)
 Total runtime: 19.575 ms
```



Спасибо за Внимание !